Studies Related to the Carbohydrate Sectors of Esperamicin and Calicheamicin: Definition of the Stability Limits of the Esperamicin Domain and Fashioning of a Glycosyl Donor from the Calicheamicin Domain

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Abstract: The core trisaccharide regions of esperamicin and the aryltetrasaccharide region of calicheamicin have been synthesized. The minimum protection modalities necessary to stabilize structures against rearrangement to an isomeric azafuranose series were ascertained (see compounds **12** and **65**). Deprotection of the 2-(trimethylsilyl)-ethoxycarbonyl carbamate from **65** led to azafuranose **14** characterized as methyl glycoside **15**. Using this insight, it was possible to fashion, for the first time, a pre-glycosyl donor (see compound **128**) corresponding to the complete arylsaccharide sector of calicheamicin γ_1^I at the oxidation level of the domain. Among the key assembly strategies were the conversion of α-thiophenylpseudoglycals to allal derivatives (see **44** → **45**); the interfacing of epoxide-mediated glycosylation with iodoglycosylation (see **30** → **47** → **48**); the synthesis of hydroxylamine glycosides via triflate displacement (see **61** + **91** → **101**); and a new route to *p*-hydroxybenzonitriles (see formation of **86**).

Background, Synthetic Goals, and Overview

The structures of calicheamicin γ_1^I (**1**)[1] and esperamicin A_{1a} (**2**)[2] were disclosed in 1987 by workers at Lederle Laboratories and at Bristol-Myers. Rarely has the discovery of a class of compounds initiated such intense research activity in issues of synthesis,[3−7] mechanism of action, and drug design.[8]

An important step in realizing a total synthesis of calicheamicin γ_1^I involved the total synthesis of the aglycon, which we termed calicheamicinone.[6] With this goal accomplished, and with major advances in the carbohydrate sector being registered on a continuing basis,[5] the next threshold would be the total synthesis of calicheamicin. Indeed, the completion of this total synthesis by Nicolaou and co-workers[7] is a milestone in synthetic organic chemistry.

Here and in the following paper, we document our approach which, building from our calicheamicinone total synthesis, allowed us to achieve the total synthesis of calicheamicin γ_1^I.[6c] To accomplish our goal, it was necessary to gain insight as to the sorts of transformations which might be feasible for assembling the carbohydrate domain and then to assemble this domain in such a fashion that it might be presented as a glycosyl

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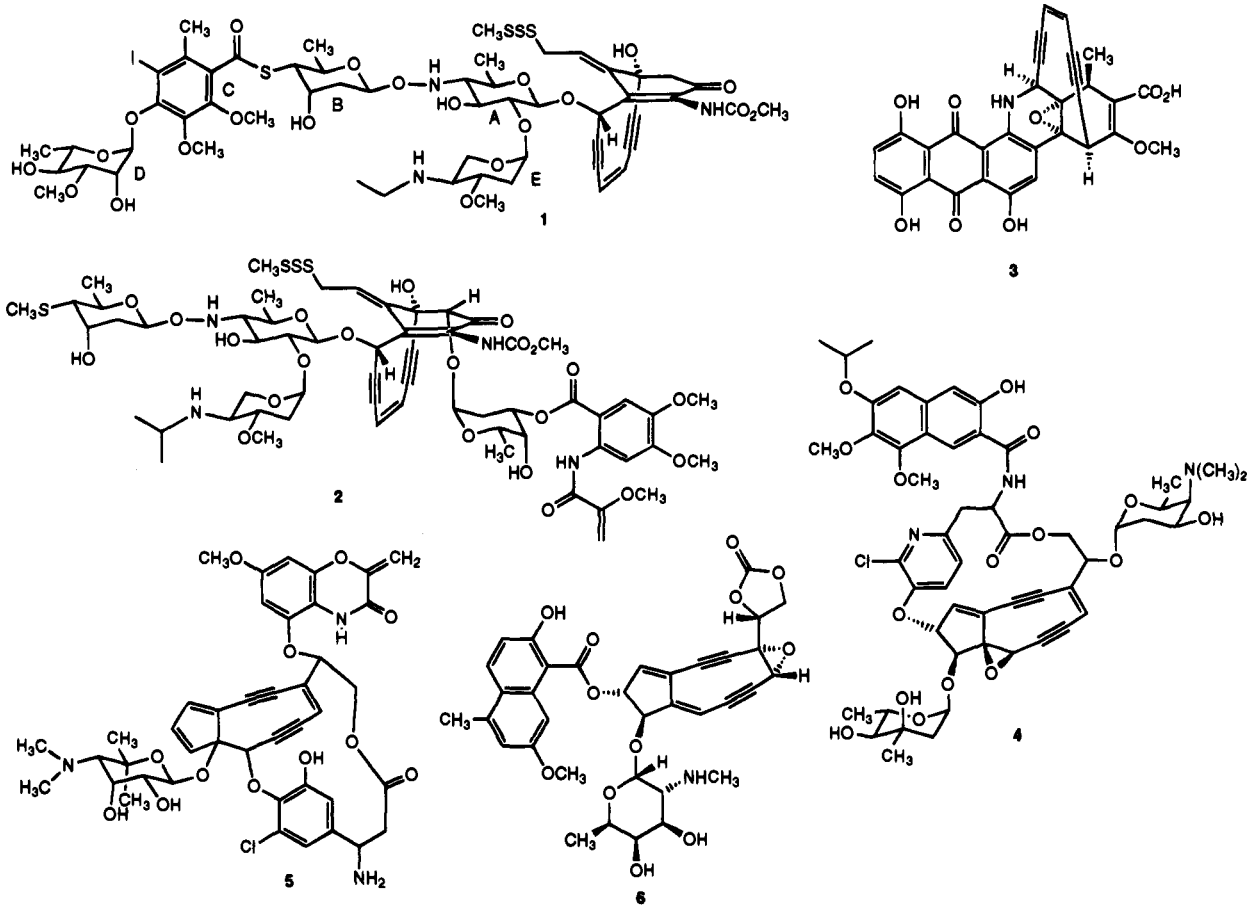

Figure 1.

donor to a late stage version of the aglycon. As will be described, these studies were amply rewarded when it was shown to be possible to deliver this carbohydrate domain to calicheamicinone protected only as its ketal.[6c]

Before describing these investigations, it is instructive to briefly place the problem in a somewhat broader context. Calicheamicin and esperamicin are the first two characterized members of a growing class of enediyne-containing antibiotics (Figure 1) which now includes dynemicin A (**3**),[9] kedarcidin chromophore (**4**),[10] and C-1027 chromophore (**5**).[11] The previously isolated neocarzinostatin chromophore (**6**)[12] possesses an epoxidized variant of the enediyne unit and is included in this class of compounds because of its related structure and mechanism of action.[12]

Both calicheamicin and esperamicin are extraordinarily active against a number of tumor cell lines. They exhibit a potency 3−4 orders of magnitude greater than that of adriamycin in some assays.[1,2] Presumptive evidence indicates that the cytotoxicity of these drugs is derived from their known ability to cleave DNA in a double-stranded fashion.[13] This process is initiated by an *in vivo* reduction of the trisulfide functionality of the

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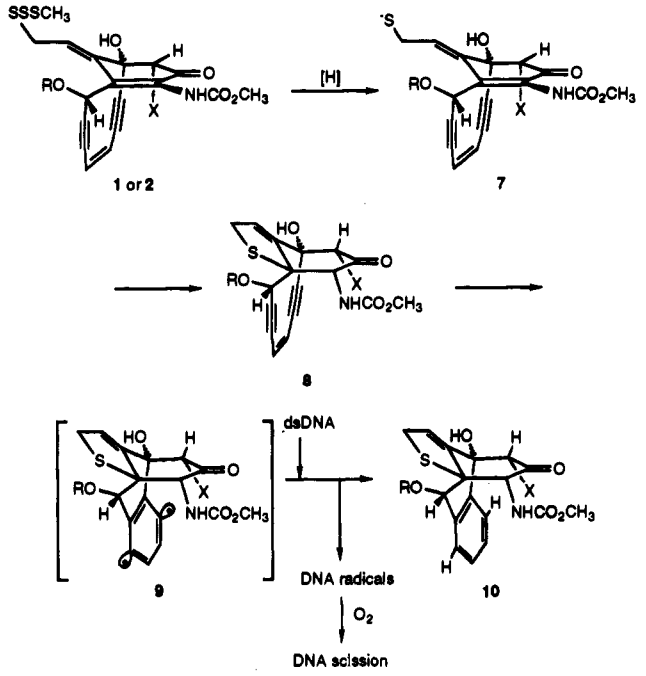
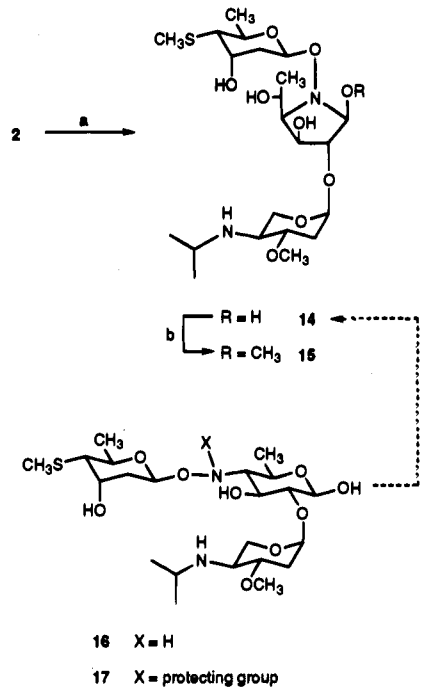
Scheme 1



aglycon to an allylic thiolate **7** (Scheme 1).[8e] This thiolate species cyclizes to the bridgehead enone to generate the intermediate **8**. Bergman-type cycloaromatization[14] of the enediyne unit in **1** or **2** is itself prevented by the enone double bond because the resulting 1,4-diradical would contain a highly strained anti-Bredt olefin. The rehybridization of the bridgehead center from sp^2 to sp^3 lowers the strain of the resulting diyl **9** and provides an attainable kinetic pathway for cyclization under mild conditions.[15] The 1,4-diradical **9** produced by the cycloaromatization abstracts hydrogen atoms from the sugar backbone of DNA. Further reaction of these DNA radicals with O_2 results in DNA strand scission.[16a]

Calicheamicin and esperamicin each bind to DNA in the minor groove.[16,17] Calicheamicin was shown to be quite sequence selective in cleaving DNA;[13a] esperamicin is less selective.[16] Calicheamicin cleaves DNA predominantly by abstracting the *pro-S* hydrogen atom from C-5′ of the 5′-cytosine of TCCT sequences and another from C-4′ of the residue on the opposing strand, which is three base pairs in the 3′ direction from this site.[18] Other sequences were identified as also being susceptible to cleavage.[19] Although the origins of sequence-selective cleavage by **1** are the subject of some debate, it is clear that the aryltetrasaccharide domain plays a very important role in the DNA recognition event prior to cleavage. It was proposed that the major contributions to binding made by the carbohydrate subunit are hydrophobic in nature.[20] Walker *et al.*[21] and Paloma *et al.*[22] have shown, through NMR studies, that calicheamicin adopts an extended, highly preorganized conformation in solution, making it well suited to function as a minor groove binder. They have further demonstrated that the hydroxylamine glycosidic linkage plays a key role in maintaining this extended structure.[23] An early line of evidence which identified the role of the carbohydrate domain in DNA recognition was the finding that our synthetic aglycon, calicheamicinone, lacked any discernible sequence selectivity though it retained modest double-strand cleavage tendencies.[24]

Scheme 2[a]



[a] Reagents: (a) $NaBH_4$, CH_3OH; (b) CH_3OH, AcOH.

The studies described herein were initiated with several goals in mind. It was felt that synthetic routes to the carbohydrate domains of **1** and **2** provided more promising avenues for obtaining material than degradation of the natural products. The likelihood of obtaining the two drugs in amounts which were ample for proper chemical investigation was not promising. Such information suggested that the prospect of retrieving the entire carbohydrate by hydrolysis, even if the drug were available, was unlikely. The indications were that, at least in the case of calicheamicin, this domain would not survive detachment of the carbohydrate A ring from the aglycon, calicheamicinone (**11**).[6a-c] Furthermore, in the esperamicin series, there was a report which suggested that the carbohydrate domain, containing a free "reducing end" in ring A (see **16**, Scheme 2), was inherently unstable and underwent rapid rearrangement.[25] The finding was that treatment of compound **2** with sodium borohydride led not to **16** (or its derived alditol reduction

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product) but to a compound whose structure was assigned as **14**[25] (Scheme 2).

Thus, synthesis was seen to provide several advantages relative to retrieval of the carbohydrates from the natural products. The length and nature of the carbohydrate domain could be strictly defined. Also, synthesis seemed to provide the most promising prospect for exploring the rearrangement of a properly defined system of the type **16** to the pyrrolidine sugar **14**. Only in this way could one evaluate whether the formation of **14** from **16** was so fast as to effectively preclude the use of the latter in a total synthesis venture.

As mentioned above, the aglycon, calicheamicinone, retains a double-stranded cleaving capacity which, while only 10−20% that of the drug itself, is still formidable in the broader world of organic DNA cleaving agents. However, the aglycon exhibited no sequence specificity. These studies by implication identified the saccharide section as the source of specific DNA recognition. This surmise was validated by studies of methyl glycoside **13** conducted concurrently by Nicolaou and ourselves.[21b,26-28] It was to establish the role of the aryltetrasaccharide segment in DNA recognition and to document its chemical character that these studies were undertaken. Furthermore, synthesis carried with it, in principle, the possibility of protecting the hydroxylamino nitrogen during the synthetic buildup. In that way, rearrangement to systems of the type **14** would be avoided until it could be examined in a clear setting.

A final goal of our synthesis was that the entire carbohydrate domain, particularly that of calicheamicin, be rendered presentable as a viable glycosyl donor to an appropriate aglycon construct. This concept was, from the beginning, our guiding paradigm for a total synthesis of **1**. If the rearrangement of presumed **16** to **14** as described by the Bristol-Myers workers[25] was spontaneous, it would be necessary to protect the connecting hydroxylamino NH linkage in addition to the *N*-ethyl function in the E ring (as well as some or all of the hydroxyl functions in the domain). Through chemical synthesis of this domain, the tolerance of the aryltetrasaccharide sector for the steps required in a total synthesis could be delineated. In this paper, we describe the attainment of these objectives. The evolving logic employed in the syntheses of the carbohydrate domains **12** and **13** of esperamicin and calicheamicin, respectively, is presented and documented (Figure 2).

As a result of our studies, the rearrangement of **16** to **14** was rigorously demonstrated rather than surmised. The feasibility for precluding this rearrangement (see compounds **12**, **13**, and **17**) was also established. Armed with this insight, we established that the goal of generating a construct of the calicheamicin domain which is suitably protected and activated to function as a glycosyl donor was achieved.[6c] *Finally, the actual glycosylation of a calicheamicin construct with a glycosyl donor embracing the full calicheamicin carbohydrate domain was demonstrated for the first time.*[29,30] It was through a detailed command of the nuances of the aryltetrasaccaharide domain that a maximally advanced glycosyl donor could, in time, be

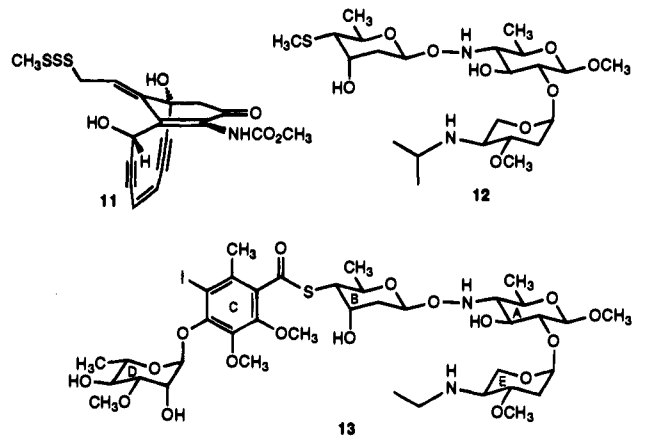
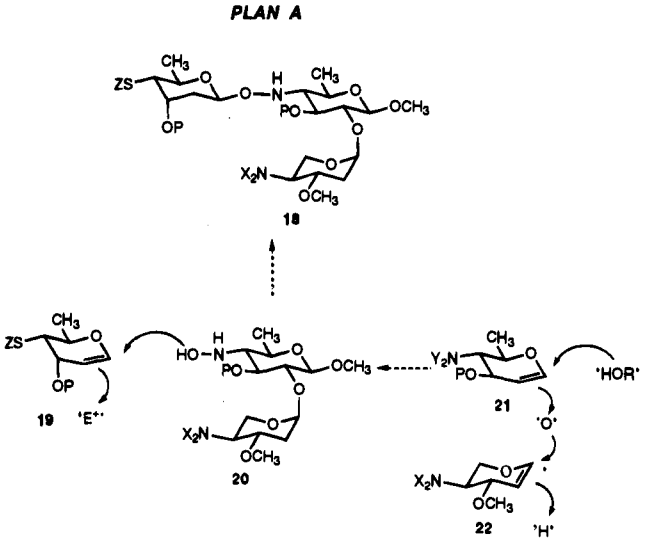


Figure 2.

Scheme 3



fashioned and presented to a maximally advanced acceptor in our total synthesis of the drug itself.[6c]

Synthetic Planning

Not distant from our plans was the notion of employing glycals as building blocks. It was anticipated that significant relief from lengthy functional group manipulations would follow from their use. The targets of the synthesis seemed appropriate for expanding the glycal-based methodologies developed in our group.[31] The fashioning and assembly of each building block would be used to further probe the limitations in the emerging chemistry of glycals.

Two general approaches to the core trisaccharide (cf. **18**) were conceived. In Scheme 3, we leave unspecified the nature of

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(27) (a) Nicolaou, K. C.; Tsay, S.-C.; Suzuki, T.; Joyce, G. F. *J. Am. Chem. Soc.* **1992**, *114*, 7555. (b) Li, T.; Estevez, V. A.; Baldenius, K. U.; Nicolaou, K. C.; Joyce, G. F. *J. Am. Chem. Soc.* **1994**, *116*, 3709.

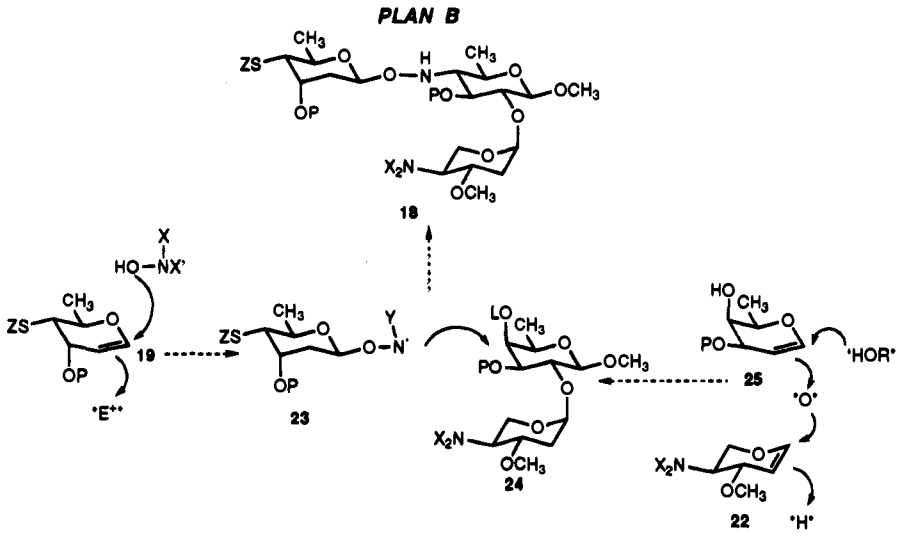
(28) Previously, the Schrieber group used molecular modeling to propose that the sequence selectivity was due to the oligosaccharide fragment. Hawley, R. C.; Kiessling, L. L.; Schreiber, S. L. *Proc. Natl. Acad. Sci. U.S.A.* **1989**, *86*, 1105.

(29) For a preliminary account of the synthetic work in the esperamicin series, see: Halcomb, R. L.; Wittman, M. D.; Olson, S. H.; Danishefsky, S. J.; Golik, J.; Wong, H.; Vyas, D. *J. Am. Chem. Soc.* **1991**, *113*, 5080.

(30) For a preliminary account in the calicheamicin series and the first account of glycosylation by the entire carbohydrate domain see: Halcomb, R. L.; Boyer, S. H.; Danishefsky, S. J. *Angew. Chem., Int. Ed. Engl.* **1992**, *31*, 338.

(31) (a) Halcomb, R. L.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1989**, *111*, 6661. (b) Friesen, R. W.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1989**, *111*, 6656. (c) Griffith, D. A.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1990**, *112*, 5811. (d) Suzuki, K.; Sulikowsky, G. A.; Friesen, R. W.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1990**, *112*, 8895. (e) Griffith, D. A.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1991**, *113*, 5863. (f) Danishefsky, S. J.; Gervay, J.; Peterson, J. M.; McDonald, F. E.; Koseki, K.; Oriyama, T.; Griffith, D. A.; Wong, C.-H.; Dumas, D. P. *J. Am. Chem. Soc.* **1992**, *114*, 8329. (g) Danishefsky, S. J.; Koseki, K.; Griffith, D. A.; Gervay, J.; Peterson, J. M.; McDonald, F. E.; Oriyama, T. *J. Am. Chem. Soc.* **1992**, *114*, 8331. (h) Randolph, J. T.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1993**, *115*, 8473. (i) Danishefsky, S. J.; McClure, K. F.; Randolph, J. T.; Ruggeri, R. B. *Science* **1993**, *260*, 1307.

Scheme 4



X, Y, and Z. Thus, in principle, the plan could be considered either for the core trisaccharide of esperamicin or the aryltetrasaccharide domain of calicheamicin (compounds **12** and **13**, respectively).

In the first approach, plan A (Scheme 3), we envisioned the addition of the oxygen atom of a hydroxylamine, present in disaccharide **20**, to the double bond of glycal **19** or its derivatives. It was postulated that a sterically demanding protecting group on O-3 of **19** would coax addition of the nucleophile to the β face of the double bond. The disaccharide subunit, in turn, was to be synthesized from glycals **21** and **22**.

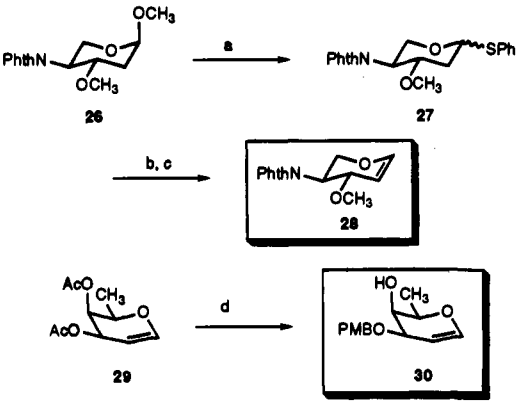
The second approach, plan B (Scheme 4), differed fundamentally from the first in the manner in which the hydroxylamine linkage would be installed. This scheme involved using a nucleophilic version of a suitable *O*-glycosylhydroxylamine (**23**) to displace an axial leaving group at C-4 of the disaccharide **24**.[5b] Compound **23** was to be synthesized by addition of an *N*-protected hydroxylamine of the β face of the glycal **19**. Disaccharide **24** was to be synthesized from **25** and **22** in a fashion analogous to that in plan A.

After initial explorations, it was found that plan A could not be implemented. At no point could we realize any version of the transformation generalized as **19** + **20** → **18**.[32] While the bicyclic domain corresponding to **20** was synthesized, the hydroxyl linkage of the hydroxylamine moiety never functioned as a glycosyl acceptor in the context needed. Hence we confine this report to a description of plan B, which was implemented in both the esperamicin and the calicheamicin series.

Results and Discussion

The first task undertaken was the synthesis of the three glycal building blocks. The synthesis of the glycal precursor to the amino sugar began with the known methyl glycoside **26**[33] (Scheme 5). Treatment of **26** with thiophenol and $BF_3{\cdot}Et_2O$[34] provided a mixture of thioglycosides **27**. Oxidation of these thioglycosides with MCPBA followed by thermally induced elimination of the resulting sulfoxides[35] gave glycal **28** in 83% overall yield.

Scheme 5[a]



[a] Conditions: PhSH, $BF_3{\cdot}Et_2O$, CH_2Cl_2; (b) MCPBA, CH_2Cl_2, 0 °C; (c) benzene, reflux; (d) (i) NaOMe, MeOH; (ii) Bu_2SnO; (iii) PMB-Br, CsF, DMF, 80 °C.

Di-*O*-acetyl-D-fucal (**29**)[36] was chosen as the starting point for the synthesis of the glycal precursor to the hydroxylamino sugar (Scheme 5). Deacetylation of **29** with sodium methoxide, stannylene formation with di-*n*-butyltin oxide, and selective benzylation of the equatorial hydroxyl,[37] in sequence, provided glycal **30** in 73% yield.

Initial proposals to synthesize a glycal bearing the thio functionality of the B ring (cf. **19**) contemplated S_N2-like inversion of configuration at C-3 of substrates such as **31** to establish the axial oxygen functionality at C-3.[38] However, in practice, several such attempts to achieve direct displacements on substrates such as **31** led, instead, to products (cf. **33**) derived from the well-known Ferrier rearrangement[39] (Scheme 6).

Additionally, sequences involving oxidation to the corresponding ketone followed by selective reduction were not

(32) In our initial explorations, (M. D. Wittman and R. L. Halcomb), the possibility of directly *O*-glycosylating hydroxylamines such as **20** with glycal donors such as **19** was examined and met with limited success, though not in the desired sense. Most successful attempts to join the two fragments produced nitrones, apparrently via an *N*-glycosylated intermediate. For the synthesis of hydroxylamines such as **20**, see: Wittman, M. D.; Halcomb, R. L.; Danishefsky, S. J. *J. Org. Chem.* **1991**, *55*, 1981.

(33) Golik, J.; Wong, H.; Vyas, D.; Doyle, T. W. *Tetrahedron Lett.* **1989**, *30*, 2497.

(34) (a) Hanessian, S.; Guindon, Y. J. *Carbohydr. Res.* **1980**, *86*, C3. (b) Nicolaou, K. C.; Selitz, S. P.; Paphatjis, D. P. *J. Am. Chem. Soc.* **1983**, *105*, 2430.

(35) Danishefsky, S. J.; Armistead, D. M.; Wincott, F. E.; Selnick, H. G.; Hungate, R. *J. Am. Chem. Soc.* **1989**, *111*, 2967.

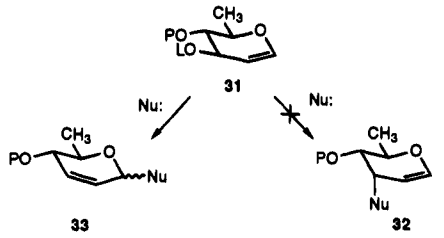
(36) Whistler, R. C.; Wolfrom, M. L. *Methods Carbohydr. Chem.* **1963**, *2*, 457.

(37) David, S.; Hanessian, S. *Tetrahedron* **1985**, *41*, 643.

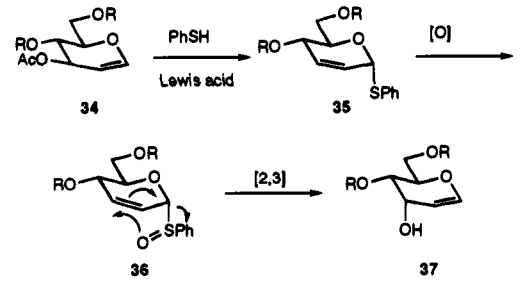
(38) Lopez, J. C.; Fraser-Reid, B. *J. Chem. Soc., Chem. Commun.* **1992**, 94.

(39) (a) Valverde, S.; Garcia-Ochoa, S.; Martin-Lomas, M. *J. Chem. Soc., Chem. Commun.* **1987**, 383. (b) Ferrier, J. J. *Adv. Carbohydr. Chem. Biochem.* **1969**, *24*, 199.

Scheme 6



Scheme 7

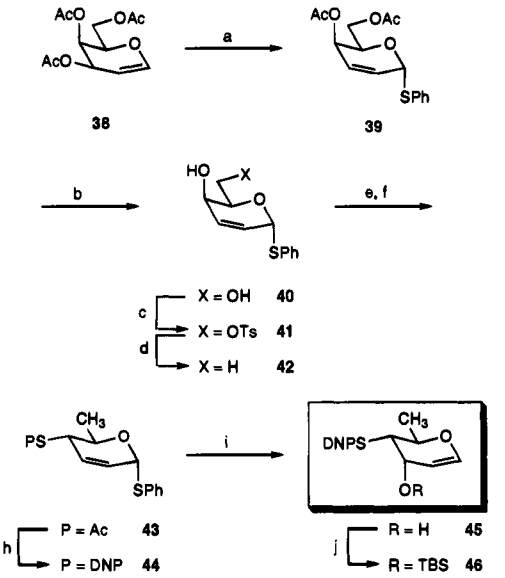


satisfactory. These reverses prompted the development of a new and general methodology for the synthesis of glycals bearing axial C-3 oxygenation.[40] The crux of the method, as illustrated in Scheme 7, is a [2,3]-sigmatropic rearrangement of an anomeric sulfoxide **36**[41] to afford glycal **37**, exploiting the suprafacial nature of the process to transfer chirality from C-1 to C-3. In this way, advantage could be taken of the tendency of the Ferrier rearrangement to direct nucleophiles to the α face of glycals at C-1.[42]

Our starting material was tri-*O*-acetyl-D-galactal (**38**, Scheme 8).[43] Reaction of **38** with thiophenol[39] provided the pseudoglycal **39**, which upon deacylation and subsequent selective tosylation provided **41** via the intermediate diol **40**. Reductive cleavage of the tosylate afforded **42**, and subsequent introduction of sulfur functionality at C-4 by displacement of the corresponding axial mesylate with KSAc led to thiolacetate **43**. The thiol group, obtained by reductive deacylation, was protected as a dinitrophenyl thioether (see compound **44**).[44] This protective arrangement was intended to serve two important ends. It would differentiate the two sulfur atoms and thus allow chemoselective oxidation of the anomeric sulfide. Furthermore, it would help to circumvent the otherwise likely migration of the acetyl group from the thiol at C-4 to the hydroxyl group at C-3.[45]

In practice, treatment of compound **44** with MCPBA selectively oxidized the anomeric sulfide to the corresponding sulfoxide. Upon exposure to diethylamine, the presumed sulfoxide gave rise to glycal **45** ostensibly by [2,3]-sigmatropic

Scheme 8[a]



[a] Conditions: (a) PhSH, $SnCl_4$, CH_2Cl_2, −20 °C; (b) NaOMe, MeOH; (c) (i) Bu_2SnO, MeOH, reflux; (ii) TsCl, $CHCl_3$, Bu_4NBr, room temperature; (d) $LiAlH_4$, THF, reflux; (e) MsCl, CH_2Cl_2, Et_3N, 0 °C; (f) KSAc, DMF, room temperature; (g) $LiAlH_4$, THF, 0 °C; (h) DNP-F, room temperature; (i) (i) MCPBA, CH_2Cl_2, −40 °C; (ii) Et_2NH, THF, room temperature; (j) TBSOTf, pyr, CH_2Cl_2, 0 °C.

rearrangement. The axial alcohol function of compound **45** was protected as the silyl ether **46** in anticipation of further transformations.

The core trisaccharide was rapidly assembled from the three glycal building blocks as shown in Scheme 9. Treatment of glycal **30** with dimethyldioxirane[31a] followed by methanol afforded the methyl glycoside **47**, along with a minor amount (<5%) of the α anomer. This diol was chemoselectively coupled, with use of collidine-complexed iodonium perchlorate,[31b,46] with glycal **28** to produce compound **48** in 49% yield. Minor amounts of the O-4 glycosylated (5−10%) and the bis-glycosylated (10−15%) compounds were also produced. Deiodination with triphenyltin hydride led to disaccharide **49**, which was converted to coupling candidate **50** upon treatment with triflic anhydride and pyridine. Thus, glycal assembly had provided rapid access to an otherwise complicated AE construct.

Several options were explored which would have avoided the need for a selective glycosylation of the diol **47**. These involved protection of the axial C-4 hydroxyl of **30** prior to the epoxidation/methanolysis sequence. In the model studies discussed herein, this refinement was not pursued. The possibility was revived and reduced to practice in fashioning the actual donor sugar for the total synthesis of calicheamicin γ_1^I (*vide infra*).

The *O*-glycosylhydroxylamine linkage was installed by treating a mixture of glycal **46** and *N*-(2-(trimethylsilyl)-ethoxycarbonyl)hydroxylamine (TEOC-NHOH) with a catalytic amount of triphenylphosphine hydrobromide,[47] thus producing **51** in 52% yield. Unfortunately, this reaction produced a substantial amount (37%) of byproduct which resulted from *N*-glycosylation. The bulky TBS protecting group on the axial

(40) Wittman, M. D.; Halcomb, R. L.; Danishefsky, S. J.; Golik, J.; Vyas, D. *J. Org. Chem.* **1990**, *55*, 1979.

(41) (a) Evans, D. A.; Andrews, G. C. *Acc. Chem. Res.* **1974**, *7*, 147. (b) Bickart, P.; Carson, F. W.; Jacobus, J.; Miller, E. G.; Mislow, K. *J. Am. Chem. Soc.* **1968**, *90*, 4869.

(42) (a) Deslongchamps, P. *Stereoelectronic Effects in Organic Chemistry*; Pergamon: New York, 1983. (b) Kirby, A. J. *The Anomeric Effect and Related Stereoelectronic Effects at Oxygen*; Springer-Verlag: Berlin, 1983.

(43) All attempts to accomplish a Ferrier rearrangement with di-*O*-acetyl-D-fucal and thiophenol failed to provide useful yields of the desired pseusoglycal. Therefore, this process was formally carried out by performing the rearrangement with tri-*O*-acetyl-D-galactal and later deoxygenating C-6.

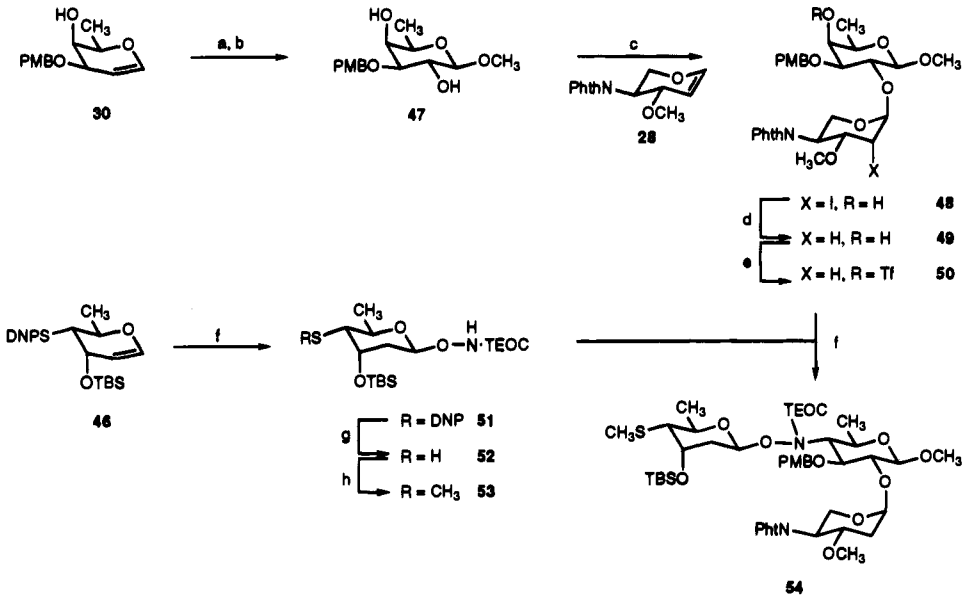
(44) Shaltiel, S. *Biochem. Biophys. Res. Commun.* **1967**, *29*, 178.

(45) Such migrations had been observed from C-4 acetates,[40] prompting consideration of the possibility of participation of the C-4 acetate as an alternative to the [2,3]-sigmatropic shift in producing the axial alcohol at C-3 of glycals from C-1α phenylsulfinyl pseudoglycals.[40] This mechanistic issue has not been investigated further.

(46) (a) Thiem, J.; Karl, H.; Schwentner, J. *Synthesis* **1978**, *7*, 696. (b) Thiem, J. In *Trends in Synthetic Carbohydrate Chemistry*; Horton, D., Hawkins, L. D., McGarvey, G. J., Eds.; ACS Symposium Series 386; American Chemical Society: Washington, DC, 1989; Chapter 8 and references therein. (c) Lemieux, R. U.; Morgan, A. R. *Can. J. Chem.* **1965**, *43*, 2190.

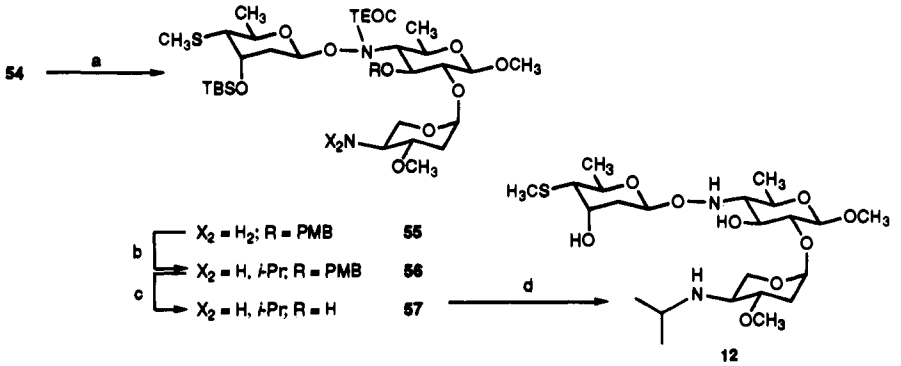
(47) Bolitt, V.; Mioskowski, C.; Lee, S.-G.; Falck, J. R. *J. Org. Chem.* **1990**, *55*, 5812.

Scheme 9[a]



[a] Conditions: (a) dimethyldioxirane, CH_2Cl_2, acetone, 0 °C; (b) CH_3OH, room temperature; (c) $I^+(sym\text{-collidine})_2ClO_4^-$, **28**, −48 °C to room temperature; (d) Ph_3SnH, AIBN, benzene, reflux; (e) Tf_2O, pyr, CH_2Cl_2, 0 °C; (f) TEOC-NHOH, $Ph_3P{\cdot}HBr$, CH_2Cl_2, room temperature; (g) EtSH, K_2CO_3, MeOH, room temperature; (h) CH_3I, DBU, benzene, room temperature; (i) **53**, NaH, DMF, 0 °C → room temperature, then **50**, 0 °C.

Scheme 10[a]



[a] Conditions: (a) N_2H_4, EtOH, reflux; (b) acetone, $NaCNBH_3$, *i*-PrOH, $MgSO_4$, room temperature; (c) DDQ, CH_2Cl_2, H_2O, room temperature; (d) Bu_4NF, THF, 0 °C → room temperature.

alcohol of **46** had served the anticipated end of directing the attack of the nucleophile to the β face of the glycal double bond, and no α-glycosides were observed.[48] However, the lack of chemoselectivity between the hydroxy and urethane functions was certainly a significant complication in processing our component glycals. The DNP protecting group in **51** was removed by treatment with potassium ethanethiolate to afford the thiol **52**, which was methylated to give the thioether **53** in 89% overall yield. Following the important precedents of Kahne,[5b,49] the fragments **50** and **53** were joined by first deprotonation of **53** with sodium hydride in DMF, followed by coupling of the urethane anion with triflate **50**.[5b] The fully protected trisaccharide **54** was thus obtained in 78% yield.

The final manipulations required to obtain the core trisaccharide **12** found in esperamicin were accomplished in a straightforward manner (Scheme 10). Cleavage of the phthalimide group with hydrazine in refluxing ethanol provided compound **55**. Reductive amination conditions were chosen as the most suitable for monoalkylation of the amine.[50] Treatment of the primary amine **55** with acetone and sodium cyanoborohydride cleanly provided the secondary amine **56**. Compound **56** was treated with DDQ[51] to cleave the 4-methoxybenzyl group, providing compound **57**. Finally, removal of the silyl protecting groups with tetrabutylammonium fluoride provided the core trisaccharide **12**. Evidence for the structure of **12** was supported by the presence of a triplet for H-4 (δ 2.32, J = 9.7 Hz)[52] in the ^1H NMR spectrum, which was diagnostic for the presence of the equatorial hydroxylamine at C-4.

As discussed above, no comparison sample of such a trisaccharide was available from esperamicin. Accordingly, with a synthetic route to compound **12** having been established, the next objective was to synthesize the rearranged trisaccharide **14**. This compound could provide the structural link between the fully synthetic **12** and material derived from esperamicin itself. With a view to reaching a fully synthetic esperamicin

(48) (a) Kaila, N.; Blumenstein, M.; Bielawska, H.; Franck, R. W. *J. Org. Chem.* **1992**, *57*, 4576. (b) Franck, R. W.; Kaila, N.; Blumenstein, M.; Geer, A.; Huang, X. L.; Dannenberg, J. J. *J. Org. Chem.* **1993**, *58*, 5335.

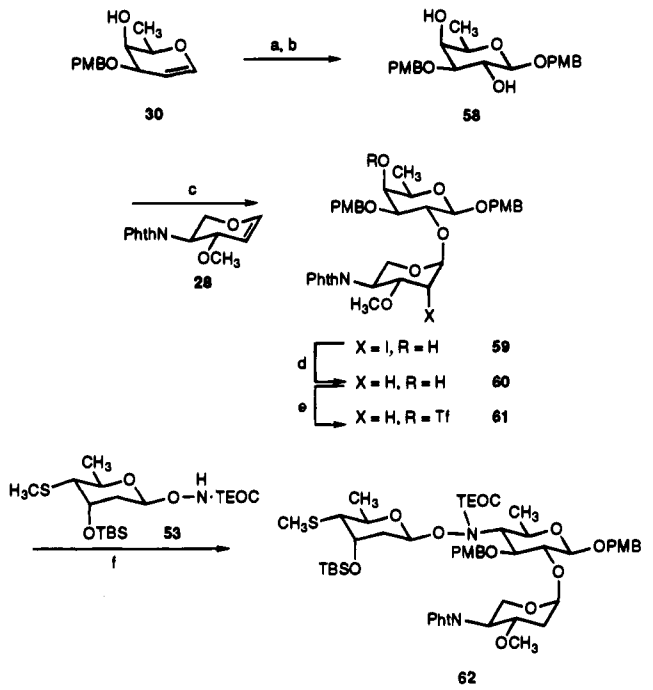
(49) Attempts to displace the axial triflate of **50** with the NH_2 group of *O*-glycosylhydroxylamines whose amino functionality did not bear an activating group (e.g., the TEOC carbamate) produced woefully low yields of the desired trisaccharide, with the major products arising from elimination of triflic acid. For related observations, see ref 5b.

(50) Borch, R. F. *Org. Synth.* **1972**, *52*, 124.

(51) Oikawa, Y.; Yoshioka, T.; Yonemitsu, O. *Tetrahedron Lett.* **1982**, *23*, 885.

(52) In an esperamicin degradation product (ref 2b), this proton appears as a dd at δ 2.26 (J = 9.6, 10.3 Hz).

Scheme 11[a]



[a] Conditions: (a) dimethyldioxirane, CH_2Cl_2, acetone, 0 °C; (b) PMBOH, CH_2Cl_2, room temperature; (c) $I^+(sym\text{-collidine})_2ClO_4^-$, **28**, −48 °C to room temperature; (d) Ph_3SnH, AIBN, benzene, reflux; (e) Tf_2O, pyr, CH_2Cl_2, 0 °C; (f) **53**, NaH, DMF, 0 °C → room temperature, then **61**, 0 °C.

core trisaccharide which contained a free reducing end, it was necessary to fashion a structure analogous to **12** in which the anomeric hydroxyl of the A ring could be exposed under mild conditions, consistent with survival of the domain. A *p*-methoxybenzyl (PMB) group was chosen, in anticipation of its removal (along with the PMB protecting group at C-3) at a late stage of the synthesis.

Introduction of the anomeric PMB function was accomplished by exposure of the epoxide[31a] derived from glycal **30** to 4-methoxybenzyl alcohol, providing **58** (Scheme 11). In contrast to the relatively clean methanolysis result which led to **47**, similar solvolysis with *p*-methoxybenzyl alcohol afforded a serious mixture of both α and β anomers (1.5:1) in 55% total yield. Fortunately, the two compounds were easily separated, and each could be selectively glycosylated at O-2, permitting the use of either compound in the synthetic sequence.[53] Compound **58** was selectively iodoglycosylated with glycal **28** to afford **59** (62%), which was cleanly deiodinated in the usual manner to give **60** in 93% yield. Activation of compound **60** as its triflate was accomplished as before, providing **61**. Displacement of the axial triflate of **61** with the anion of carbamate **53** under the Kahne conditions[5b] gave the trisaccharide **62** in 74% yield.

Hydrazinolysis and reductive alkylation provided, via the intermediate primary amine **63**, the protected trisaccharide **64** in 85% overall yield (Scheme 12). Removal of both 4-methoxybenzyl groups with DDQ provided compound **65** as a 1:1 mixture of anomers (66%). *We note that the TEOC urethane had served a purpose which will later prove to be vital in subsequent glycosylation studies. It had maintained the integrity of the pyranose hemiacetal (see below), thus permitting activation of the reducing end for coupling to aglycons.*

The time was at hand to attempt a comparison with aza sugar **14**, available by degradation of esperamicin. In the event, discharge of the urethane from **65** induced an apparently spontaneous rearrangement to the azafuranose form. Thus, treatment of compound **65** with fluoride ion effectively cleaved all silyl protecting groups and provided compound **14**. A comparison of the ^1H NMR spectrum of **14** with a spectrum of the same compound derived from degradation showed the two to be virtually identical, although some small differences were of concern, primarily in the chemical shifts of the exchangeable protons. Unequivocal structural proof was obtained after conversion of fully synthetic **14** to its methyl glycoside **15** (45% from **65**) upon treatment with methanol and acetic acid. Compound **15** was identical (^1H and ^{13}C NMR) to an authentic sample obtained via methyl acetalization of **14** derived from esperamicin itself.

The work described above had established that the coexistence of a free "reducing end" on the A ring sugar and the unprotected hydroxylamine linker in the esperamicin trisaccharide (cf. compound **16**) would not be feasible because of the formation of rearrangement product **14**. On the other hand, maintenance of a protecting group at either of these centers provides a viable structure (cf. **12** or **65**). In principle, a structure such as **65**, or a calicheamicin equivalent thereof, could be activated to function as a glycosyl donor. Since the domain represented by **65** is in its required oxidation level, one could contemplate using a relatively advanced form of the aglycon acceptor, thereby minimizing the need for postglycosidation maneuvers and promoting maximum convergence.

We directed our efforts primarily toward the calicheamicin series. It was anticipated that in shifting our attentions toward this goal, we could not only take advantage of the synthetic logic developed above but also make use of several of the synthetic intermediates already prepared. The largest new task which presented itself was the synthesis of the CD aryl glycoside block. The opening strategy for the synthesis of the phenyl glycoside subunit sought to employ a formal overall oxidative addition of the previously reported phenol **75**[54] (see below) to the double bond of an L-rhamnal derivative. As will be seen, in practice we utilized a Ferrier rearrangement as the initial step, with the oxidation delayed until a later stage.

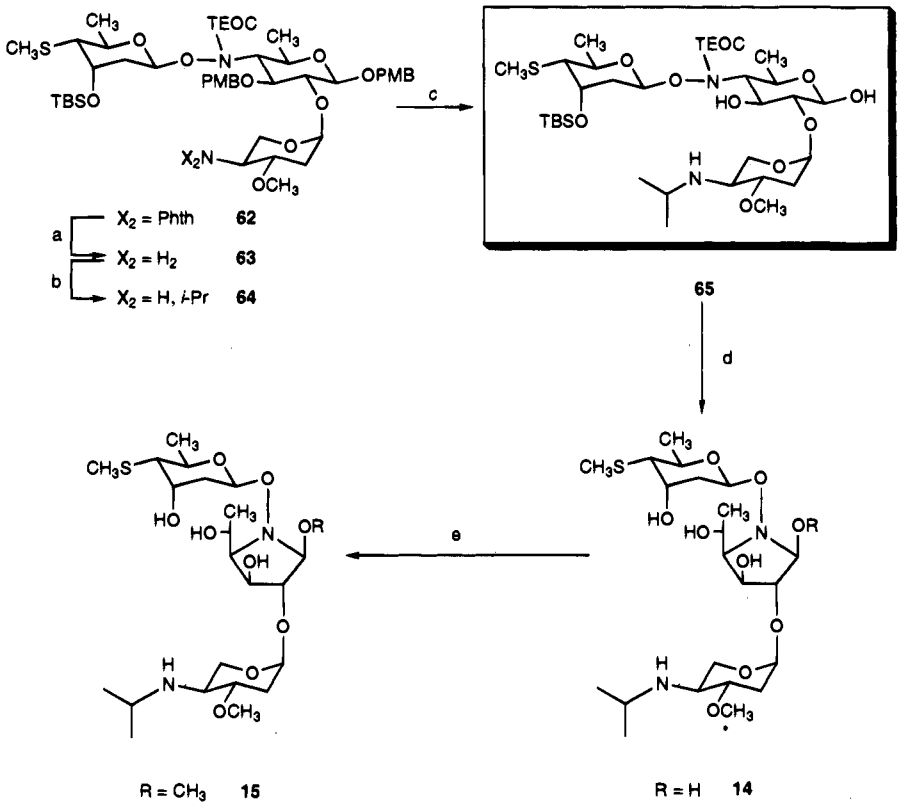
The synthesis began with a Lewis acid-catalyzed Ferrier rearrangement[39b] of di-*O*-acetyl-L-rhamnal (**66**) and benzyl alcohol, providing the pseudoglycal **67** (Scheme 13). Attempts to achieve Ferrier rearrangement using **75** (see below) as a nucleophile were unsuccessful. After exchange of the acetate for a TBS protecting group (91% overall yield), the double bond was dihydroxylated using catalytic osmium tetraoxide and *N*-methylmorpholine *N*-oxide. Compound **70** was thus produced in 96% yield. Osmylation of acetate **67** gave a mixture of the two possible diols.[53] The diol **70** was selectively methylated via its derived dibutylstannylene[37] at the equatorial hydroxyl group, to afford compound **71** along with some of the O-2 methylated derivative (ratio of O-3:O-2 methylation, 4:1).

To achieve the desired anomeric configuration in the glycosylation of an aromatic acceptor, a participating protecting group at C-2 was desired. This purpose was served quite well by the acetate group in **72**, which arose from treatment of compound **71** with acetic anhydride and pyridine (Scheme 13). Hydrogenolysis of the anomeric benzyl group of **72** provided compound **73**, which was activated as its corresponding trichlo-

(53) Halcomb, R. L. Ph.D. Thesis, Yale University, New Haven, CT, 1992.

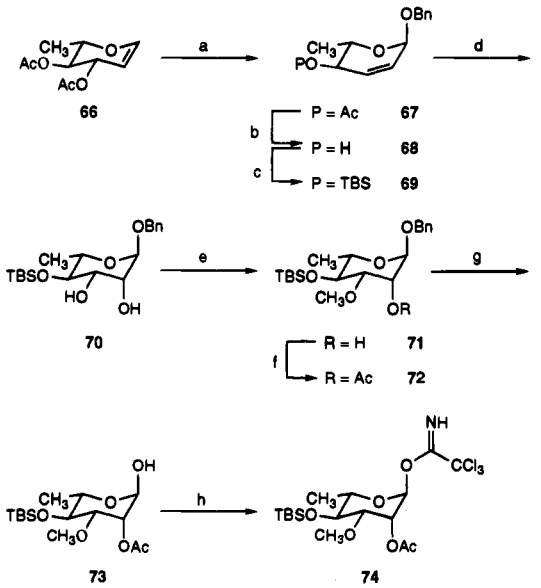
(54) Nicolaou, K. C.; Ebata, T.; Stylianides, N. A.; Groneberg, R. D.; Carrol, P. J. *Angew. Chem., Int. Ed. Engl.* **1988**, *27*, 1097.

Scheme 12[a]



[a] Conditions: (a) N_2H_4, EtOH, reflux; (b) acetone, $NaCNBH_3$, *i*-PrOH, $MgSO_4$, room temperature; (c) DDQ, CH_2Cl_2, H_2O, room temperature; (d) Bu_4NF, THF, 0 °C → room temperature; (e) CH_3OH, AcOH.

Scheme 13[a]



[a] Conditions: (a) BnOH, CH_2Cl_2, $BF_3{\cdot}Et_2O$, room temperature; (b) NaOMe, MeOH; (c) TBSCl, imidazole, CH_2Cl_2, room temperature; (d) OsO_4, NMO, acetone, H_2O, room temperature; (e) (i) Bu_2SnO, MeOH, reflux; (ii) CH_3I, Bu_4NBr, benzene, reflux; (f) Ac_2O, pyridine; (g) H_2, $Pd(OH)_2$, MeOH; (h) Cl_3CCN, NaH, CH_2Cl_2, 0 °C.

roacetimidate by treatment with trichloroacetonitrile and NaH (87% for two steps).[55]

In seeking our first entry into the arylrhamnose sector, we used as our glycosyl acceptor phenol **75** prepared through a protocol described by Nicolaou.[54] According to the procedure of Schmidt,[55] addition of boron trifluoride etherate to a solution of **74** and **75** cleanly provided the aryl glycoside **76** (89%). After serving its purpose of directing the course of the glycosylation, the acetate was cleaved, and the resulting alcohol was protected with a *tert*-butyldimethylsilyl ether (91% for two steps) to avoid complications anticipated in later steps.

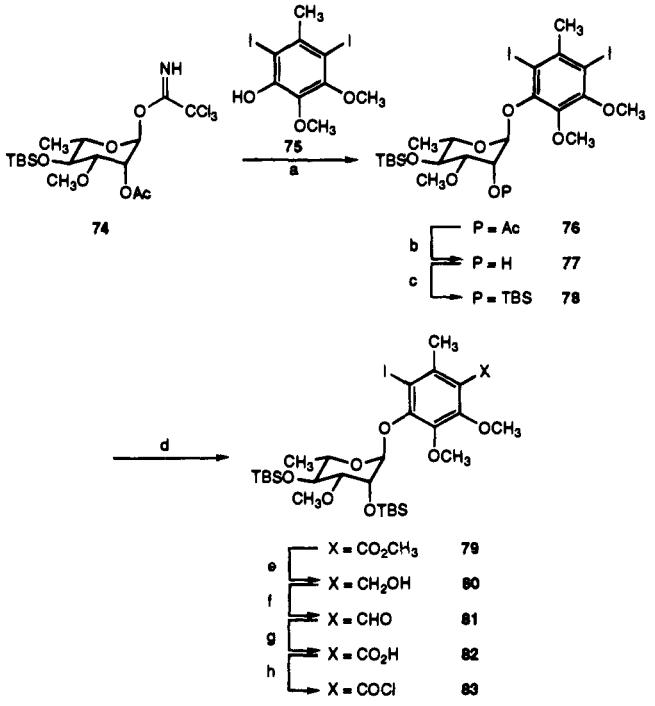
Previously, the BOM ether of phenol **75** was selectively methoxycarbonylated, under palladium catalysis, at the site para to the sterically bulky BOM group (para:ortho 4.5:1).[54] We reasoned that the glycosyl substituent would be more sterically demanding than a BOM group and might well enhance the regioselectivity in this carbonylation. This indeed was shown to be the case. Upon heating a mixture of **78**, methanol, and Pd under a carbon monoxide atmosphere at 65 °C, compound **79** was produced in 45% yield (Scheme 14). The regioisomeric methyl ester and the bis-ester were also produced as minor products (7 and 17% yields, respectively).

Experiments designed to obtain the corresponding carboxylic acid **81** directly in the carbonylation reaction by substituting H_2O for methanol led only to reductive deiodination of the aromatic ring. Additionally, all attempts to hydrolyze or dealkylate the methyl ester of **79** were unsuccessful. Forcing conditions led to cleavage of the silyl ethers with subsequent cleavage of the glycoside bond, presumably through a 1,2-epoxide intermediate.[56] However, a reduction−oxidation sequence was found to effectively achieve the same overall transformation. Reduction of **79** with DIBAL-H provided the benzyl alcohol **80** (90%). Two-step oxidation, first with Dess−

(55) Schmidt, R. R. *Angew. Chem., Int. Ed. Engl.* **1986**, *25*, 212.

(56) Treatment of **79** with with methoxide under forcing conditions led to loss of the silyl groups and the production of an α-methyl glycoside. Presumably this reaction occurs by desilylation followed by intramolecular displacement of the aglycon by the alkoxide generated at the 2-position. The 1,2-anhydro sugar epoxide intermediate is then nucleophilically opened by methoxide. See also ref. 62.

Scheme 14[a]

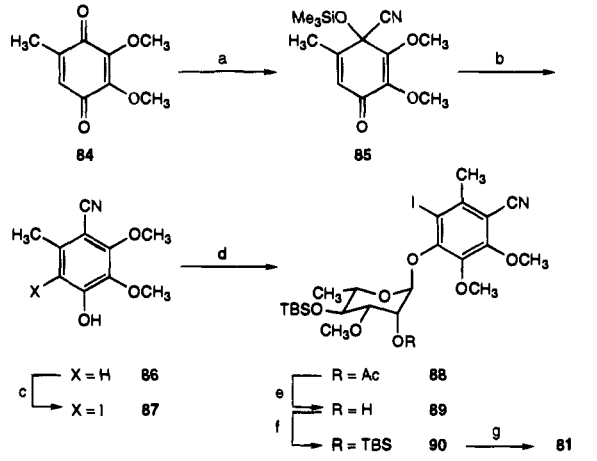


[a] Conditions: (a) $BF_3{\cdot}Et_2O$, CH_2Cl_2, −48 °C; (b) NaOMe, MeOH; (c) TBSOTf, DMAP, pyridine, CH_2Cl_2, 0 °C; (d) CO, $Pd(OAc)_2$, MeOH, Et_3N, $Ph_2P(CH_2)_2PPh_2$, DMSO, 65 °C; (e) *i*-Bu_2AlH, CH_2Cl_2, −78 °C; (f) Dess−Martin periodinane, CH_2Cl_2, 0 °C → room temperature; (g) $NaClO_2$, H_2O, *t*-BuOH, 2-methyl-2-butene, NaH_2PO_4; (h) $(COCl)_2$, room temperature.

Martin periodinane[57] and then with sodium chlorite,[58] provided the acid **82** (96% for two steps) via aldehyde **81**. Activation of the carboxylic acid as its acyl chloride **83** occurred upon treatment with oxalyl chloride.[59]

Though this route provided substantial quantities of the CD fragment **82**, the loss of material and the tedious separation of products at the stage of the methoxycarbonylation warranted the development of a more efficient synthesis. Fortunately, a novel and practical method for synthesizing highly substituted *p*-hydroxybenzoic acids was conceived and reduced to practice[60] (Scheme 15). The application of the finding to the problem at hand began with a chemoselective generation of the silylcyanohydrin **85** upon treatment of commercially available quinone **84** with trimethylsilyl cyanide and potassium cyanide.[61] Compound **85** was reduced by samarium(II) iodide to give the desired phenol **86** in 82% yield for the two steps.[62] This method was found to be quite general for the synthesis of such systems.[60] Iodination of **86** with ICl[63] afforded **87** (93%). Glycosylation of **87** with the imidate **74** afforded the aryl glycoside **88** (95%). Exchange of the acetate blocking group at O-2 for a silyl group provided **90** in 87% overall yield. Finally, reduction of the aromatic nitrile gave rise to aldehyde **81** (77%), an intermediate which intersects the synthesis practiced above. This new route

Scheme 15[a]



[a] Conditions: (a) Me_3SiCN, KCN, 18-crown-6, room temperature; (b) SmI_2, THF, MeOH, −78 °C; (c) ICl, $CH_3C{\equiv}N$, room temperature; (d) **74**, $BF_3{\cdot}Et_2O$, CH_2Cl_2, −48 °C; (e) NaOMe, MeOH; (f) TBSOTf, pyridine, CH_2Cl_2, 0 °C; (g) *i*-Bu_2AlH, CH_2Cl_2, −78 °C.

to the arylrhamnose sector offers major advantages in terms of material throughput, relative to the route via **75** described above.

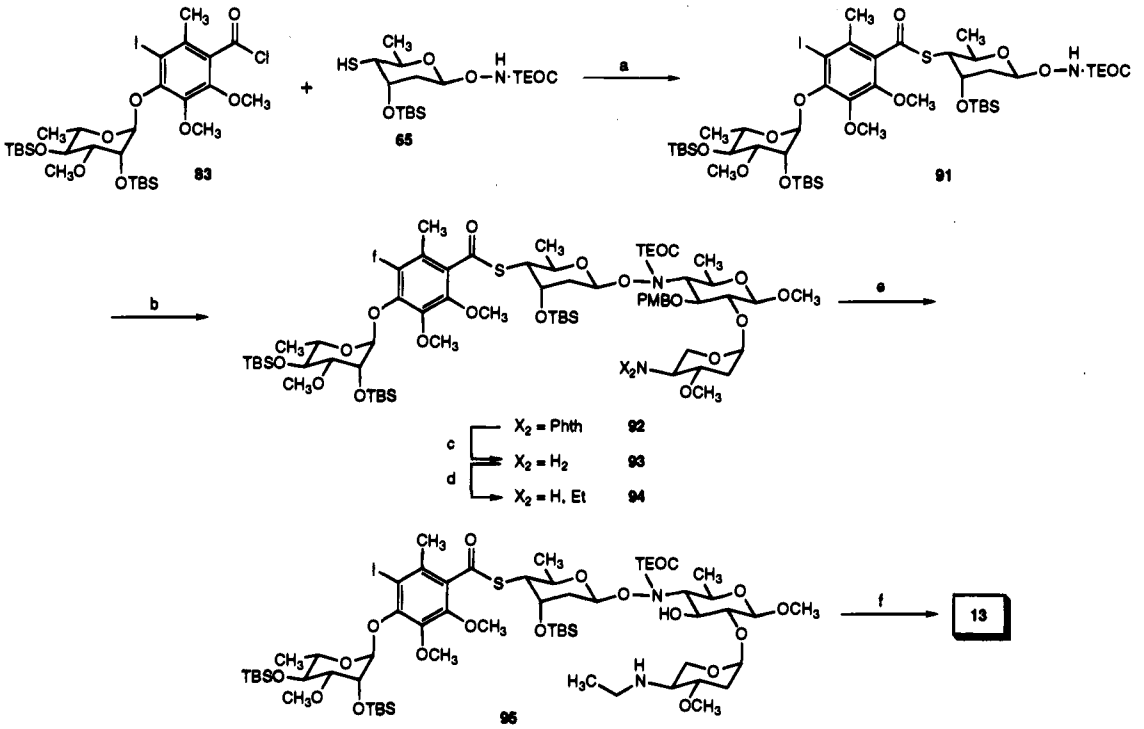
The synthesis of the aryltetrasaccharide was then completed as shown in Scheme 16. Acylation of the thiol **65** with the acid chloride **83** afforded the thiolester **91** (85% from **65**). Deprotonation of the carbamate nitrogen and subsequent alkylation with the triflate **50** provided **92**. Hydrazinolysis of the phthalimide provided the amine **93**, which was *N*-ethylated via a reductive amination reaction with acetaldehyde and $NaCNBH_3$ (89% for two steps) to give **94**. Treatment with DDQ then afforded **95** in 75% yield.

The final deprotection step was less than straightforward. Prolonged exposure of **95** to fluoride ion at room temperature led to cleavage of the aryl glycoside bond between the C and D units before the desilylation was complete.[64] The use of HF buffered with bases (pyridine, Et_3N) also failed to give complete desilylation. However, it was discovered that exposure of **95** to Bu_4NF in THF at 0 °C for up to 7 days did afford the calicheamicin aryltetrasaccharide **13** in good yield. While the result was gratifying and methyl glycoside **13** was in hand, there was concern as to the consequences of subjecting an enediyne-containing glycoside, not to speak of an allylic trisulfide, to long-term exposure to the action of fluoride.

Synthesis of a Truncated Calicheamicin Carbohydrate Domain. A feature designed into the route to the calicheamicin aryltetrasaccharide was the versatility to allow for the synthesis of structural analogues. It was hoped that access to a variety of structurally modified versions of the aryltetrasaccharide would be useful for probing the subtle interactions in the recognition event between DNA and calicheamicin. One such structure chosen for synthesis and study was the truncated compound **100** (Scheme 17), which lacks the amino sugar (E ring) residue. This was deemed an interesting compound for study because of the hypothesis that an electrostatic interaction between the protonated secondary amine of the amino sugar and the negatively charged phosphate backbone of DNA is important for binding.[65]

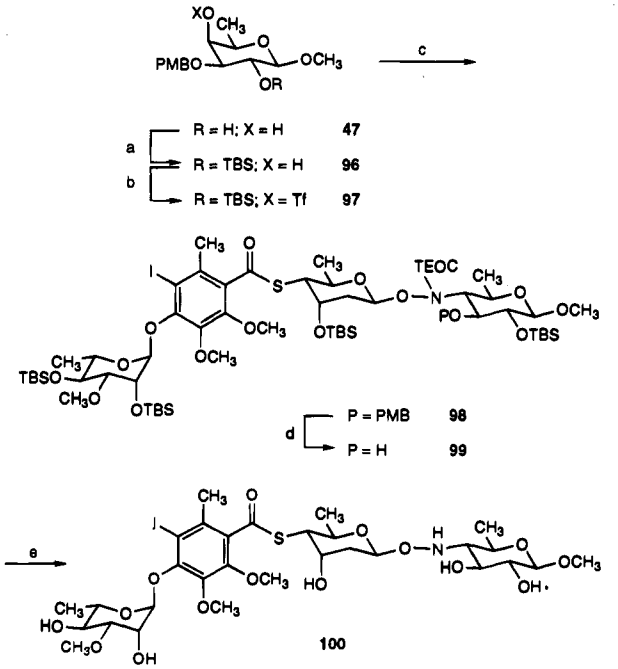
(57) Dess, D. B.; Martin, J. C. *J. Org. Chem.* **1983**, *48*, 1983.
(58) Lindgren, B. O.; Nilson, T. *Acta Chem. Scand.* **1973**, *27*, 888. (b) Bottano, J. C.; Berchtold, G. A. *J. Org. Chem.* **1980**, *45*, 1176.
(59) Beeby, P. J. *Tetrahedron Lett.* **1977**, *18*, 3379.
(60) Olson, S. H. and Danishefsky, S. J. *Tetrahedron Lett.* **1994**, *43*, 7901.
(61) (a) Hegedus, L. S.; Evans, B. R. *J. Am. Chem. Soc.* **1978**, *100*, 3461. (b) Evans, D. A.; Hoffman, J. M.; Truesdale, L. K. *J. Am. Chem. Soc.* **1973**, *95*, 5822.
(62) Yoneda, R.; Harusawa, S.; Kurihara, T. *Tetrahedron Lett.* **1989**, *30*, 3681.
(63) (a) Bennett, F. W.; Sharpe, A. G. *J. Chem. Soc.* **1950**, *105*, 1383. (b) van Laak, K.; Scharf, H.-D. *Tetrahedron* .**1989**, *45*, 5511.
(64) Boyer, S. H. Ph.D. Thesis, Yale University, New Haven, CT, 1994. At higher temperatures, the alkoxide generated at the 2-position of the D-ring apparently nucleophilically displaces the phenol moiety at the anomeric center. This process can be suppressed by maintaining the reaction temperature at 0 °C. The mechanism of this degradation is supported by earlier observations (ref 56).
(65) Cramer, K. D.; Townsend, C. A. *Tetrahedron Lett.* **1991**, *32*, 4635.

Scheme 16[a]



[a] Conditions: (a) Et_3N, DMAP, CH_2Cl_2, 0 °C; (b) (i) NaH, **91**, DMF, 0 °C → room temperature; (ii) **50**, DMF, 0 °C; (c) N_2H_4, EtOH, reflux; (d) CH_3CHO, $NaCNBH_3$, $MgSO_4$, MeOH; (e) DDQ, CH_2Cl_2, H_2O; (f) Bu_4NF, THF, 0 °C.

Scheme 17[a]



[a] Conditions: (a) TBSCl, Et_3N, DMF; (b) Tf_2O, pyridine, CH_2Cl_2, 0 °C; (c) NaH, **91**, DMF, 0 °C → room temperature; then **97**, 0 °C; (d) DDQ, CH_2Cl_2, H_2O, room temperature; (e) Bu_4NF, THF, 0 °C.

The synthesis made use of the previously described methyl glycoside **47**. Selective silylation of the equatorial alcohol provided compound **96** (Scheme 17), which was activated as its corresponding triflate (**97**). Addition of compound **97** to the anion of carbamate **91** produced, in high yield, compound **98**. Removal of the 4-methoxybenzyl group with DDQ (88%) followed by complete desilylation (47%) provided the target compound **100**. Evaluation of the DNA binding properties of compound **100** is currently in progress. The synthesis of other structurally modified aryltetrasaccharides using this strategy of modular synthesis and the evaluation of their DNA binding properties are also subjects of current investigations.

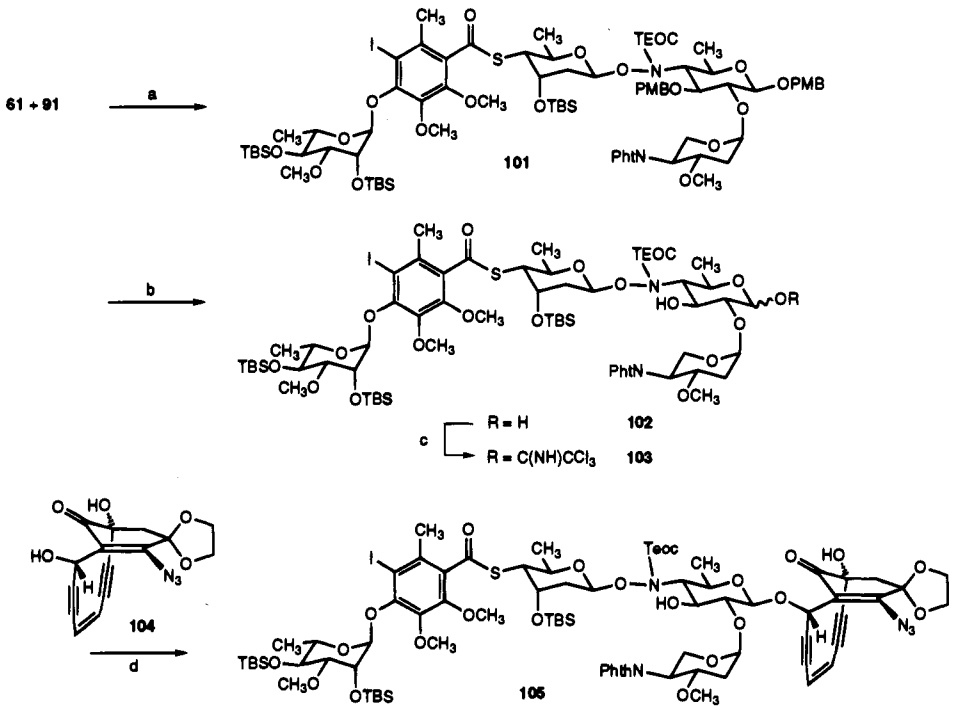
We set as our next goal the demonstration that a competent glycosyl donor corresponding to the aryltetrasaccharide domain of calicheamicin could be fashioned and that this would glycosylate an enediyne acceptor. Prior to this first report,[30] there had been no demonstration that such a coupling was possible. At this stage, we were more interested in establishing gross feasibility than in exploring the ultimate limits of sophistication in terms of realistic deprotectable functionality which could be accommodated in the two domains. In this initial undertaking, we would be benefiting from hard won lessons learned in the esperamicin trisaccharide campaign as to protection of the domain against rearrangement to an azafuranose.

Glycosylation of Synthetic Aglycons. In developing a route to a form of the aryltetrasaccharide of calicheamicin which allows for coupling to various aglycons, advantage was taken of an earlier finding in the esperamicin series. Rearrangement of **65** to an azafuranose of the type **14** had been blocked by engaging the hydroxylamine nitrogen as a TEOC urethane. Furthermore, at least in the synthesis of methyl glycoside **13**, removal of this TEOC urethane proved to be possible. It was hoped that such stabilization could be achieved in the calicheamicin series, thereby allowing for activation at the anomeric center to fashion a glycosyl-donating version of the aryltetrasaccharide domain of calicheamicin.

We started with the 4-methoxybenzyl glycoside **61** (Scheme 18). Deprotonation of the carbamate **91** with NaH followed by addition of triflate **61** provided the masked aryltetrasaccharide **101** (80%). Simultaneous removal of both PMB blocking groups with DDQ generated compound **102**, which possesses the reducing hemiacetal terminus appropriate for activation.

The Schmidt method[55] of glycosylation was chosen because of its generality and because of the mild conditions used in both

Scheme 18[a]



[a] Conditions: (a) (i) NaH, **91**, DMF, 0 °C → room temperature; (ii) **61**, DMF, 0 °C; (b) DDQ, CH_2Cl_2, H_2O; (c) Cl_3CCN, DBU, CH_2Cl_2, room temperature; (d) **104**, $BF_3{\cdot}Et_2O$, CH_2Cl_2, −78 °C.

the activation and the subsequent coupling reactions. In the event, treatment of compound **102** with trichloroacetonitrile and DBU selectively generated the α-trichloroacetimidate **103** (Scheme 18). It appears that, initially, a ca. 1:1 mixture of α and β anomeric imidates was produced. However, simply stirring the reaction mixture for longer periods of time promoted equilibration to a 3:1 mixture favoring the α anomer. It also appears that the C-3 hydroxyl was relatively unreactive under the reaction conditions, as no bis-imidate was observed. The aglycon coupling partner chosen was the azide (−)-**104**, an enantiomerically pure intermediate in our previous synthesis of calicheamicinone.[4n] Treatment of a solution of the imidate **103** and azide (−)-**104** in CH_2Cl_2 with $BF_3{\cdot}Et_2O$ at low temperature produced the glycoside **105** in 28% yield as a mixture (β:α 3:1) of anomers.[66] This reaction demonstrated *for the first time* the feasibility of using the intact calicheamicin aryltetrasaccharide as a donor in glycosylation reactions with aglycons.

It quickly became apparent from experiments with **105** and related compounds that any hydrazine-based conditions required for removal of the phthalimide protecting group would be incompatible with the sensitive functionality within more advanced aglycons. Long before the phthalimide was cleaved, the enediyne had been compromised. Additionally, complications encountered in desilylation reactions, even those of methyl glycoside **95**, revealed that oxygen protecting groups which were more labile than *tert*-butyldimethylsilyl ethers would probably be needed to complete a total synthesis of calicheamicin. With the dangers well established in these model studies and with important precedents from the late stages of the Nicolaou total synthesis,[7] the protection strategy of the aryltetrasaccharide was revised. The amino group of the E ring was functionalized as the fluorenylmethoxycarbonyl (FMOC) *N*-ethylcarbamate[67] and the TBS ethers were replaced with triethylsilyl ethers. Both of these protecting groups would be sufficiently labile to allow for survival of the aglycon functionality.[6] The TEOC urethane, which was used to mask the hydroxylamine nitrogen, was retained since it had proven to be reliable and reasonably labile.

Initial attempts to install the FMOC functionality at a late stage of the synthesis met with only limited success. It was found that the *N*-ethylamine of advanced aryltetrasaccharide intermediates could not, in our hands, reproducibly be protected as an FMOC carbamate. Therefore, recourse was made to incorporate this group at an early stage. We thus returned to the mesylate **106** (Scheme 19), readily available from an intermediate in the synthesis of the amino sugar **26**. Treatment of **106** with sodium azide gave **107** (95%), which was converted to the *N*-ethylamine **109** (81% for two steps) via the acetamide **108**.[68] Compound **109** was readily protected under Schotten−Baumann conditions as its FMOC carbamate **110** in 95% yield. Compound **110** was converted to the corresponding phenyl thioglycosides (95%, α:β 1:1) using a modification of the procedure described earlier. Due to differences in the oxidation rates of the two thioglycosides, they were separated and independently converted to the same glycal. Each was treated with oxone to provide the corresponding sulfoxides,[69] which were thermally eliminated to give **112** (82%).

The triethylsilyl groups were installed as shown in Scheme 20. Compound **88** was chosen as a point for exchange of

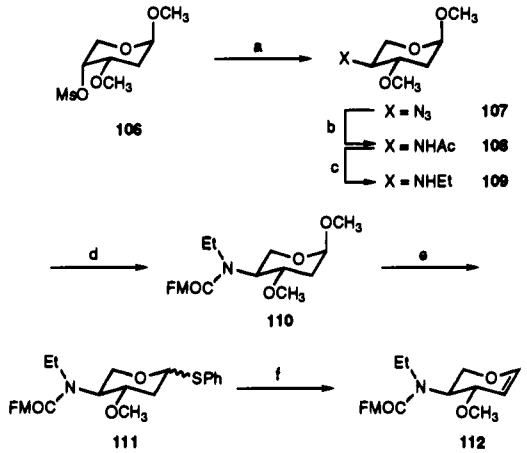
(66) The anomeric ratio obtained in the coupling reaction is worthy of further comment. Approximately a 3:1 mixture of β:α anomers was obtained in the coupling reaction. The same preference for the formation of β anomers, generally in a ratio ca. 3:1, was observed in the glycosylation of several acceptors in the (−) series. In contrast, glycosylation reactions with aglycons in the (+) series exhibited either no anomeric preference or a preference for α anomers (see refs 30 and 6c). Additionally, the chemical yield was generally somewhat lower. Apparently there is a significant difference in the energies between the two diastereomeric transition states leading to either the β or the α product. This phenomenon is more thoroughly investigated in the following paper in this issue (Hitchcock, S. A.; Chu-Moyer, M. Y.; Boyer, S. H.; Olson, S. H.; Danishefsky, S. J. *J. Am. Chem. Soc.* **1995**, *117*, XXXXX). For an earlier striking example of this effect, see: Spijker, N. M.; van Boeckel, C. A. A. *Angew. Chem., Int. Ed. Engl.* **1991**, *30*, 180.

(67) Carpino, L. A.; Han, G. Y. *J. Org. Chem.* **1972**, *37*, 3404.

(68) Saito, S.; Nakajima, H.; Inaba, M.; Moriwake, T. *Tetrahedron* **1989**, *30*, 837.

(69) Trost, B. M.; Curran, D. P. *Tetrahedron Lett.* **1981**, *22*, 1287.

Scheme 19[a]



[a] Conditions: (a) NaN_3, DMF, 100 °C; (b) H_2, Pd/C, Ac_2O, EtOAc; (c) $LiAlH_4$, Et_2O, heat; (d) FMOC-Cl, K_2CO_3, THF, H_2O; (e) PhSH, $BF_3{\cdot}Et_2O$, CH_2Cl_2, −20 °C → room temperature; (f) (i) oxone, MeOH, H_2O, 0 °C; (ii) benzene, reflux.

protecting groups. Removal of the acetate and TBS groups of **88** gave the diol **114** (93% for two steps), which was converted to the bis-TES ether **115** in high yield. The nitrile functionality of **115** was converted to the carboxylic acid **117** as before (77% overall) via the aldehyde intermediate **116**. Subsequent treatment of **117** with oxalyl chloride gave the acyl chloride **118**.

Compound **45** was protected as its corresponding TES ether by treatment with TESOTf, affording **119** in 95% yield. When compound **118** was subjected to the same conditions employed earlier to install the hydroxylamine, only a moderate yield (35%) of the desired product **120** was obtained. Significant amounts of the β-linked *N*-glycoside and the α-linked *O*-glycoside were also produced, with a typical ratio of desired/β-*N*-linked/α-*O*-linked being 31:39:9. Nonetheless, compound **120** could be obtained in sufficient quantities for the purposes at hand. Deprotection of the thiol then provided **121** (89%), which was subsequently acylated with **118** to give the thiolester **122** (62%).

The complete aryltetrasaccharide bearing the requisite protecting groups was constructed as shown in Scheme 21. As alluded to earlier, an improvement over the previous iodoglycosylations was implemented in this construction. The diol **58** was bis-silylated with TMSOTf, and the equatorial trimethylsilyl group was regioselectively methanolyzed to give **123** in 85% overall yield. Compound **123** was iodoglycosylated with glycal **112** to give, after acid treatment of the crude mixture to facilitate separation, the disaccharide **124** (90%). This procedure avoids the need to effect regioselective iodoglycosylation of the diol **58**, thus greatly improving the overall efficiency of the route. Radical deiodination of **124** gave **125** (99%), which was subsequently transformed into the triflate **126** (93%). Treatment of the anion of **122** with the triflate **126** under the standard Kahne coupling conditions gave a 68% yield of **127**. Removal of the PMB protecting groups was accomplished by subjecting **127** to DDQ; however, an extensive amount of desilylation of O-4 of the rhamnose residue was also observed. This side reaction could, however, be reduced by carrying out the DDQ oxidation in the presence of pH 7 buffer. In this manner, compound **128** was obtained in 80% yield. *The goal of synthesizing a fully functional glycosyl donor precursor with a free "reducing end" corresponding to the aryltetrasaccharide domain had been accomplished. Our domain was to be presented in the required oxidation level.* Since redox chemistry would not be necessary after glycosylation, it might be possible to conduct glycosylations with particularly advanced versions of the aglycon. This, indeed, turned out to be the case.[6c]

Summary

In summary, we have described the full details of the synthesis of the core trisaccharide of esperamicin. The structure of this esperamicin trisaccharide was established by correlating the fully synthetic, rearranged azafuranose **15** with that obtained from degradation of esperamicin. The versatility of the strategy was demonstrated in the synthesis of the calicheamicin aryltetrasaccharide and a truncated derivative thereof which lacks the E monosaccharide residue. Additionally, the synthesis of a calicheamicin aryltetrasaccharide which was activated for coupling to aglycons (see formation of compound **105**), as well as a demonstration of its viability as a glycosyl donor, was realized. Finally, the synthesis of the aryltetrasaccharide which bears an array of protecting groups suitable for the total synthesis of calicheamicin and which can be activated as a glycosyl donor was accomplished. We also note that the capacity of the methyl glycoside **13** to bind to the minor groove of DNA may find application in the modulation of transcriptional activiation.[70]

Experimental Section

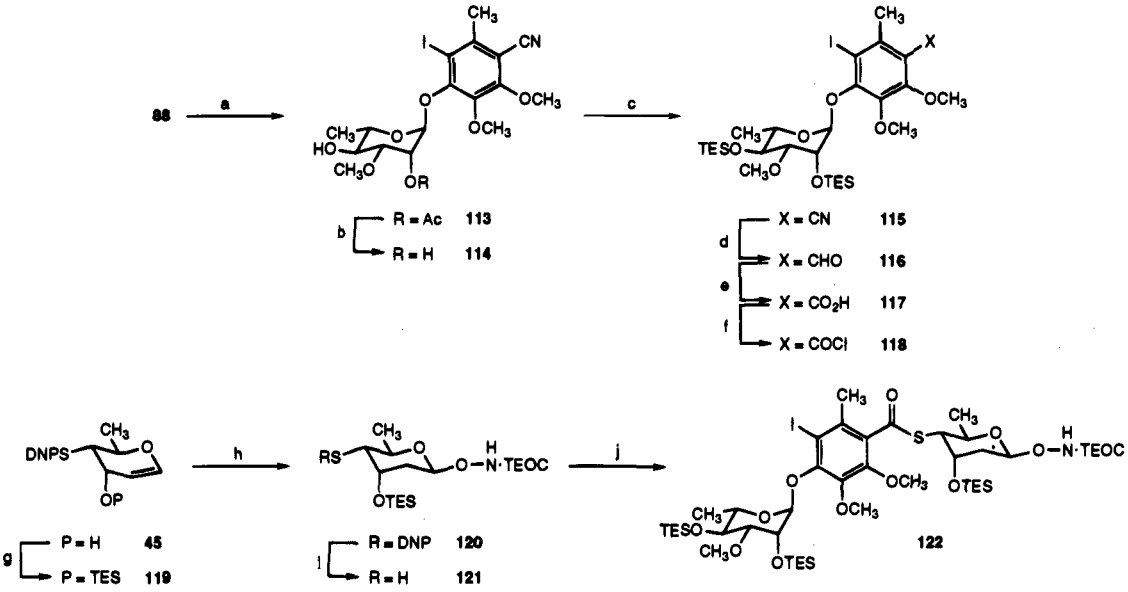
Phenyl 2,4-Dideoxy-3-*O*-methyl-4-phthalimido-1-thio-α- and -β-L-*threo*-pentopyranoside (27). Thiophenol (8.4 mL, 82 mmol) and boron trifluoride etherate (5 mL, 41 mmol) were sequentially added to a solution of methyl glycoside **26** (7.93 g, 27.25 mmol) in CH_2Cl_2 (270 mL) at −48 °C. After being stirred for 1 h at −48 °C, the reaction mixture was warmed slowly to 15 °C over the course of 2 h and quenched with saturated aqueous $NaHCO_3$. The mixture was diluted with CH_2Cl_2 (100 mL) and washed with saturated aqueous $NaHCO_3$ (150 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 80:20 to 65:35) to provide phenyl thioglycoside **27** (9.3 g, 92.5%) as an inseparable mixture of anomers (α/β 1:1): ^1H NMR (250 MHz, $CDCl_3$) δ 7.90−7.82 (m), 7.78−7.70 (m), 7.58−7.46 (m), 7.38−7.25 (m), 5.76 (d, J = 5.4 Hz), 4.97−4.80 (m), 4.56 (dt, J = 10.9, 4.5 Hz), 4.40−4.25 (m), 4.18−4.03 (m), 3.95 (dd, J = 11.6, 4.6 Hz), 3.67 (dd, J = 10.9, 5.1 Hz), 3.29 (s), 3.27 (s), 2.72−2.60 (m), 2.12−1.98 (m).

1,5-Anhydro-2,4-dideoxy-3-*O*-methyl-4-phthalimido-L-*threo*-pent-1-enopyranose (28). Powdered 85% *m*-CPBA (2.88 g, 14.2 mmol) was added to a solution of sulfides **27** (5.23 g, 14.2 mmol) in CH_2Cl_2 (140 mL) at 0 °C. After being stirred for 20 min at 0 °C, the reaction mixture was quenched with saturated aqueous $NaHCO_3$, diluted with CH_2Cl_2 (300 mL), and washed with saturated aqueous $NaHCO_3$ (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was dissolved in benzene (280 mL), and this solution was refluxed for 90 min. After cooling to room temperature, the reaction mixture was washed with saturated aqueous $NaHCO_3$ (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 80:20 to 70:30) to provide glycal **28** (3.31 g, 90%): white solid; mp 97.5−99 °C; $[\alpha]^{25}_D$ +95.6° (*c* 1.03, $CHCl_3$); IR ($CHCl_3$) 3010, 1770, 1720, 1645, 1390 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.88−7.82 (m, 2 H, ArH), 7.78−7.72 (m, 2 H, ArH), 6.40 (dd, 1 H, J = 6.2, 1.5 Hz, H-1), 4.94 (dd, 1 H, J = 6.2, 2.1 Hz, H-2), 4.85−4.81 (m, 1 H, H-3), 4.72−4.54 (m, 2 H, H-4, $H\text{-}5_{ax}$), 4.05−3.99 (m, 1 H, $H\text{-}5_{eq}$), 3.30 (s, 3 H, OCH_3); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 168.0, 145.8, 134.2, 131.7, 123.4, 100.9, 71.8, 54.1, 54.5, 48.9; CI HRMS for $C_{14}H_{14}NO_4$ ($M + H^+$), calcd 260.0923, found 260.0909. Anal. Calcd for $C_{14}H_{13}NO_4$: C, 64.86; H, 5.05; N, 5.40. Found: C, 64.77; H, 5.01; N, 5.30.

1,5-Anhydro-2,6-dideoxy-3-*O*-[(4-methoxyphenyl)methyl]-D-*lyxo*-hex-1-enopyranose (30). Sodium methoxide (20 mg) was added to a solution of di-*O*-acetyl-D-fucal (**29**) (1.445 g) in 40 mL of MeOH. After 12 h, additional MeOH (40 mL) and Bu_2SnO (1.70 g) were added. The mixture was refluxed for 1 h, after which the solvent was removed under reduced pressure. Residual MeOH was removed by coevaporating with 2 × 50 mL of benzene. The resulting stannylene was taken

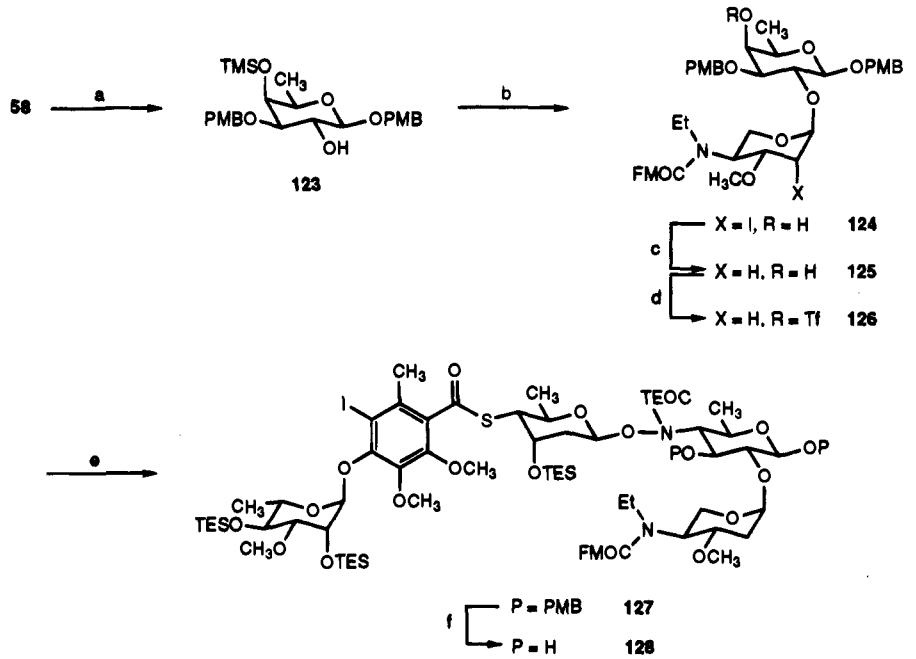
(70) Ho, S. N.; Boyer, S. H.; Schreiber, S. L.; Danishefsky, S. J.; Crabtree, G.R. *Proc. Natl. Acad. Sci. U.S.A.* **1994**, *91*, 9203.

Scheme 20[a]



[a] Conditions: (a) Bu_4NF, THF, 0 °C; (b) NaOMe, MeOH, −20 °C; (c) TESOTf, DMAP, pyridine, CH_2Cl_2, 0 °C → room temperature; (d) *i*-Bu_2AlH, toluene, 0 °C; (e) $NaClO_2$, H_2O, *t*-BuOH, 2-methyl-2-butene, NaH_2PO_4; (f) $(COCl)_2$, room temperature; (g) TESOTf, pyridine, CH_2Cl_2, 0 °C; (h) TEOC-NHOH, Ph_3P·HBr, CH_2Cl_2, room temperature; (i) EtSH, K_2CO_3, MeOH, room temperature; (j) **118**, Et_3N, DMAP, CH_2Cl_2, 0 °C.

Scheme 21[a]



[a] Conditions: (a) (i) TMSOTf, pyridine, CH_2Cl_2, room temperature; (ii) K_2CO_3, MeOH, room temperature; (b) (i) **112**, I^+(*sym*-collidine)$_2ClO_4^-$, 4 Å molecular sieves, CH_2Cl_2, 0 °C; (ii) AcOH, THF, H_2O; (c) Ph_3SnH, AIBN, benzene, reflux; (d) Tf_2O, pyridine, CH_2Cl_2, −20 °C; (e) NaH, **122**, DMF, room temperature, then **126**, DMF, −20 °C; (f) DDQ, CH_2Cl_2, pH 7 buffer, room temperature.

up in DMF (70 mL), followed by the addition of CsF (1.1 g) and 4-methoxybenzyl bromide (2.0 mL). The reaction mixture was heated to 80 °C for 3 h. The mixture was added to 250 mL of EtOAc and washed with 100 mL of saturated NaCl, 3 × 100 mL of H_2O, and 50 mL more of saturated NaCl. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 7:3) to give 1.233 g (73%) of **30**: $[\alpha]^{25}_D$ −11.9° (*c* 2.01, $CHCl_3$); IR ($CHCl_3$) 3550, 3020, 2920, 1650, 1615, 1250, 1100 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 7.32−7.28 (m, 2 H, ArH), 6.92−6.88 (m, 2 H, ArH), 6.41 (dd, 1 H, J = 6.3, 1.6 Hz, H-1), 4.66 (dt, 1 H, J = 6.3, 1.9 Hz, H-2), 4.59 (app d, 1 H, J = 11.4 Hz, ArCH), 4.54 (app d, 1 H, J = 11.4 Hz, ArCH), 4.20 (m, 1 H, H-3), 3.95 (q, 1 H, J = 6.6 Hz, H-5), 3.85 (m, 1 H, H-4), 3.82 (s, 3 H, OCH_3), 2.46 (m, 1 H, OH), 1.41 (d, 3 H, J = 6.7 Hz, 3 H-6); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 159.5, 145.4, 129.8, 129.4, 114.0, 99.0, 72.8, 71.0, 70.1, 65.6, 55.3, 16.8; CI HRMS for $C_{14}H_{19}O_4$ (M + H^+), calcd 251.1284, found 251.1273.

Phenyl 4,6-Di-*O*-acetyl-2,3-dideoxy-1-thio-α-D-threo-hex-2-enopyranoside (39). Thiophenol (17.1 mL, 167 mmol) was added to a solution of tri-*O*-acetyl-D-galactal (**38**) (45.10 g, 166 mmol) in 500 mL of CH_2Cl_2. After the mixture was cooled to −20 °C, a solution of $SnCl_4$ in CH_2Cl_2 (1.0 M, 8.3 mmol) was added over a period of 20 min. After 40 min, the solution was washed with saturated aqueous $NaHCO_3$ (250 mL), dried ($MgSO_4$), and concentrated, and the residue was purified by flash column chromatography (10 → 15 → 25% ethyl acetate in hexanes). The α- and β-thiophenyl glycosides were isolated in 81% (43.3 g) and 15% (8.0 g) yields, respectively. **39** was characterized as follows: white solid; mp 92−93 °C; $[\alpha]^{25}_D$ +67.5° (*c*

= 5.2, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$) δ 7.51−7.55 (m, 2 H, ArH), 7.23−7.27 (m, 3 H, ArH), 6.19 (dd, 1 H, J = 10.0, 3.2 Hz, H-2), 6.06 (ddd, 1 H, J = 9.9, 5.3, 1.6 Hz, H-3), 5.81 (dd, 1 H, J = 3.2, 1.6 Hz, H-1), 5.09 (dd, 1 H, J = 5.3, 2.5 Hz, H-4), 4.66 (dt, 1 H, J = 6.3, 2.5 Hz, H-5), 4.23 (d, 2 H, J = 6.4 Hz, H-6), 2.04 (s, 3 H, $COCH_3$), 1.99 (s, 3 H, $COCH_3$); ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 170.5, 170.2, 134.6, 131.7, 131.2, 128.8, 127.5, 124.4, 83.3, 67.2, 63.2, 62.6, 20.7, 20.6; IR ($CHCl_3$) 3000, 1730, 1470, 1430, 1365, 1215, 1065, 1045 cm^{-1}; CI HRMS for $C_{16}H_{18}O_5SH$ ($M + H^+$), calcd 323.0954, found 323.0969. Anal. Calcd for $C_{16}H_{18}O_5S$: C, 59.61; H, 5.63. Found: C, 59.76; H, 5.31.

Phenyl 2,3-Dideoxy-1-thio-6-*O*-tosyl-α-D-*threo*-hex-2-enopyranoside (41). The α-thioglycoside **39** (38.2 g, 118 mmol) was dissolved in methanol (1 L) and stirred at ambient temperature. A 25% solution of sodium methoxide in methanol (4.7 mL, 21 mmol) was added, and the reaction was stirred for 1 h. The solution was neutralized with solid NH_4Cl, concentrated, and filtered through silica gel (hexanes/ethyl acetate 2:1) to give the diol **40** as a white solid. The crude diol **40** was taken up in methanol (1 L) and refluxed with dibutyltin oxide (41.3 g, 166 mmol) for 5 h. The solution was cooled, concentrated *in vacuo*, and redissolved in 1 L of $CHCl_3$. *p*-Toluenesulfonyl chloride (33.8 g, 177 mmol) and tetrabutylammonium bromide (76.1 g, 236 mmol) were added, and the solution was stirred at room temperature. After 3 days, the solution was washed with saturated aqueous $NaHCO_3$ (2 × 250 mL), dried ($MgSO_4$), and concentrated. The residue was chromatographed over silica gel (33 → 50% ethyl acetate in hexanes) to give tosylate **41** (86%, 39.8 g): white solid; mp 104−105 °C; $[\alpha]^{25}_D$ +111.9° (c = 1.2, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$) δ 7.76 (d, 2 H, J = 8.3 Hz, ArH), 7.54−7.56 (m, 2 H, ArH), 7.27−7.32 (m, 5 H, ArH), 6.07 (m, 2 H, H-2, H-3), 5.67 (s, 1 H, H-1), 4.59 (m, 1 H, H-5), 4.36 (dd, 1 H, J = 10.7, 4.6 Hz, H-6), 4.19 (dd, 1 H, J = 10.7, 7.7 Hz, H-6), 3.90 (bs, 1 H, H-4), 2.43 (s, 3 H, $ArCH_3$), 1.91 (bs, 1 H, OH); ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 144.9, 134.1, 132.7, 132.6, 129.8, 129.5, 128.9, 127.9, 127.8, 83.9, 69.0, 68.9, 61.6, 21.6; IR ($CHCl_3$) 3795, 3110, 3100, 3005, 1655, 1520, 1480, 1435, 1145, 1425, 1240, 1125, 1090, 1035, 860 cm^{-1}; CI HRMS for $C_{19}H_{20}O_5S_2H$ ($M + H^+$), calcd 393.0831, found 393.0819. Anal. Calcd for $C_{19}H_{20}O_5S_2$: C, 58.14; H, 5.14; S, 16.34. Found: C, 58.38; H, 5.20; S, 15.90.

Phenyl 2,3,6-Trideoxy-1-thio-α-D-*threo*-hex-2-enopyranoside (42). A suspension of lithium aluminum hydride (3.63 g, 91 mmol) in THF (250 mL) was warmed to reflux, and a solution of tosylate **41** (24.0 g, 61.1 mmol) in THF (250 mL) was added over 30 min. The solution was refluxed for an additional 30 min, cooled to ambient temperature and quenched by slow addition of 3.5 mL if H_2O, 3.5 mL of 3 N NaOH, and 10 mL of brine. The solution was dried ($MgSO_4$), filtered, and concentrated, and the residue was chromatographed (flash column, 33 → 50% ethyl acetate in hexanes) to afford **42** (91%, 12.3 g): clear oil; $[\alpha]^{25}_D$ +91.8° (c 2.15, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$) δ 7.51−7.57 (m, 2 H, ArH), 7.28−7.36 (m, 3 H, ArH), 6.18 (ddd, 1 H, J = 9.8, 5.3, 1.5 Hz, H-3), 6.07 (dd, 1 H, J = 9.8, 3.2 Hz, H-2), 5.70 (m, 1 H, H-1), 4.44 (dq, 1 H, J = 6.5, 2.1 Hz, H-5), 3.73 (ddd, 1 H, J = 10.4, 5.3, 2.2 Hz, H-4), 1.51 (d, 1 H, J = 11.0 Hz, OH), 1.35 (d, 3 H, J = 6.5 Hz, H-6); ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 135.3, 131.2, 129.2, 128.7, 127.0, 83.8, 67.0, 15.8; IR ($CHCl_3$) 3565, 2990, 2915, 1475, 1430, 1375, 1115, 1070, 1050, 980, 940, 890, 840 cm^{-1}; EI HRMS for $C_{12}H_{14}O_2S$ (M^+), calcd 222.0715, found 222.0715. Anal. Calcd for $C_{12}H_{14}O_2S$: C, 64.84; H, 6.35. Found: C, 64.80; H, 6.37.

Phenyl 2,3,4,6-Tetradeoxy-4-(acetylthio)-1-thio-α-D-*erythro*-hex-2-enopyranoside (43). A solution of allylic alcohol **42** (9.32 g, 42.1 mmol) in CH_2Cl_2 (400 mL) was cooled to 0 °C. Triethylamine (12.0 mL, 86.1 mmol) and methanesulfonyl chloride (5.0 mL, 63.3 mmol) were added, and the solution was stirred for 30 min. The reaction was washed with saturated aqueous $NaHCO_3$ (200 mL), dried over $MgSO_4$, and concentrated. The residue was dissolved in DMF (300 mL), and potassium thioacetate (7.96 g, 69.7 mmol) was added. After being stirred overnight at room temperature, the solution was diluted with ether, washed with saturated aqueous $NaHCO_3$ (250 mL), dried ($MgSO_4$), concentrated, and chromatographed (flash column, 5 → 10% ethyl acetate in hexanes) to give 10.5 g of waxy solid **43** (89%), which was crystallized with hexane: white needles; mp 45−46 °C; $[\alpha]^{25}_D$ +375° (c 2.5, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$) δ 7.50−7.54 (m, 2 H, ArH), 7.26−7.34 (m, 3 H, ArH), 6.01 (ddd, 1 H, J = 9.8, 3.6, 2.3 Hz, H-3), 5.79 (dt, *1 H*, J = 9.8, 1.8 Hz, H-2), 5.75 (m, 1 H, H-1), 4.27 (dq, 1 H, J = 10.0, 6.0 Hz, H-5), 4.10 (dq, 1 H, J = 10.0, 2.2 Hz, H-4), 2.40 (s, 3 H, S-$COCH_3$), 1.33 (d, 3 H, J = 6.0 Hz, H-6); ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 193.4, 135.4, 131.0, 129.2, 128.6, 127.4, 126.9, 83.0, 66.6, 43.5, 30.3, 18.4; IR ($CHCl_3$) 3000, 1700, 1570, 1470, 1430, 1380, 1345, 1145, 1120, 1095, 1060, 960, 850 cm^{-1}; EI HRMS for $C_{14}H_{16}O_2S_2$ (M^+), calcd 280.0592, found 280.0594. Anal. Calcd for $C_{14}H_{16}O_8S_2$: C, 59.97; H, 5.75; S, 22.87. Found: C, 60.26; H, 5.62; S, 22.71.

Phenyl 2,3,4,6-Tetradeoxy-4-[(2,4-dinitrophenyl)dithio]-1-thio-α-D-*erythro*-hex-2-enopyranoside (44). Lithium aluminum hydride (1.52 g, 47.6 mmol) was carefully added to a rapidly stirring solution of thioacetate **43** (13.36 g, 47.7 mmol) in THF (400 mL) at 0 °C. After 1 h, 2,4-dinitrofluorobenzene (6.22 mL, 52.4 mmol) was added, and the reaction was slowly warmed to room temperature and stirred overnight. The red solution was quenched by dropwise addition of water, diluted with ether (300 mL), washed with water (250 mL), dried ($MgSO_4$), and concentrated. The residue was purified by flash column chromatography (15% ethyl acetate in hexanes) to give **44** (17.1 g, 89%), which was recrystallized from ethyl acetate/hexanes: yellow solid; mp 119−120 °C; $[\alpha]^{25}_D$ +494° (c 2.4, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$) δ 9.08 (d, 1 H, J = 2.5 Hz, ArH), 8.40 (dd, 1 H, J = 9.0, 2.4 Hz, ArH), 7.77 (d, 1 H, J = 9.0 Hz, ArH), 7.52−7.55 (m, 2 H, ArH), 7.30−7.38 (m, 3 H, ArH), 6.17 (dt, 1 H, J = 10.0, 2.7 Hz, H-3), 5.93 (bd, 1 H, J = 10.0 Hz, H-2), 5.80 (bs, 1 H, H-1), 4.25 (dq, 1 H, J = 9.6, 6.1 Hz, H-5), 3.90 (dq, 1 H, J = 9.6, 2.1 Hz, H-4), 1.50 (d, 3 H, J = 6.1 Hz, H-6); ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 145.8, 144.1, 143.8, 134.6, 131.3, 128.9, 128.8, 128.1, 127.4, 126.9, 126.7, 121.6, 83.1, 65.6, 46.5, 19.4; IR ($CHCl_3$) 3000, 1590, 1525, 1340, 1085, 1050, 945, 912, 845, 830 cm^{-1}; EI HRMS for $C_{18}H_{16}N_2O_5S_2$ (M^+), calcd 404.0501, found 404.0496. Anal. Calcd for $C_{18}H_{16}N_2O_5S_2$: C, 53.45; H, 3.99; N, 6.93. Found: C, 53.46; H, 3.99; N, 7.12.

1,5-Anhydro-2,4,6-trideoxy-4-[(2,4-dinitrophenyl)thio]-D-*ribo*-hex-1-eno pyranose (45). A solution of *m*-chloroperbenzoic acid (2.86 g, ca. 80%, 13.3 mmol) in CH_2Cl_2 (100 mL) was slowly added to a −48 °C solution of pseudoglycal **44** (4.47 g, 11.1 mmol) in CH_2Cl_2 (500 mL). After 30 min, the reaction mixture was washed with saturated aqueous $NaHCO_3$ (300 mL), dried ($MgSO_4$), and concentrated. The crude sulfoxide was evaporated with dry benzene (2 × 100 mL) and placed under vacuum for 1 h. The intermediate was then dissolved in THF (250 mL), freshly distilled diethyl amine (3.50 mL, 33.8 mmol) was added, and the reaction was stirred for 3 h at room temperature. The reaction was concentrated and immediately chromatographed (flash column, 25 → 33% ethyl acetate in hexanes) to give glycal **45** (3.02 mg, 87%): dark yellow foam; $[\alpha]^{25}_D$ +329° (c 0.2, $CHCl_3$); ^1H NMR (250 MHz, $CDCl_3$) δ 8.99 (d, 1 H, J = 2.5 Hz, ArH), 8.37 (dd, 1 H, J = 8.9, 2.5 Hz, ArH), 7.78 (d, 1 H, J = 9.0 Hz, ArH), 6.53 (d, 1 H, J = 6.0 Hz, H-1), 5.06 (dd, 1 H, J = 5.9, 5.2 Hz, H-2), 4.38 (m, 1 H, H-3), 4.31 (dq, 1 H, J = 9.9, 6.4 Hz, H-5), 3.61 (dd, 1 H, J = 9.9, 3.5 Hz, H-4), 2.16 (d, 1 H, J = 5.8 Hz, OH), 1.46 (d, 3 H, J = 6.4 Hz, H-6); ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 146.9, 146.5, 144.5, 143.6, 129.1, 126.8, 121.5, 101.8, 70.7, 61.6, 53.2, 18.9; IR ($CHCl_3$) 3600, 3075, 3000, 1650, 1605, 1640, 1450, 1355, 1230, 1100, 1050 cm^{-1}. Anal. Calcd for $C_{12}H_{12}N_2O_6S$: C, 46.15; H, 3.87; N, 8.97. Found: C, 46.56; H, 4.02; N, 8.97.

1,5-Anhydro-2,4,6-trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-[(2,4-dinitrophenyl)thio]-D-ribo-hex-1-enopyranose (46). Glycal **45** (3.03 g, 9.7 mmol) was dissolved in CH_2Cl_2 (50 mL) and stirred at 0 °C. Pyridine (6.75 mL, 48.4 mmol) and *tert*-butyldimethylsilyl trifluoromethanesulfonate (4.90 mL, 21.3 mmol) were sequentially added to the solution, and the reaction mixture was slowly warmed to room temperature. After 48 h, the solution was washed with saturated aqueous $NaHCO_3$ (100 mL), dried ($MgSO_4$), concentrated, and chromatographed (flash column, 15% ethyl acetate in hexanes) to provide **46** (3.64 g, 88%): yellow oil; $[\alpha]^{25}_D$ +267° (c 1.65, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 9.00 (d, 1 H, J = 2.5 Hz, ArH), 8.35 (dd, 1 H, J = 9.0, 2.5 Hz, ArH), 7.76 (d, 1 H, J = 9.0 Hz, ArH), 6.49 (d, 1 H, J = 6.0 Hz, H-1), 4.96 (t, 1 H, J = 5.7 Hz, H-2), 4.35 (dd, 1 H, J = 5.6, 3.2 Hz, H-3), 4.33 (dq, 1 H, J = 10.9, 6.5 Hz, H-5), 3.57 (dd, 1 H, J = 10.9, 3.3 Hz, H-4), 1.38 (d, 3 H, J = 6.5 Hz, H-6), 0.93 (s, 9 H, $C(CH_3)_3$), 0.08 (s, 6 H, $SiCH_3$); ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 146.3, 145.8, 145.4, 144.0, 128.7, 126.5, 121.7, 103.0, 70.8, 63.4, 52.8,

25.8, 18.7, −3.9, −5.0; IR (neat) 3097, 2954, 2929, 2886, 2856, 1645, 1593, 1524, 1471, 1462, 1341, 1253, 1232, 1091, 1071, 1048, 1000, 834 cm^{-1}; FAB HRMS for $C_{18}H_{26}N_2O_6SSiH$ ($M + H^+$), calcd 427.1359, found 427.1365.

Methyl 6-Deoxy-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (47). A solution of dimethyldioxirane (20 mL, 0.088 M) in acetone was added to a solution of **30** (321 mg) in CH_2Cl_2 (10 mL) at 0 °C. After 15 min, MeOH (10 mL) was added, and the mixture was concentrated to ca. 10 mL under reduced pressure. Additional MeOH (10 mL) was added, and the mixture was stirred at room temperature for 2 h. The solvent was removed, and the residue was chromatographed on silica gel (hexane/EtOAc 4:6 to 2:8) to give 253 mg (66%) of **47** and 37 mg of the faster-eluting α-anomer. **47**: $[\alpha]^{25}_D$ +33.2° (*c* 0.69, $CHCl_3$); IR ($CHCl_3$) 3580, 3030, 1620, 1520 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.37−7.25 (m, 2 H, ArH), 6.96−6.85 (m, 2 H, ArH), 4.68 (AB, 2 H, J = 11.1 Hz, $\Delta\nu$ = 9.7 Hz, $ArCH_2$), 4.14 (d, 1 H, J = 7.4 Hz, H-1), 3.82 (s, 3 H, $ArOCH_3$), 3.76 (dd, 1 H, J = 3.3, 1.0 Hz, H-4), 3.71 (dd, 1 H, J = 9.1, 7.4 Hz, H-2), 3.57 (dq, 1 H, J = 6.2, 1.0 Hz, H-5), 3.55 (s, 3 H, OCH_3), 3.41 (dd, 1 H, J = 9.5, 3.3 Hz, H-3), 2.30 (bs, 2 H, 2 OH), 1.38 (d, 3 H, J = 6.2 Hz, 3 H-6); EI HRMS for $C_{15}H_{22}O_6$, calcd 298.1416, found 298.1403.

Methyl *O*-(2,4-Dideoxy-2-iodo-3-*O*-methyl-4-phthalimido-α-L-*lyxo*-pyranosyl)-(1→2)-6-deoxy-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (48). A solution of diol **47** (253 mg) in CH_2Cl_2 (25 mL) was stirred with powdered 4 Å molecular sieves for 15 min. Solid I^+(*sym*-collidine)ClO_4^- (516 mg) was added, and the mixture was cooled to −48 °C. A solution of glycal **28** (210 mg) in CH_2Cl_2 (5 mL) was added over 15 min. After being stirred at −48 °C for 3 h, the mixture was warmed to room temperature over the course of 1 h. The mixture was stirred at room temperature for 2 h, filtered through Celite, and diluted with 100 mL of CH_2Cl_2. The organic layer was washed with 3 × 40 mL of 10% $Na_2S_2O_3$ and 4 × 40 mL of 10% $CuSO_4$, dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 1:1 to 3:7) to give 270 mg (49%) of **48**, along with varying amounts (10−15%) of O-4 glycosylated compound and the bis-glycosylated compound. **48**: mp 223−224 °C; $[\alpha]^{25}_D$ −28.6° (*c* 0.63, $CHCl_3$); IR ($CHCl_3$) 3680, 3015, 1720, 1620, 1520, 1390 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 7.88−7.80 (m, 2 H, phth), 7.78−7.69 (m, 2 H, phth), 7.38−7.30 (m, 2 H, ArH), 7.00−6.94 (m, 2 H, ArH), 5.65 (bs, 1 H, H-1′), 4.71−4.62 (m, 2 H, H-4′, H-5′$_{ax}$), 4.57 (AB, 2 H, J = 11.6 Hz, $\Delta\nu$ = 107.5 Hz, $ArCH_2$), 4.37 (dd, 1 H, J = 4.0, 1.0 Hz, H-2′), 4.25 (d, 1 H, J = 7.8 Hz, H-1), 3.86 (bs, 1 H, H-4), 3.82 (s, 3 H, $ArOCH_3$), 3.78 (dd, 1 H, J = 9.4, 3.7 Hz, H-3′), 3.72 (dd, 1 H, J = 9.3, 7.8 Hz, H-2), 3.63−3.50 (m, 3 H, H-3, H-5, H-5′$_{eq}$), 3.56 (s, 3 H, OCH_3), 3.16 (s, 3 H, OCH_3), 2.27 (d, 1 H, J = 2.9 Hz, OH), 1.39 (d, 3 H, J = 6.5 Hz, 3 H-6); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 168.1, 159.7, 134.0, 131.8, 130.1, 129.3, 123.3, 114.1, 102.8, 102.2, 81.3, 74.0, 70.9, 70.6, 70.0, 68.2, 59.4, 57.0, 55.3, 50.2, 34.8, 16.4; FAB HRMS for $C_{29}H_{34}INO_{10}Na$ ($M + Na^+$), calcd 706.1126, found 706.1162. Anal. Calcd for $C_{29}H_{34}INO_{10}$: C, 50.96; H, 5.01; N, 2.05. Found: C, 51.11; H, 4.82; N, 1.83.

Methyl *O*-(2,4-Dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl)-(1→2)-6-deoxy-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (49). A solution of **48** (525 mg), triphenyltin hydride (283 mg), and AIBN (20 mg) in benzene (25 mL) was heated to reflux for 1 h. The solution was concentrated and chromatographed on silica gel (hexane/EtOAc 4:6) to give 405 mg (95%) of **49**: mp 154−156 °C; $[\alpha]^{25}_D$ −38.1° (*c* 0.89, $CHCl_3$); IR ($CHCl_3$) 3520, 3020, 1720, 1610, 1515, 1390 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 7.88−7.82 (m, 2 H, phth), 7.76−7.70 (m, 2 H, phth), 7.32−7.26 (m, 2 H, ArH), 6.95−6.89 (m, 2 H, ArH), 5.40 (br d, 1 H, J = 2.7 Hz, H-1′), 4.68 (t, 1 H, J = 11.3 Hz, H-5′$_{ax}$), 4.60 (AB, 2 H, J = 11.4 Hz, $\Delta\nu$ = 69.7 Hz, $ArCH_2$), 4.52 (dt, 1 H, J = 11.0, 4.8 Hz, H-4′), 4.28 (dt, 1 H, J = 11.3, 5.2 Hz, H-3′), 4.26 (d, 1 H, J = 7.8 Hz, H-1), 3.82 (s, 3 H, $ArOCH_3$), 3.78 (bt, 1 H, J = 2.8 Hz, H-4), 3.74 (dd, 1 H, J = 9.3, 7.8 Hz, H-2), 3.58 (s, 3 H, OCH_3), 3.57−3.53 (m, 2 H, H-5, H-3), 3.46 (dd, 1 H, J = 10.8, 5.2 Hz, H-5′$_{eq}$), 3.23 (s, 3 H, OCH_3), 2.27 (ddd, 1 H, J = 12.8, 4.7, 1.1 Hz, H-2′$_{eq}$), 2.25 (d, 1 H, J = 3.7 Hz, OH), 1.54 (m, 1 H, H-2′$_{ax}$), 1.37 (d, 3 H, J = 6.5 Hz, 3 H-6); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 168.2, 159.5, 133.9, 131.9, 129.6, 129.5, 123.2, 114.0, 103.1, 98.3, 82.0, 77.2, 73.5, 71.3, 71.0, 69.9, 68.6, 58.9, 57.2, 55.9, 55.3, 55.2, 52.7, 35.5, 29.7, 16.4; FAB HRMS for $C_{29}H_{35}NO_{10}Na$ ($M + Na^+$), calcd 580.2160, found 580.2173. Anal. Calcd for $C_{29}H_{35}NO_{10}$: C, 62.47; H, 6.33; N, 2.51. Found: C, 62.73; H, 6.63; N, 2.25.

Methyl *O*-(2,4-Dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl)-(1→2)-6-deoxy-3-*O*-[(4-methoxyphenyl)methyl]-4-*O*-(trifluoromethanesulfonyl)-β-D-galactopyranoside (50). Trifluoromethanesulfonic anhydride (20 μL) was added to a solution of **49** (35.6 mg) and pyridine (25 μL) in CH_2Cl_2 (3.0 mL) at 0 °C. After 1 h at 0 °C, the reaction was quenched with saturated aqueous $NaHCO_3$. The mixture was added to 25 mL of CH_2Cl_2 and washed with 3 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 6:4) to give 29.7 mg (67%) of **50**: ^1H NMR (490 MHz, $CDCl_3$) δ 7.75−7.72 (m, 2 H, phth), 7.65−7.61 (m, 2 H, phth), 7.23−7.19 (m, 2 H, ArH), 6.83−6.78 (m, 2 H, ArH), 5.21 (d, 1 H, J = 2.6 Hz, H-1′), 4.92 (d, 1 H, J = 2.7 Hz, H-4), 4.55 (t, 1 H, J = 11.3 Hz, H-5′$_{ax}$), 4.52 (AB, 2 H, J = 11.4 Hz, $\Delta\nu$ = 187.0 Hz, $ArCH_2$), 4.35 (dt, 1 H, J = 10.9, 4.9 Hz, H-3′), 4.23 (d, 1 H, J = 7.7 Hz, H-1), 4.16 (ddd, 1 H, J = 11.6, 10.7, 5.1 Hz, H-4′), 3.72 (s, 3 H, $ArOCH_3$), 3.70−3.64 (m, 2 H, H-2, H-5), 3.56 (dd, 1 H, J = 9.6, 2.9 Hz, H-3), 3.49 (s, 3 H, OCH_3), 3.38 (dd, 1 H, J = 10.8, 5.2 Hz, H-5′$_{eq}$), 3.11 (s, 3 H, OCH_3), 2.03 (ddd, 1 H, J = 12.8, 4.8, 1.0 Hz, H-2′$_{eq}$), 1.38 (ddd, 1 H, J = 12.9, 11.3, 3.7 Hz, H-2′$_{ax}$), 1.30 (d, 3 H, J = 6.5 Hz, 3 H-6).

***N*-[2-(Trimethylsilyl)ethoxycarbonyl]hydroxylamine.**[71] Hydroxylamine hydrochloride (5.9 g) was added to a mixture of NaOH (3.4 g), H_2O (25 mL), and dioxane (25 mL). 2-(Trimethylsilyl)ethoxycarbonyl chloride (3.1 g) was added, the the mixture was adjusted to pH 10−11 with 1.0 N NaOH. After being stirred for 14 h, the mixture was added to 100 mL of H_2O and extracted with 3 × 50 mL of EtOAc. The organics were dried over $MgSO_4$, filtered, and concentrated under reduced pressure to give 1.78 g (60%) of TEOC-NHOH: IR ($CHCl_3$) 3490, 3380, 3020, 2950, 1725, 1460, 1260, 1120, 865, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.22 (bs, 1 H), 4.31−4.21 (m, 2 H), 1.08−0.98 (m, 2 H), 0.05 (s, 9 H).

[(2,4,6-Trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-[(2,4-dinitrophenyl)thio]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)-ethoxycarbonyl]amine (51). Triphenylphosphine hydrobromide (20 mg) was added to a solution of **46** (492 mg) and TEOC-NHOH (530 mg) in CH_2Cl_2 (25 mL). After being stirred at room temperature for 20 min, the mixture was diluted with 100 mL of CH_2Cl_2 and washed with 3 × 30 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 75:25 to 65:35) to give 363 mg (52%) of **51** along with 37% of the *N*-glycosylated compound **51a**. **51**: $[\alpha]^{25}_D$ +13.6° (*c* 0.655, $CHCl_3$); IR ($CHCl_3$) 3030, 2960, 1750, 1720, 1595, 1530, 1350, 1095, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 9.00 (d, 1 H, J = 2.5 Hz, ArH), 8.35 (dd, 1 H, J = 9.0, 2.5 Hz, ArH), 7.70 (d, 1 H, J = 9.1 Hz, ArH), 7.68 (s, 1 H, NH), 5.18 (dd, 1 H, J = 9.9, 2.0 Hz, H-1), 4.41 (m, 1 H, H-3), 4.28 (m, 2 H, OCH_2), 4.10 (dq, 1 H, J = 10.2, 6.4 Hz, H-5), 3.35 (dd, 1 H, J = 10.2, 2.1 Hz, H-4), 2.20 (ddd, 1 H, J = 13.5, 3.5, 2.1 Hz, H-2$_{eq}$), 1.83 (ddd, 1 H, J = 12.9, 10.2, 2.6 Hz, H-2$_{ax}$), 1.33 (d, 3 H, J = 6.4 Hz, 3 H-6), 1.04 (m, 2 H, CH_2Si), 0.95 (s, 9 H, CMe_3), 0.10 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$), 0.06 (s, 9 H, $SiMe_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 157.2, 146.3, 144.9, 144.1, 128.2, 126.7, 125.7, 121.8, 101.6, 70.5, 69.0, 64.7, 53.9, 37.6, 25.8, 19.4, 18.1, 17.7, −1.5, −4.4, −5.0.

2-(Trimethylsilyl)ethyl [(2,4,6-Trideoxy-3-*O*-[(1,1-dimethylethyl)-dimethylsilyl]-4-thio-β-D-*ribo*-hexopyranosyl)oxy]carbamate (52). Ethanethiol (2.3 mL, 30 mmol) and K_2CO_3 (1.71 g, 12 mmol) were added to a solution of dinitrophenyl sulfide **51** (373 mg, 0.6 mmol) in MeOH (37 mL) at room temperature. After being stirred at room temperature for 20 min, the reaction mixture was diluted with CH_2Cl_2 (100 mL) and washed with saturated aqueous $NaHCO_3$ (30 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 85:15) to provide thiol **52** (266 mg, 98%): colorless oil; $[\alpha]^{25}_D$ −35.2° (c 1.745, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3370, 3020, 3000, 2950, 2930, 2890, 2850, 1745, 1710, 1460, 1255, 1090, 1040, 865, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.56 (s 1 H, NH), 5.08 (dd, 1 H, J = 10.0, 2.1 Hz, H-1), 4.30−4.20 (m, 2 H, OCH_2

(71) (a) Harris, R. B.; Wilson, I. B. *Tetrahedron Lett.* **1983**, *24*, 231. (b) Shute, R. E.; Rich, D. H. *Synthesis* **1987**, 346.

(TEOC)), 4.16 (m, 1 H, H-3), 3.78 (dq, 1 H, J = 10.1, 6.2 Hz, H-5), 2.49 (ddd, 1 H, J = 10.1, 10.6, 2.4 Hz, H-4), 2.13 (ddd, 1 H, J = 13.2, 3.5, 2.1 Hz, H-2_{eq}), 1.71 (ddd, 1 H, J = 13.2, 10.0, 2.4 Hz, H-2_{ax}), 1.61 (d, 1 H, J = 10.6 Hz, SH), 1.38 (d, 3 H, J = 6.2 Hz, CH_3), 1.07–0.98 (m, 2 H, $SiCH_2$ (TEOC)), 0.94 (s, 9 H, $SiC(CH_3)_3$), 0.15 (s, 3 H, $SiCH_3$), 0.14 (s, 3 H, $SiCH_3$), 0.04 (s, 9 H, $Si(CH_3)_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 157.2, 101.6, 72.7, 70.7, 64.3, 47.2, 37.9, 25.9, 19.6, 18.1, 17.7, −1.6, −4.4, -4.7; HRMS (FAB) for $C_{18}H_{39}NO_5SSi_2Na$ (M + Na), calcd 447.2180, found 447.2210. Anal. Calcd for $C_{18}H_{39}NO_5SSi_2$: C, 49.39; H, 8.98; N, 3.20; S, 7.32. Found: C, 49.60; H, 8.91; N, 3.03; S, 7.36.

[(2,4,6-Trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amine (53). A mixture of **51** (161 mg), K_2CO_3 (500 mg), and EtSH (0.7 mL) in MeOH (7 mL) was stirred at room temperature for 20 min. The mixture was added to 20 mL of CH_2Cl_2 and washed with 2 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was taken up in benzene (5 mL), and DBU (150 μL) and MeI (100 μL) were added. The mixture was stirred for 4 h at room temperature, after which it was added to 20 mL of CH_2Cl_2 and washed with 2 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 8:2) to give 107 mg (89%) of **53**: $[\alpha]^{25}_D$ −31.8° (c 2.145, $CHCl_3$); IR ($CHCl_3$) 3380, 3030, 2960, 1750, 1720, 1465, 1260, 1100, 850 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.73 (s, 1 H, NH), 5.09 (dd, 1 H, J = 9.9, 2.0 Hz, H-1), 4.30 (m, 1 H, H-3), 4.25 (m, 2 H, OCH_2), 3.90 (dq, 1 H, J = 10.3, 6.3 Hz, H-5), 2.22 (dd, 1 H, J = 10.3, 2.4 Hz, H-4), 2.13 (s, 3 H, SCH_3), 2.07 (ddd, 1 H, J = 13.2, 3.5, 2.3 Hz, H-2_{eq}), 1.66 (ddd, 1 H, J = 12.7, 10.0, 2.5 Hz, H-2_{ax}), 1.40 (d, 3 H, J = 6.3 Hz, 3 H-6), 1.03 (m, 2 H, CH_2Si), 0.91 (s, 9 H, CMe_3), 0.14 (s, 3 H, $SiCH_3$), 0.11 (s, 3 H, $SiCH_3$), 0.04 (s, 9 H, $SiMe_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 157.2, 101.7, 71.9, 70.1, 64.4, 56.3, 37.8, 25.8, 19.7, 18.1, 17.7, 16.7, −1.5, −4.5, −4.9; CI HRMS for $C_{19}H_{42}NO_5SSi_2$ (M + H^+), calcd 452.2322, found 452.2326. Anal. Calcd for $C_{19}H_{41}NO_5SSi_2$: C, 50.51; H, 9.15; N, 3.10; S, 7.10. Found: C, 50.63; H, 9.41; N, 3.06; S, 6.85.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio)-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl]-3-*O*-(4-methoxyphenyl)methyl-β-D-glucopyranoside (54). Sodium hydride (60% dispersion in mineral oil, 10 mg) was added to a solution of urethane **53** (20.2 mg) in DMF (1.0 mL) at 0 °C. The suspension was warmed to room temperature for 15 min and recooled to 0 °C. A solution of triflate **50** (29.7 mg) in DMF (0.7 mL) was added dropwise. After being stirred for 15 min, the reaction was quenched at 0 °C by addition of AcOH (50 μL) over 5 min. The mixture was warmed to room temperature, added to 25 mL of EtOAc, and washed with 10 mL of saturated aqueous NH_4Cl and 3 × 10 mL of H_2O. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 7:3) to give 32.8 mg (78%) of **54**: $[\alpha]^{25}_D$ −32.4° (c 1.72, $CHCl_3$); IR ($CHCl_3$) 3010, 2950, 1720, 1690, 1515, 1390, 1255 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.89–7.82 (m, 2 H), 7.78–7.68 (m, 2 H), 7.30–7.20 (m, 2 H), 6.90–6.82 (m, 2 H), 5.39 (bs, 1 H), 5.20–5.12 (m, 1 H), 4.84–4.42 (m, 4 H), 4.38–4.05 (m, 6 H), 4.02–3.90 (m, 1 H), 3.80 (s, 3 H), 3.85–3.75 (m, 1 H), 3.59 (s, 3 H), 3.66–3.43 (m, 2 H), 3.23 (s, 3 H), 3.25–3.15 (m, 1 H), 2.40–2.05 (m, 3 H), 2.15 (s, 3 H), 1.85–1.75 (m, 1 H), 1.55–1.45 (m, 4 H), 1.40–1.38 (m, 3 H), 0.92 (s, 9 H), 1.10–0.95 (m, 2 H), 0.16 (s, 3 H), 0.14 (s, 3 H), 0.03 (s, 9 H); FAB HRMS for $C_{48}H_{74}N_2O_{14}SSi_2Na$ (M + Na^+), calcd 1013.4299, found 1013.4373.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio)-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[4-amino-2,4-dideoxy-3-*O*-methyl-α-L-*threo*-pentopyranosyl]-3-*O*-(4-methoxyphenyl)methyl-β-D-glucopyranoside (55). A solution of **54** (64.3 mg) and hydrazine (0.4 mL) in 95% EtOH (5 mL) was heated to reflux for 15 min. The reaction mixture was cooled to room temperature, added to 25 mL of CH_2Cl_2, and washed with 10 mL of saturated aqueous $NaHCO_3$ and 3 × 10 mL of H_2O. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel ($CHCl_3$/MeOH 95:5) to give 48.8 mg (87%) of **55**: $[\alpha]^{25}_D$ −33.8° (c 1.035, $CHCl_3$); IR ($CHCl_3$) 3020, 2950, 1700, 1515, 1255, 1065, 1040 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.27–7.17 (m, 2 H), 6.88–6.79 (m, 2 H), 5.30 (bs, 1 H), 5.12 (br d, 1 H, J = 9.5 Hz), 4.78–4.65 (m, 1 H), 4.64–4.50 (m, 1 H), 4.35–4.27 (m, 1 H), 4.26–4.10 (m, 5 H), 3.99–3.78 (m, 2 H), 3.78 (s, 3 H), 3.71 (t, 1 H, J = 10.7 Hz), 3.60–3.48 (m, 2 H), 3.51 (s, 3 H), 3.35 (s, 3 H), 3.34–3.22 (m, 1 H), 2.89–2.72 (m, 1 H), 2.30–2.10 (m, 3 H), 2.13 (s, 3 H), 1.80–1.63 (m, 1 H), 1.55–1.38 (m, 4 H), 1.35–1.25 (m, 3 H), 1.08–0.95 (m, 2 H), 0.90 (s, 9 H), 0.14 (s, 3 H), 0.13 (s, 3 H), 0.01 (s, 9 H); FAB HRMS for $C_{40}H_{72}N_2O_{12}SSi_2Na$ (M + Na^+), calcd 861.4425, found 861.4502.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio)-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-[(1-methylethyl)amino]-α-L-*threo*-pentopyranosyl]-3-*O*-(4-methoxyphenyl)methyl-β-D-glucopyranoside (56). A mixture of **55** (45.7 mg), acetone (0.6 mL), $NaCNBH_3$ (100 mg), and $MgSO_4$ (100 mg) in 2-propanol (3 mL) was stirred at room temperature for 40 h. The mixture was added to 20 mL of $CHCl_3$ and washed with 20 mL of saturated aqueous $NaHCO_3$. The aqueous layer was extracted with an additional 10 mL of $CHCl_3$. The combined organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel ($CHCl_3$/MeOH 95:5) to provide 47.0 mg (98%) of **56**: $[\alpha]^{25}_D$ −25.2° (c 1.13, $CHCl_3$); IR ($CHCl_3$) 3020, 2960, 1710, 1520, 1255, 1070, 1045 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.27–7.18 (m, 2 H), 6.88–6.78 (m, 2 H), 5.25 (bs, 1 H), 5.12 (br d, 1 H, J = 9.9 Hz), 4.78–4.65 (m, 1 H), 4.65–4.50 (m, 1 H), 4.31 (bs, 1 H), 4.25–4.08 (m, 4 H), 3.98–3.85 (m, 1 H), 3.82–3.78 (m, 1 H), 3.78 (s, 3 H), 3.77–3.62 (m, 2 H), 3.58–3.38 (m, 3 H), 3.50 (s, 3 H), 3.32 (s, 3 H), 2.85 (sept, 1 H, J = 6.2 Hz), 2.77–2.62 (m, 1 H), 2.30–2.05 (m, 3 H), 2.13 (s, 3 H), 1.80–1.62 (m, 1 H), 1.60–1.35 (m, 4 H), 1.35–1.25 (m, 3 H), 1.06 (d, 3 H, J = 6.2 Hz), 1.05–0.90 (m, 2 H), 0.90 (s, 9 H), 0.15 (s, 3 H), 0.13 (s, 3 H), 0.01 (s, 9 H); FAB HRMS for $C_{43}H_{79}N_2O_{12}SSi_2$ (M + H^+), calcd 903.4894, found 903.4920.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio)-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-[(1-methylethyl)amino]-α-L-*threo*-pentopyranosyl]-β-D-glucopyranoside (57). A mixture of **56** (43.3 mg), DDQ (50 mg), CH_2Cl_2 (3.0 mL), and H_2O (0.3 mL) was stirred vigorously at room temperature for 40 h. The mixture was added to 25 mL of CH_2Cl_2 and washed with 2 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel ($CHCl_3$/MeOH 95:5) to give 37.2 mg (99%) of **57**: $[\alpha]^{25}_D$ −46.7° (c 1.86, $CHCl_3$); IR ($CHCl_3$) 3500, 2965, 1720, 1465, 1390, 1260, 1100, 1065 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 5.44 (bs, 1 H, H-1′), 5.24 (br d, 1 H, H-1″), 4.32 (m, 1 H, H-3″), 4.23 (br t, 1 H, OCH_2), 4.19 (d, 1 H, J = 7.8 Hz, H-1), 4.03 (dq, 1 H, J = 10.5, 6.5 Hz, H-5″), 3.97 (br t, 1 H, J = 10.3 Hz, H-4), 3.75–3.65 (m, 2 H, H-5′$_{ax}$, H-5′$_{eq}$), 3.61 (dq, 1 H, J = 9.7, 6.8 Hz, H-5), 3.56 (dd, 1 H, H = 9.5, 7.9 Hz, H-2), 3.51 (s, 3 H, OCH_3), 3.45 (dt, 1 H, J = 9.7, 4.5 Hz, H-3′), 3.36 (s, 3 H, OCH_3), 2.87 (sept, 1 H, J = 6.2 Hz, $NCHMe_2$), 2.73 (dt, 1 H, J = 9.5, 4.9 Hz, H-4′), 2.28 (dd, 1 H, J = 9.7, 2.4 Hz, H-4″), 2.23 (ddd, 1 H, J = 12.9, 4.7, 2.1 Hz, H-2′$_{eq}$), 2.16 (s, 3 H, SCH_3), 2.15–2.05 (br m, 1 H, H-2″$_{eq}$), 1.63–1.53 (m, 2 H, H-2″$_{ax}$, H-2′$_{ax}$), 1.44 (d, 3 H, J = 6.6 Hz, 3 H-6), 1.19 (d, 3 H, J = 6.5 Hz, 3 H-6″), 1.08 (d, 3 H, J = 6.2 Hz, NC-CH_3), 1.07 (d, 3 H, J = 6.2 Hz, NC-CH_3), 1.05–0.95 (m, 2 H, CH_2Si), 0.95 (s, 9 H, CMe_3), 0.16 (s, 3 H, $SiCH_3$), 0.14 (s, 3 H, $SiCH_3$), 0.06 (s, 9 H, $SiMe_3$); FAB HRMS for $C_{35}H_{71}N_2O_{11}SSi_2$ (M + H^+), calcd 783.4316, found 783.4326.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-(methylthio)-β-D-*ribo*-hexopyranosyl)oxy]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-[(1-methylethyl)amino]-α-L-*threo*-pentopyranosyl]-β-D-glucopyranoside (12). Tetrabutylammonium fluoride (1.0 M in THF, 100 μL) was added to a solution of **57** (20.4 mg) in THF (2.0 mL) at 0 °C. The mixture was warmed to room temperature and stirred for 12 h. The reaction was quenched with 1 drop of H_2O, and the mixture was added to 20 mL of CH_2Cl_2 and washed with 2 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel ($CHCl_3$/MeOH 95:5) to give 12.6 mg (92%) of **12**: $[\alpha]^{25}_D$ −42.2° (c 0.825, $CHCl_3$); IR ($CHCl_3$) 3480, 2940, 1450, 1390, 1080 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 6.30 (bs, 1 H,

ONH), 5.36 (t, 1 H, J = 2.9 Hz, H-1′), 4.98 (dd, 1 H, J = 10.2, 1.8 Hz, H-1″), 4.20 (d, 1 H, J = 7.7 Hz, H-1), 4.11 (m, 1 H, H-3″), 3.96 (t, 1 H, J = 9.6 Hz, H-3), 3.79 (dq, 1 H, J = 10.6, 6.2 Hz, H-5″), 3.40−3.65 (m, 2 H, H-5′$_{ax}$, H-5′$_{eq}$), 3.63 (dq, 1 H, J = 9.4, 6.2 Hz, H-5), 3.51 (s, 3 H, OCH_3), 3.46 (dd, 1 H, J = 9.6, 8.0 Hz, H-2), 3.48−3.42 (m, 1 H, H-3′), 3.36 (s, 3 H, OCH_3), 2.86 (sept, 1 H, NC*H*Me$_2$), 2.72 (dt, 1 H, J = 8.9, 5.1 Hz, H-4′), 2.50 (dd, 1 H, J = 10.5, 2.5 Hz, H-4″), 2.32 (t, 1 H, J = 9.7 Hz, H-4), 2.24 (ddd, 1 H, J = 12.8, 4.1, 2.4 Hz, H-2′$_{eq}$), 2.18−2.12 (m, 1 H, H-2″$_{eq}$), 2.12 (s, 3 H, SCH_3), 1.60−1.51 (m, 2 H, H-2′$_{ax}$, H-2″$_{ax}$), 1.40 (d, 3 H, J = 6.2 Hz, 3 H-6″), 1.33 (d, 3 H, J = 6.2 Hz, 3 H-6), 1.08 (d, 3 H, J = 6.3 Hz, $NCCH_3$), 1.07 (d, 3 H, J = 6.3 Hz, $NCCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 102.6, 99.7, 98.4, 78.5, 77.2, 71.0, 69.2, 68.4, 68.1, 64.5, 63.0, 56.6, 56.4, 55.9, 55.7, 46.5, 35.2, 33.8, 29.7, 24.5, 22.8, 19.9, 17.7; FAB HRMS for $C_{23}H_{45}N_2O_9S$ (M + H$^+$), calcd 525.2844, found 525.2874.

(4-Methoxyphenyl)methyl 6-Deoxy-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (58) and (4-Methoxyphenyl)methyl 6-Deoxy-3-*O*-[(4-methoxyphenyl)methyl]-α-D-galactopyranoside (58a). A solution of dimethyldioxirane (17 mL, 0.09 M) in acetone was added to a solution of **30** (304 mg) in CH_2Cl_2 (10 mL) at 0 °C. After 30 min, 4-methoxybenzyl alcohol (5 mL) was added, and the solution was concentrated under reduced pressure to ca. 8 mL total volume. The mixture was stirred at room temperature for 12 h, concentrated, and chromatographed on silica gel (hexane/EtOAc 4:6 to 3:7) to give 162 mg (33%) of **58** and 110 mg (22%) of the slower-eluting **58a**. **58**: $[\alpha]^{25}_D$ −37.1° (*c* 1.345, $CHCl_3$); IR ($CHCl_3$) 3580, 3020, 1610, 1515, 1250 cm^{-1}; ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.35−7.25 (m, 4 H, ArH), 6.95−6.87 (m, 4 H, ArH), 4.71 (AB, 2 H, J = 11.4 Hz, $\Delta\nu$ = 81.7 Hz, $ArCH_2$), 4.66 (s, 2 H, $ArCH'_2$), 4.26 (d, 1 H, J = 7.8 Hz, H-1), 3.80 (s, 6 H, 2 $ArOCH_3$), 3.82−3.72 (m, 2 H, H-2, H-4), 3.54 (q, 1 H, J = 6.5 Hz, H-5), 3.39 (dd, 1 H, J = 9.4, 3.4 Hz, H-3), 2.37 (bs, 2 H, 2 OH), 1.39 (d, 3 H, J = 6.5 Hz, 3 H-6); ^{13}C NMR (62.5 MHz, $CDCl_3$), 159.4, 159.3, 129.8, 129.5, 129.2, 113.9, 113.8, 106.4, 101.3, 80.2, 71.6, 70.8, 70.4, 70.2, 69.1, 55.2, 16.3; EI HRMS for $C_{22}H_{28}O_7$, calcd 404.1835, found 404.1811. Anal. Calcd for $C_{22}H_{28}O_7$: C, 65.33; H, 6.98. Found: C, 65.06; H, 6.88. **58a**: $[\alpha]^{25}_D$ +104.3° (*c* 1.555, $CHCl_3$); IR ($CHCl_3$) 3560, 3015, 1620, 1520, 1260 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 7.35−7.27 (m, 4 H, ArH), 6.95−6.87 (m, 4 H, ArH), 4.97 (d, 1 H, J = 4.0 Hz, H-1), 4.65 (AB, 2 H, J = 11.4 Hz, $\Delta\nu$ = 22.2 Hz, $ArCH_2$), 4.58 (AB, 2 H, J = 11.5 Hz, $\Delta\nu$ = 76.4 Hz, $ArCH'_2$), 3.97−3.88 (m, 2 H, H-4, H-5), 3.81 (s, 3 H, $ArOCH_3$), 3.80 (s, 3 H, $ArOCH_3$), 3.82−3.78 (m, 1 H, H-2), 3.63 (dd, 1 H, J = 9.7, 3.3 Hz, H-3), 2.45 (bs, 1 H, OH), 2.14 (d, 1 H, J = 8.3 Hz, OH), 1.28 (d, 3 H, J = 6.6 Hz, 3 H-6); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 159.3, 129.9, 129.7, 129.3, 129.2, 113.8, 113.7, 97.6, 78.5, 71.7, 69.5, 69.4, 68.2, 65.7, 55.2, 16.1.

(4-Methoxyphenyl)methyl 2-*O*-(2,4-Dideoxy-2-Iodo-3-*O*-methyl-4-phthalimido-α-L-*lyxo*-pyranosyl)-(1→2)-6-deoxy-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (59). A solution of diol **58** (579 mg) in CH_2Cl_2 (25 mL) was stirred over powdered 4 Å molecular sieves for 1 h. Solid I$^+$(*sym*-collidine)$_2$ClO$_4^-$ (621 mg) was added, and the mixture was cooled to −23 °C. A solution of glycal **28** (352 mg) in CH_2Cl_2 (8 mL) was added over 10 min, and the resulting solution was stirred for 2 h, after which it was warmed to room temperature over the course of 1 h. After being stirred for an additional 3 h, the mixture was filtered through Celite and diluted with 100 mL of CH_2Cl_2. The organic layer was washed with 3 × 40 mL of 10% $Na_2S_2O_3$ and 4 × 40 mL of 10% $CuSO_4$, dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 1:1 to 4:6) to give 660 mg (62%) of **59** along with 12% of the O-4 glycosylated compound and trace amounts of the bis-glycosylated compound. **59**: $[\alpha]^{25}_D$ −52.6° (*c* 0.525, $CHCl_3$); IR ($CHCl_3$) 3680, 3030, 1720, 1615, 1515, 1390 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 7.85−7.82 (m, 2 H, phth), 7.76−7.72 (m, 2 H, phth), 7.37−7.30 (m, 2 H, ArH), 7.29−7.25 (m, 2 H, ArH), 6.98−6.94 (m, 2 H, ArH), 6.64−6.60 (m, 2 H, ArH), 5.62 (s, 1 H, H-1′), 4.71 (AB, 2 H, J = 10.9 Hz, $\Delta\nu$ = 158.2 Hz, $ArCH_2$), 4.58 (AB, 2 H, J = 11.6 Hz, $\Delta\nu$ = 110.8 Hz, $ArCH_2$), 4.55 (dt, 1 H, J = 11.5, 5.3 Hz, H-4′), 4.44 (t, 1 H, J = 11.3 Hz, H-5′$_{ax}$), 4.40 (d, 1 H, J = 7.8 Hz, H-1), 4.37 (dd, 1 H, J = 4.1, 0.8 Hz, H-2′), 3.88−3.82 (m, 2 H, H-3′, H-4), 3.81 (s, 3 H, $ArOCH_3$), 3.77 (dd, 1 H, J = 9.3, 7.8 Hz, H-2), 3.57 (s, 3 H, $ArOCH_3$), 3.60−3.52 (m, 2 H, H-3, H-5), 3.26 (dd, 1 H, J = 10.8, 5.2 Hz, H-5′$_{eq}$), 3.15 (s, 3 H, OCH_3), 2.30 (d, 1 H, J = 2.9 Hz, OH), 1.40 (d, 3 H, J = 6.5 Hz, 3 H-6); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 168.0, 159.7, 158.9, 133.9, 131.8, 130.1, 130.0, 129.3, 123.2, 114.1, 113.3, 102.4, 100.1, 81.3, 74.8, 70.7, 70.6, 70.5, 70.0, 68.2, 59.8, 55.2, 55.0, 50.3, 35.0, 16.4; FAB HRMS for $C_{36}H_{40}INO_{11}Na$ (M + Na$^+$), calcd 812.1545, found 812.1604. Anal. Calcd for $C_{36}H_{40}INO_{11}$: C, 54.76; H, 5.11; N, 1.77. Found: C, 54.71; H, 5.15; N, 1.58.

(4-Methoxyphenyl)methyl 2-*O*-(2,4-Dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl)-(1→2)-6-deoxy-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (60). A solution of **59** (235 mg), triphenyltin hydride (125 mg), and AIBN (20 mg) in benzene (15 mL) was heated to reflux for 1 h. The solution was concentrated and chromatographed on silica gel (hexane/EtOAc 6:4 to 4:6) to give 183 mg (93%) of **60**: $[\alpha]^{25}_D$ −63.2° (*c* 1.86, $CHCl_3$), IR ($CHCl_3$) 3550, 3020, 1720, 1615, 1520, 1390, 1250 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 7.86−7.82 (m, 2 H, phth), 7.75−7.71 (m, 2 H, phth), 7.33−7.26 (m, 4 H, ArH), 6.92−6.88 (m, 2 H, ArH), 6.68−6.64 (m, 2 H, ArH), 5.37 (d, 1 H, J = 2.8 Hz, H-1′), 4.73 (AB, 2 H, J = 10.9 Hz, $\Delta\nu$ = 139.7 Hz, $ArCH_2$), 4.60 (AB, 2 H, J = 11.4 Hz, $\Delta\nu$ = 63.9 Hz, $ArCH_2$), 4.61 (dt, 1 H, J = 10.6, 4.8 Hz, H-4′), 4.48 (t, 1 H, J = 11.4 Hz, H-5′$_{ax}$), 4.40 (d, 1 H, J = 7.8 Hz, H-1), 4.19 (dt, 1 H, J = 10.7, 5.1 Hz, H-3′), 3.81 (s, 3 H, $ArOCH_3$), 3.86−3.77 (m, 2 H, H-2, H-4), 3.58 (s, 3 H, $ArOCH_3$), 3.57−3.50 (m, 2 H, H-3, H-5), 3.23 (s, 3 H, OCH_3), 3.22−3.20 (m, 1 H, H-5′$_{eq}$), 2.33 (bs, 1 H, OH), 2.28 (dd, 1 H, J = 12.9, 4.8 Hz, H-2′$_{eq}$), 1.53−1.50 (m, 1 H, H-2′$_{ax}$), 1.38 (d, 3 H, J = 6.5 Hz, 3 H-6); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 168.1, 159.5, 158.9, 133.8, 131.9, 130.1, 129.6, 129.5, 123.1, 114.0, 113.3, 106.3, 100.3, 98.6, 82.0, 74.2, 71.1, 71.0, 70.4, 69.9, 68.6, 59.2, 55.8, 55.2, 54.9, 52.8, 35.5, 16.4.

(4-Methoxyphenyl)methyl 2-*O*-(2,4-Dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl)-(1→2)-6-deoxy-3-*O*-[(4-methoxyphenyl)methyl]-4-*O*-(trifluoromethanesulfonyl)-β-D-galactopyranoside (61). Trifluoromethanesulfonic anhydride (20 μL) was added to a solution of **60** (61.3 mg) and pyridine (40 μL) in CH_2Cl_2 (15 mL) at 0 °C. After being stirred for 1 h, the solution was added to 25 mL of CH_2Cl_2 and washed with 2 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 55:45) to give 52.3 mg (71%) of **61**: ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.90−7.82 (m, 2 H, phth), 7.78−7.71 (m, 2 H, phth), 7.35−7.25 (m, 4 H, ArH), 6.95−6.86 (m, 2 H, ArH), 6.71−6.63 (m, 2 H, ArH), 5.28 (d, 1 H, J = 2.6 Hz, H-1′), 5.01 (d, 1 H, J = 2.9 Hz, H-4), 4.73 (AB, 2 H, J = 10.8 Hz, $\Delta\nu$ = 67.6 Hz, $ArCH_2$), 4.62 (AB, 2 H, J = 11.4 Hz, $\Delta\nu$ = 93.1 Hz, $ArCH_2$), 4.52 (dt, 1 H, J = 11.6, 4.4 Hz, H-3′), 4.46 (d, 1 H, J = 7.7 Hz, H-1), 4.44 (t, 1 H, J = 11.9 Hz, H-5′$_{ax}$), 4.17 (dt, 1 H, J = 11.9, 4.9 Hz, H-4′), 3.86−3.78 (m, 1 H, H-2), 3.81 (s, 3 H, $ArOCH_3$), 3.73 (q, 1 H, J = 6.7 Hz, H-5), 3.64 (dd, 1 H, J = 9.7, 2.9 Hz, H-3), 3.60 (s, 3 H, OCH_3), 3.21 (dd, 1 H, J = 10.8, 5.0 Hz, H-5′$_{eq}$), 3.20 (s, 3 H, OCH_3), 2.14 (m, 1 H, H-2′$_{eq}$), 1.50 (m, 1 H, H-2′$_{ax}$), 1.39 (d, 3 H, J = 6.4 Hz, 3 H-6).

(4-Methoxyphenyl)methyl 4,6-Dideoxy-4-{[(2,4,6-Trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio)-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-(2,4-dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl)-3-*O*-(4-methoxyphenyl)methyl-β-D-glucopyranoside (62). Sodium hydride (10 mg, 60% dispersion in mineral oil) was added to a solution of carbamate **53** (34.8 mg) in DMF (1.5 mL) at 0 °C. The suspension was warmed to room temperature for 15 min and recooled to 0 °C. A solution of triflate **61** (52.3 mg) in DMF (1.0 mL) was added dropwise, and the mixture was stirred for 20 min. The reaction was quenched at 0 °C by dropwise addition of AcOH (100 μL). The mixture was added to 25 mL of EtOAc and washed with 10 mL of saturated aqueous NH_4Cl and 3 × 10 mL of H_2O. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 65:35) to give 53.6 mg (74%) of **62**: $[\alpha]^{25}_D$ −45.1° (*c* 1.425, $CHCl_3$); IR ($CHCl_3$) 3020, 2960, 1720, 1700, 1615, 1520, 1390, 1260, 1070 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 7.89−7.83 (m, 2 H), 7.78−7.72 (m, 2 H), 7.36−7.30 (m, 2 H), 7.28−7.20 (m, 2 H), 6.88−6.82 (m, 2 H), 6.71−6.66 (m, 2 H), 5.41−5.32 (m, 1 H), 5.19−5.09 (m, 1 H), 4.85 (app d, 1 H, J = 11.3 Hz), 4.82−4.75 (m, 1 H), 4.67−4.56 (m, 3 H), 4.50 (t, 1 H, J = 11.1 Hz), 4.45 (d, 1 H, J = 7.8 Hz), 4.33 (bs, 1 H), 4.26−4.13 (m, 4 H), 4.00−3.88 (m, 1 H), 3.84−3.74 (m, 1 H), 3.79 (s, 3 H), 3.69−3.60 (m, 1 H), 3.60 (s, 3 H), 3.27−3.20 (m, 2 H),

3.22 (s, 3 H), 2.40−2.15 (m, 3 H), 2.17 (s, 3 H), 1.80−1.70 (m, 1 H), 1.58−1.42 (m, 4 H), 1.40−1.30 (m, 3 H), 1.05−0.95 (m, 2 H), 0.93 (s, 9 H), 0.16 (s, 3 H), 0.14 (s, 3 H), 0.03 (bs, 9 H); FAB HRMS for $C_{55}H_{81}N_2O_{15}SSi_2$ (M + H$^+$), calcd 1097.4715, found 1097.4858.

(4-Methoxyphenyl)methyl 4,6-Dideoxy-4-{[(2,4,6-Trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-(4-amino-2,4-dideoxy-3-*O*-methyl-α-L-*threo*-pentopyranosyl)-3-*O*-(4-methoxyphenyl)methyl-β-D-glucopyranoside (63). A solution of **62** (48.8 mg) and hydrazine (0.3 mL) in 95% EtOH (5 mL) was heated to reflux for 20 min. The mixture was cooled to room temperature, added to 25 mL of CH_2Cl_2, and washed with 3 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel ($CHCl_3$/MeOH 96:4) to give 40.6 mg (94%) of **63**: $[\alpha]^{25}_D$ −36.7° (*c* 0.785, $CHCl_3$); IR ($CHCl_3$) 3010, 2960, 1720, 1615, 1520, 1260, 1070 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 7.37−7.32 (m, 2 H), 7.25−7.19 (m, 2 H), 6.92−6.87 (m, 2 H), 6.86−6.81 (m, 2 H), 5.37−5.28 (m, 1 H), 5.17−5.09 (m, 1 H), 4.84 (app d, 1 H, *J* = 11.4 Hz), 4.78−4.67 (m, 1 H), 4.60−4.52 (m, 1 H), 4.54 (app d, 1 H, *J* = 11.4 Hz), 4.39 (d, 1 H, *J* = 7.8 Hz), 4.31 (bs, 1 H), 4.26−4.10 (m, 3 H), 3.98−3.88 (m, 1 H), 3.85−3.75 (m, 1 H), 3.80 (s, 3 H), 3.78 (s, 3 H), 3.70−3.61 (m, 2 H), 3.44−3.35 (m, 2 H), 3.35 (s, 3 H), 3.24−3.14 (m, 1 H), 2.30−2.05 (m, 3 H), 2.14 (s, 3 H), 1.79−1.69 (m, 1 H), 1.50−1.40 (m, 4 H), 1.40−1.29 (m, 3 H), 1.05−0.95 (m, 2 H), 0.92 (s, 9 H), 0.16 (s, 3 H), 0.13 (s, 3 H), 0.02 (s, 9 H); FAB HRMS for $C_{47}H_{79}N_2O_{13}SSi_2$ (M + H$^+$), calcd 967.4840, found 967.4870.

(4-Methoxyphenyl)methyl 4,6-Dideoxy-4-{[(2,4,6-Trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-[(1-methylethyl)amino]-α-L-*threo*-pentopyranosyl]-3-*O*-(4-methoxyphenyl)methyl-β-D-glucopyranoside (64). A mixture of **63** (40.6 mg), acetone (0.5 mL), $NaCNBH_3$ (100 mg), and $MgSO_4$ (100 mg) in 2-propanol (3 mL) was stirred at room temperature for 48 h. The mixture was added to 25 mL of CH_2Cl_2 and washed with 2 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel ($CHCl_3$/MeOH 96:4) to give 38.3 mg (90%) of **64**: $[\alpha]^{25}_D$ −28.6 (*c* 1.645, $CHCl_3$); IR ($CHCl_3$) 3010, 2960, 1710, 1615, 1520, 1260, 1070, 1045 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 7.38−7.34 (m, 2 H), 7.26−7.19 (m, 2 H), 6.90−6.85 (m, 2 H), 6.85−6.80 (m, 2 H), 5.30−5.24 (m, 1 H), 5.18−5.08 (m, 1 H), 4.84 (app d, 1 H, *J* = 11.4 Hz), 4.77−4.67 (m, 1 H), 4.65−4.55 (m, 1 H), 4.53 (app d, 1 H, *J* = 11.4 Hz), 4.37 (d, 1 H, *J* = 7.8 Hz), 4.31 (bs, 1 H), 4.25−4.10 (m, 3 H), 3.98−3.90 (m, 1 H), (3.84−3.75 (m, 1 H), 3.80 (s, 3 H), 3.78 (s, 3 H), 3.68 (t, 1 H, *J* = 10.6 Hz), 3.67−3.58 (m, 1 H), 3.46 (dd, 1 H, *J* = 11.1, 4.6 Hz), 3.42−3.30 (m, 2 H), 3.31 (s, 3 H), 2.75 (sept, 1 H, *J* = 6.2 Hz), 2.69−2.61 (m, 1 H), 2.30−2.05 (m, 3 H), 2.14 (s, 3 H), 1.78−1.69 (m, 1 H), 1.60−1.38 (m, 4 H), 1.35−1.28 (m, 3 H), 1.03 (d, 3 H, *J* = 6.2 Hz), 1.01 (d, 3 H, *J* = 6.2 Hz), 1.05−0.90 (m, 2 H), 0.92 (s, 9 H), 0.16 (s, 3 H), 0.13 (s, 3 H), 0.02 (s, 9 H); FAB HRMS for $C_{50}H_{85}N_2O_{13}SSi_2$ (M + H$^+$), calcd 1009.5310, found 1009.5382.

4,6-Dideoxy-4-{[(2,4,6-Trideoxy-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-(methylthio-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)-ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-[(1-methylethyl)amino]-α-L-*threo*-pentopyranosyl]-D-glucopyranose (65). A mixture of **64** (17.6 mg), DDQ (25 mg), and H_2O (0.2 mL) in CH_2Cl_2 (2.0 mL) was stirred vigorously at room temperature for 40 h. The mixture was added to 20 mL of CH_2Cl_2 and washed with 3 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel ($CHCl_3$/MeOH 95:5) to provide 8.9 mg (66%) of **65** as a 1:1 mixture of anomers: $[\alpha]^{25}_D$ −20.9° (*c* 0.43, $CHCl_3$); IR ($CHCl_3$) 3480, 3020, 2920, 1715 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 5.37 (m), 5.30−5.20 (m), 5.24 (d, *J* = 3.6 Hz), 5.17 (m), 4.57 (d, *J* = 7.7 Hz), 4.35−4.30 (m), 4.29−4.18 (m), 4.07−3.94 (m), 3.81 (d, *J* = 6.0 Hz), 3.79−3.72 (m), 3.71−3.64 (m), 3.59−3.48 (m), 3.42 (dd, *J* = 9.5, 7.6 Hz), 3.37 (s), 3.36 (s), 2.89 (sept, *J* = 6.3 Hz), 2.76−2.69 (m), 2.32−2.26 (m), 2.15 (s), 2.14−2.01 (m), 1.80−1.73 (m), 1.65−1.54 (m), 1.47−1.42 (m), 1.28−1.20 (m), 1.17−1.13 (m), 1.12−1.05 (m), 0.95 (s), 0.95−0.88 (m), 0.18 (s), 0.15 (s), 0.08 (s); FAB HRMS for $C_{34}H_{69}N_2O_{11}SSi_2$ (M + H$^+$), calcd 769.4160, found 769.4110.

[2*S*-[2α,3β,4α,5α(*S)]]-1-[(2,4,6-Trideoxy-4-(methylthio-β-D-*ribo*-hexopyranosyl)oxy]-2,4-dihydroxy-5-(1-hydroxyethyl)-3-pyrrolidinyl 2,4-Dideoxy-3-*O*-methyl-4-[(1-methylethyl)amino]-α-L-*threo*-pentopyranoside (14).** A solution of **65** (13.9 mg) and *n*-Bu_4NF (1.0 M in THF, 80 μL) in THF (1.0 mL) was stirred at 0 °C for 40 h. The mixture was added to 20 mL of CH_2Cl_2 and washed with 2 × 10 mL of saturated aqueous $NaHCO_3$. The organic layer was dried over $MgSO_4$, filtered, and concentrated under reduced pressure to provide compound **14** (which was taken on to the next step without purification: ^{1}H NMR (490 MHz, $CDCl_3$) δ 5.35 (dd, 1 H, *J* = 10.2, 1.6 Hz), 5.00 (t, 1 H, *J* = 3.3 Hz), 4.94 (bs, 1 H), 4.55 (d, 1 H, *J* = 3.6 Hz), 4.45 (bs, 1 H), 4.33 (dq, 1 H, *J* = 6.7, 2.6 Hz), 4.14 (m, 1 H), 4.07 (d, 1 H, *J* = 5.2 Hz), 3.88 (dq, 1 H, *J* = 10.1, 5.9 Hz), 3.81−3.75 (m, 2 H), 3.56 (dd, 1 H, *J* = 11.1, 9.6 Hz), 3.42 (dt, 1 H, *J* = 9.5, 4.6 Hz), 3.39−3.30 (m, 2 H), 3.35 (s, 3 H), 2.90−2.81 (m, 2 H), 2.74 (dt, 1 H, *J* = 9.0, 4.7 Hz), 2.51 (dd, 1 H, *J* = 10.0, 2.5 Hz), 2.47 (bs, 1 H), 2.29 (dt, 1 H, *J* = 13.9, 2.5 Hz), 2.19−2.11 (m, 1 H), 2.13 (s, 3 H), 1.75−1.55 (m, 2 H), 1.45−1.40 (m, 6 H), 1.08 (d, 6 H, *J* = 6.7 Hz).

[2*S*-[2α,3β,4α,5α(*S)]]-1-[(2,4,6-Trideoxy-4-(methylthio-β-D-*ribo*-hexopyranosyl)oxy]-4-hydroxy-5-(1-hydroxyethyl)-2-methoxy-3-pyrrolidinyl 2,4-Dideoxy-3-*O*-methyl-4-[(1-methylethyl)amino]-α-L-*threo*-pentopyranoside (15).** A solution of **14**, obtained in the previous step, and AcOH (20 μL) in MeOH (2.0 mL) was stirred at room temperature for 44 h. The mixture was added to 25 mL of CH_2Cl_2 and washed with 3 × 10 mL of saturated aqueous $NaHCO_3$. The organic layer was dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (toluene/acetone 1:1) to provide 4.3 mg of **15** (45% overall from **65**): $[\alpha]^{25}_D$ −60.0° (*c* 0.21, $CHCl_3$); IR ($CHCl_3$) 3440, 3020, 2930, 1380, 1220, 1075 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 5.30 (dd, 1 H, *J* = 10.2, 1.9 Hz), 5.03 (t, 1 H, *J* = 2.8 Hz), 4.93 (bs, 1 H), 4.54 (br d, 1 H, *J* = 2.2 Hz), 4.43 (d, 1 H, *J* = 2.7 Hz), 4.33 (m, 1 H), 4.14 (dd, 1 H, *J* = 5.4, 2.6 Hz), 4.02 (d, 1 H, *J* = 4.3 Hz), 3.91 (d, 1 H, *J* = 2.8 Hz), 3.87 (dq, 1 H, *J* = 10.6, 6.2 Hz), 3.77 (dd, 1 H, *J* = 11.2, 4.4 Hz), 3.61−3.55 (m, 1 H), 3.52 (s, 3 H), 3.54−3.46 (m, 1 H), 3.36 (s, 3 H), 2.93 (bs, 1 H), 2.87 (dd, 1 H, *J* = 4.3, 2.9 Hz), 2.80−2.75 (m, 2 H), 2.51 (dd, 1 H, *J* = 10.6, 2.5 Hz), 2.24 (ddd, 1 H, *J* = 13.5, 2.9, 2.3 Hz), 2.15 (ddd, 1 H, *J* = 13.0, 3.7, 2.9 Hz), 2.13 (s, 3 H), 1.62−1.50 (m, 2 H), 1.40 (2 d, 6 H, *J* = 6.3 Hz), 1.12 (d, 6 H, *J* = 6.0 Hz); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 103.9, 100.0, 97.0 (2 C), 82.7, 72.7, 69.3, 67.5, 64.5, 63.0, 56.1, 55.8, 55.7 (2 C), 47.1, 35.4, 34.1, 23.8, 22.3, 19.7, 17.1, 13.8 (one C obscured by the $CDCl_3$ peak); FAB HRMS for $C_{23}H_{45}N_2O_9S$ (M + H$^+$), calcd 525.2846, found 525.2876.

Phenylmethyl 4-*O*-Acetyl-2,3,6-trideoxy-α-L-*erythro*-hex-2-enopyranoside (67). Boron trifluoride etherate (0.57 mL, 4.67 mmol) was added to a solution of 3,4-di-*O*-acetyl-6-deoxy-L-glucal (**66**, 10 g, 46.7 mmol) and benzyl alcohol (20 mL, 186.8 mmol) in CH_2Cl_2 (50 mL) at 0 °C. After being stirred for 30 min at 0 °C and for 4 h at room temperature, the reaction was quenched with saturated aqueous $NaHCO_3$. The mixture was diluted with CH_2Cl_2 (200 mL) and washed with saturated aqueous $NaHCO_3$ (2 × 100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 95:5 to 85:15) to provide pseudoglycal **67** (8.6 g, 70%): colorless oil; $[\alpha]^{25}_D$ −109.0° (*c* 2.10, $CHCl_3$); FT-IR (MIDAC, $CHCl_3$) ν_{max} 3031, 3011, 2982, 2935, 2904, 1736, 1455, 1404, 1376, 1104 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 7.41−7.27 (m, 5 H, ArH), 5.86 (br d, 1 H, *J* = 10.7 Hz, H-3), 5.82 (ddd, 1 H, *J* = 10.2, 2.4, 1.7 Hz, H-2), 5.08−5.05 (m, 2 H, H-1, H-4), 4.70 (AB, 2 H, *J* = 11.9 Hz, Δν = 88.0 Hz, CH_2Ar), 4.00 (dq, 1 H, *J* = 9.1, 6.3 Hz, H-5), 2.08 (s, 3 H, Ac), 1.20 (d, 3 H, *J* = 6.3 Hz, CH_3); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 170.2, 137.9, 129.6, 128.2, 127.8, 127.7, 127.5, 93.5, 70.8, 69.9, 64.8, 20.8, 17.7. Anal. Calcd for $C_{15}H_{18}O_4$: C, 68.69; H, 6.92. Found: C, 68.69; H, 6.80.

Phenylmethyl 2,3,6-Trideoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-α-L-*erythro*-hex-2-enopyranoside (69). A solution of sodium methoxide (108 mL, 0.393 mmol, 25% (w) in MeOH) was added to a solution of pseudoglycal **67** (1.03 g, 3.93 mmol) in MeOH (8 mL) at room temperature. After the mixture was stirred for 90 min at room temperature, the volatiles were removed under reduced pressure. The residue was dissolved in CH_2Cl_2 (8 mL) and imidazole (536 mg, 7.86 mmol) and *tert*-butyldimethylsilyl chloride (711 mg, 4.72 mmol) were

sequentially added. After being stirred at room temperature for 36 h, the reaction mixture was diluted with CH_2Cl_2 (150 mL) and washed with saturated aqueous $NaHCO_3$ (2 × 50 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 95:5 to 90:10) to provide pseudoglycal **69** (1.267 g, 96%): colorless oil; $[\alpha]^{25}_D$ −88.1° (*c* 2.63, $CHCl_3$); FT-IR (MIDAC, $CHCl_3$) ν_{max} 3011, 2957, 2931, 2894, 2858, 1471, 1455, 1254, 1102, 1070, 1042, 1008, 881, 838, cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 7.38–7.26 (m, 5 H, ArH), 5.85 (ddd, 1 H, J = 10.2, 1.2, 1.2 Hz, H-3), 5.69 (ddd, 1 H, J = 10.2, 2.6, 2.1 Hz, H-2), 5.01 (dd, 1 H, J = 2.1, 1.2 Hz, H-1), 4.68 (AB, 2 H, J = 11.9, $\Delta\nu$ = 100.0 Hz, CH_2Ar), 3.88 (ddd, 1 H, J = 8.7, 2.6, 1.2 Hz, H-4), 3.80 (dq, 1 H, J = 8.7, 6.2 Hz, H-5), 1.23 (d, 3 H, J = 6.2 Hz, CH_3), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.09 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 138.2, 134.6, 128.3, 127.8, 127.5, 125.5, 93.8, 70.3, 69.8, 67.8, 25.7, 18.0, 17.9, −4.3, −4.7; FAB HRMS for $C_{19}H_{30}O_3SiNa$ (M + Na), calcd 357.1861, found 357.1862. Anal. Calcd for $C_{19}H_{30}O_3Si$: C, 68.22; H, 9.04. Found: C, 68.44; H, 9.20.

Phenylmethyl 6-Deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-α-L-mannopyranoside (70). A solution of osmium tetraoxide (3.8 mL, 0.76 mmol, 0.2 M in acetone) was added to a solution of pseudoglycal **69** (12.65 g, 37.9 mmol) and *N*-methylmorpholine *N*-oxide (4.88 g, 41.69 mmol) in acetone (75 mL) and water (10 mL). After being stirred at room temperature for 16 h, the reaction mixture was quenched with 10% aqueous $NaHSO_3$, diluted with EtOAc (300 mL), and washed with 10% aqueous $NaHSO_3$ (4 × 100 mL) and brine (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 60:40 to 40:60) to provide diol **70** (13.42 g, 96%): white solid; mp 106–107 °C; $[\alpha]^{25}_D$ −80.6° (*c* 0.81, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3520, 3400, 3010, 2950, 2930, 2860, 1600, 1470, 1390, 1260, 1110, 1060, 890, 840 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.39–7.3 (m, 5 H, ArH), 4.85 (d, 1 H, J = 1.6 Hz, H-1), 4.61 (AB, 2 H, J = 12 Hz, $\Delta\nu$ = 55.4 Hz, CH_2Ar), 3.97 (ddd, 1 H, J = 4.2, 3.5, 1.6 Hz, H-2), 3.78 (ddd, 1 H, J = 9.0, 5.8, 3.4 Hz, H-3), 3.70 (dq, 1 H, J = 9.1, 6.2 Hz, H-5), 3.48 (dd, 1 H, J = 9.1, 9.0 Hz, H-4), 2.25 (d, 1 H, J = 4.2 Hz, OH), 2.16 (d, 1 H, J = 5.8 Hz, OH), 1.28 (d, 3 H, J = 6.2 Hz, CH_3), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.14 (s, 3 H, $SiCH_3$), 0.11 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 137.4, 128.4, 127.82, 127.77, 98.7, 74.8, 72.1, 71.4, 69.0, 68.6, 25.9, 18.2, 18.0, −3.8, −4.4; FAB HRMS for $C_{19}H_{32}O_5SiNa$ (M + Na), calcd 391.1916, found 391.1947. Anal. Calcd for $C_{19}H_{32}O_5Si$: C, 61.92; H, 8.75. Found: C, 62.14; H, 8.99.

Phenylmethyl 6-Deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranoside (71a) and Phenylmethyl 6-Deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-2-*O*-methyl-α-L-mannopyranoside (71). A mixture of diol **70** (13.42 g, 36.5 mmol) and dibutyltin oxide (10g, 40.15 mmol) in MeOH (300 mL) was refluxed for 5 h. The reaction mixture was cooled to room temperature, and the volatiles were removed under reduced pressure. The stannylene was dissolved in benzene (300 mL), and tetrabutylammonium bromide (20.25 g, 91.25 mmol) and iodomethane (9.1 mL, 146 mmol) were added to this solution. The resulting mixture was refluxed for 48 h, cooled to room temperature, and added to 500 mL of brine. The layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (2 × 200 mL). The combined organic extracts were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 90:10 to 70:30) to provide methoxy alcohols **71a** (2.78 g, 20%) and the slower eluting **71** (11.16 g, 80%). **71:** white solid; mp 47.5–49.5 °C; $[\alpha]^{25}_D$ −75.3° (*c* 1.1, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3560, 3030, 2950, 2880, 1600, 1465, 1390, 1255, 1185, 1115, 1085, 1060, 890, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.45–7.28 (m, 5 H, ArH), 4.91 (d, 1 H, J = 1.3 Hz, H-1), 4.60 (AB, 2 H, J = 11.9 Hz, $\Delta\nu$ = 55.7 Hz, CH_2Ar), 4.09 (dd, 1 H, J = 3.4, 1.3 Hz, H-2), 3.71 (dq, 1 H, J = 9.1, 6.3 Hz, H-5), 3.48 (dd, 1 H, J = 9.1, 8.9 Hz, H-4), 3.38 (s, 3 H, OCH_3), 3.34 (dd, 1 H, J = 8.9, 3.4 Hz, H-3), 2.40 (b, 1 H, OH), 1.28 (d, 3 H, J = 6.3 Hz, CH_3), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.09 (s, 3 H, $SiCH_3$), 0.07 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 137.4, 128.3, 127.9, 127.7, 98.3, 81.6, 72.7, 68.9, 68.6, 67.1, 56.4, 25.9, 18.1, −4.1, −4.8; FAB HRMS for $C_{20}H_{34}O_5SiNa$ (M + Na), calcd 405.2074, found 405.2110. Anal. Calcd for $C_{20}H_{34}O_5Si$: C, 62.79; H, 8.96. Found: C, 62.87; H, 9.12.

Phenylmethyl 2-*O*-Acetyl-6-deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranoside (72). Acetic anhydride (60 mL) was added to a solution of alcohol **71** (11.16 g, 29.2 mmol) and DMAP (360 mg, 2.92 mmol) in pyridine (60 mL) at room temperature. Afterthe mixture was stirred at room temperature for 1 h, the volatiles were removed by coevaporating with toluene under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 95:5 to 85:15) to provide acetate **72** (12.19 g, 99%): colorless syrup; $[\alpha]^{25}_D$ -61.2° (*c* 0.745, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3020, 2960, 2940, 2860, 1735, 1600, 1465, 1375, 1250, 1135, 1120, 1105, 1065, 870, 845, 705 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.42–7.28 (m, 5 H, ArH), 5.35 (dd, 1 H, J = 3.1, 1.7 Hz, H-2), 4.79 (d, 1 H, J = 1.6 Hz, H-1), 4.59 (AB, 2 H, J = 11.8 Hz, $\Delta\nu$ = 53.6 Hz, CH_2Ar), 3.71 (dq, 1 H, J = 8.7, 6.2 Hz, H-5), 3.48 (dd, 1 H, J = 9.1, 8.7 Hz, H-4), 3.39 (dd, 1 H, J = 9.1, 3.1 Hz, H-3), 3.30 (s, 3 H, OCH_3), 2.10 (s, 3 H, Ac), 1.29 (d, 3 H, J = 6.2 Hz, CH_3), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.08 (s, 6 H, 2 × $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 170.0, 137.1, 128.4, 127.9, 127.8, 97.0, 79.8, 73.2, 69.2, 69.1, 68.1, 56.7, 25.9, 20.8, 18.2, −4.1, −4.9; FAB HRMS for $C_{22}H_{36}O_6SiNa$ (M + Na), calcd 460.1987, found 460.2013. Anal. Calcd for $C_{22}H_{36}O_6Si$: C, 62.23; H, 8.55. Found: C, 62.37; H, 8.64.

2-*O*-Acetyl-6-deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranose (73). 20% $Pd(OH)_2/C$ (12 g) was added to a solution of benzyl glycoside **72** (12.19 g, 28.8 mmol) in MeOH (120 mL). After the mixture was stirred at room temperature under 1 atm of H_2 for 48 h, the catalyst was removed by filtering the reaction mixture through Celite and rinsing with hot MeOH. The combined filtrates were concentrated under reduced pressure, and the residue was purified by flash column chromatography (hexanes/EtOAc 70:30 to 50:50) to provide pyranose **73** (8.82 g, 92%) as an inseparable mixture of anomers (α:β 15:1): white solid; mp 100.5–101.5 °C; $[\alpha]^{25}_D$ -16.1° (*c* 1.94, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3600, 3390, 3020, 2960, 2940, 2860, 1735, 1465, 1375, 1255, 1120, 1100, 1055, 870, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 5.35 (dd, 1 H, J = 3.1, 1.9 Hz, H-2), 5.15 (dd, 1 H, J = 3.6, 1.9 Hz, H-1), 3.89 (dq, 1 H, J = 9.1, 6.3 Hz, H-5), 3.48 (dd, 1 H, J = 9.4, 9.1 Hz, H-4), 3.43 (dd, 1 H, J = 9.4, 3.1 Hz, H-3), 3.32 (s, 3 H, OCH_3), 2.51 (d, 1 H, J = 3.6 Hz, OH), 2.12 (s, 3 H, Ac), 1.28 (d, 3 H, J = 6.3 Hz, CH_3), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.09 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 170.7, 92.4, 79.3, 73.2, 69.1, 68.6, 56.9, 26.0, 20.9, 18.3, −4.1, −4.8; FAB HRMS for $C_{15}H_{30}O_6SiNa$ (M + Na), calcd 357.1710, found 357.1732. Anal. Calcd for $C_{15}H_{30}O_6Si$: C, 53.86; H, 9.04. Found: C, 54.03; H, 9.27.

2-*O*-Acetyl-6-deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl Trichloroacetimidate (74). Sodium hydride (340 mg, 8.37 mmol, 60% dispersion in mineral oil) was added to a solution of pyranose **73** (4 g, 11.96 mmol) and trichloroacetonitrile (12 mL, 119.6 mmol) in CH_2Cl_2 (120 mL) at 0 °C. After being stirred for 1 h at 0 °C, the reaction mixture was filtered through silica, and the filter pad was rinsed with EtOAc. The combined filtrates were concentrated under reduced pressure, and the residue was purified by flash column chromatography (hexanes/EtOAc 90:10 to 85:15) to provide trichloroacetimidate **74** (5.42 g, 95%) as an inseparable mixture of anoners (α:β 9:1).

4,6-Diiodo-2,3-dimethoxy-5-methylphenyl 2-*O*-Acetyl-6-deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranoside (76). A solution of boron trifluoride etherate (420 mL, 3.39 mmol) in CH_2Cl_2 (5 mL) was added to a solution of trichloroacetimidate **74** (5.41 g, 11.3 mmol) and diiodophenol **75** (9.5 g, 23.8 mmol) in CH_2Cl_2 (55 mL) at −48 °C. After being stirred for 30 min at −48 °C, the reaction mixture was quenched with saturated aqueous $NaHCO_3$ and warmed to room temperature. The mixture was diluted with CH_2Cl_2 (300 mL) and washed with saturated aqueous $NaHCO_3$ (2 × 100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 95:5 to 80:20) to provide diiodophenyl glycoside **76** (7.43 g, 89%), mixed with traces of the α anomers (α:β 20:1): white amorphous solid; IR ($CHCl_3$) ν_{max} 3000, 2950, 2930, 2855, 1740, 1455, 1410, 1370, 1315, 1245, 1120, 1085, 1065, 1005, 945,

925, 840 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 5.75 (dd, 1 H, J = 3.2, 1.8 Hz, H-2), 5.50 (d, 1 H, J = 1.8 Hz, H-1), 4.18 (dq, 1 H, J = 9.3, 6.2 Hz, H-5), 3.85 (s, 3 H, $ArOCH_3$), 3.84 (s, 3 H, $ArOCH_3$), 3.78 (dd, 1 H, J = 9.2, 3.2 Hz, H-3), 3.58 (dd, 1 H, J = 9.3, 9.2 Hz, H-4), 3.40 (s, 3 H, OCH_3), 2.84 (s, 3 H, $ArCH_3$), 2.14 (s, 3 H, Ac), 1.27 (d, 3 H, J = 6.2 Hz, CH_3), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.12 (s, 3 H, $SiCH_3$), 0.10 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 170.0, 153.9, 150.4, 141.8, 139.4, 101.1, 92.1, 91.0, 79.4, 72.6, 71.7, 68.0, 60.9, 60.4, 57.1, 35.7, 26.0, 20.9, 18.3, 18.2, −4.0, −4.8; FAB HRMS for $C_{24}H_{38}I_2O_8SiNa$ (M + Na), calcd 759.0323, found 759.0376. Anal. Calcd for $C_{24}H_{38}I_2O_8Si$: C, 39.14; H, 5.20. Found: C, 39.38; H, 5.11.

4,6-Diiodo-2,3-dimethoxy-5-methylphenyl 6-Deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranoside (77). A solution of sodium methoxide (550 μL, 1.82 mmol, 25% (w) in MeOH) was added to a solution of acetate **76** (6.7 g, 9.1 mmol) in MeOH (67 mL) at 0 °C. After being stirred 10 min at 0 °C and 4 h at room temperature, the reaction mixture was diluted with CH_2Cl_2 (300 mL) and washed with saturated aqueous $NaHCO_3$ (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 95:5 to 75:25) to provide alcohol **77** (5.97 g 95%): white amorphous solid; $[\alpha]^{25}_D$ −61.7° (*c* 0.605, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3540, 3010, 2940, 2860, 1455, 1410, 1315, 1110, 1085, 1075, 1005, 945, 890, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 5.64 (d, 1 H, J = 1.5 Hz, H-1), 4.47 (ddd, 1 H, J = 3.3, 1.5, 1.4 Hz, H-2), 4.13 (dq, 1 H, J = 9.1, 6.3 Hz, H-5), 3.86 (s, 3 H, $ArOCH_3$), 3.84 (s, 3 H, $ArOCH_3$), 3.71 (dd, 1 H, J = 8.9, 3.3 Hz, H-3), 3.58 (dd, 1 H, J = 9.1, 8.9 Hz, H-4), 3.48 (s, 3 H, OCH_3), 2.84 (s, 3 H, $ArCH_3$), 2.50 (d, 1 H, J = 1.4 Hz, OH), 1.24 (d, 3 H, J = 6.3 Hz, CH_3), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.13 (s, 3 H, $SiCH_3$), 0.09 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 154.0, 150.6, 142.2, 139.4, 102.7, 91.2, 81.4, 72.3, 71.2, 67.5, 60.9, 60.4, 56.8, 35.7, 26.0, 18.2, 18.09, −4.0, −4.6; FAB HRMS for $C_{22}H_{36}I_2O_7SiNa$ (M + Na), calcd 717.0217, found 717.0242. Anal. Calcd for $C_{22}H_{36}I_2O_7Si$: C, 38.05; H, 5.23. Found: C, 38.34; H, 5.35.

4,6-Diiodo-2,3-dimethoxy-5-methylphenyl 6-Deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranoside (78). Pyridine (4.75 mL, 59.4 mmol), DMAP (2.42 g, 19.8 mmol), and *tert*-butyldimethylsilyl trifluoromethanesulfonate (3.42 mL, 14.85 mmol) were sequentially added to a solution of alcohol **77** (6.84 g, 9.9 mmol) in CH_2Cl_2 (20 mL) at 0 °C. After being stirred 10 min at 0 °C and 24 h at room temperature, the reaction mixture was quenched with saturated aqueous $NaHCO_3$, diluted with CH_2Cl_2 (300 mL), and washed with saturated aqueous $NaHCO_3$ (2 × 100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/CH_2Cl_2 80:20 to 50:50) to provide bis-silylated diiodophenyl glycoside **78** (7.88 g, 98%): white amorphous solid; $[\alpha]^{25}_D$ −41.1° (*c* 2.94, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3000, 2950, 2925, 2890, 2850, 1455, 1410, 1360, 1255, 1140, 1110, 1085, 1015, 1005, 945, 890, 840 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 5.32 (d, 1 H, J = 1.9 Hz, H-1), 4.46 (dd, 1 H, J = 2.6, 1.9 Hz, H-2), 4.16 (dq, 1 H, J = 9.0, 6.2 Hz, H-5), 3.85 (s, 3 H, $ArOCH_3$), 3.82 (s, 3 H, $ArOCH_3$), 3.69 (dd, 1 H, J = 9.1, 9.0 Hz, H-3), 3.54 (dd, 1 H, J = 9.1, 2.6 Hz, H-4), 3.40 (s, 3 H, OCH_3), 2.84 (s, 3 H, $ArCH_3$), 1.23 (d, 3 H, J = 6.2 Hz, CH_3), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.13 (s, 3 H, $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.09 (s, 3 H, $SiCH_3$), 0.085 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 153.9, 151.4, 142.4, 139.4, 104.7, 92.0, 91.6, 81.4, 72.5, 68.8, 60.8, 60.4, 57.1, 38.8, 26.1, 25.7, 18.4, 18.3, 18.1, −4.0, −4.7, −4.8; FAB HRMS for $C_{28}H_{50}I_2O_7Si_2Na$ (M + Na), calcd 831.1081, found 831.1129. Anal. Calcd for $C_{28}H_{50}I_2O_7Si_2$: C, 41.59; H, 6.23. Found: C, 41.88; H, 6.37.

Methyl 4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoate (79). A mixture of diiodophenyl glycoside **78** (190 mg, 0.24 mmol), $Pd(OAc)_2$ (21.4 mg, 96 mmol), 1,3-bis(diphenylphosphino)propane (39.2 mg, 96 mmol), and Et_3N (170 mL, 1.2 mmol) in DMSO/MeOH (2/1, 4.8 mL) was stirred at 65 °C under 1 atm of CO for 36 h. The reaction mixture was cooled to room temperature, diluted with CH_2Cl_2 (50 mL), and washed with water (3 × 20 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (toluene/EtOAc 100:0 to 85:15) to provide methyl benzoate **79** (91.2 mg, 52%), along with regioisomeric methyl benzoate (8.8 mg, 5%) and diester (26 mg, 16%). **79**: white amorphous solid; $[\alpha]^{25}_D$ −34.5° (*c* 1.32, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3000, 2960, 2940, 2900, 2860, 1725, 1565, 1550, 1460, 1420, 1400, 1335, 1320, 1275, 1255, 1145, 1110, 1090, 1010, 970, 945, 895, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 5.36 (d, 1 H, J = 1.9 Hz, H-1), 4.45 (dd, 1 H, J = 2.5, 1.9 Hz, H-2), 4.13 (dq, 1 H, J = 9.1, 6.2 Hz, H-5), 3.92 (s, 3 H, CO_2CH_3), 3.88 (s, 3 H, $ArOCH_3$), 3.81 (s, 3 H, $ArOCH_3$), 3.69 (dd, 1 H, J = 9.1, 9.1 Hz, H-4), 3.56 (dd, 1 H, J = 9.1, 2.5 Hz, H-3), 3.40 (s, 3 H, OCH_3), 2.37 (s, 3 H, $ArCH_3$), 1.23 (d, 3 H, J = 6.2 Hz, CH_3), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.90 (s, 9 H, $SiC(CH_3)_3$), 0.13 (s, 3 H, $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.09 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 167.6, 152.1, 151.4, 143.4, 134.2, 125.5, 104.6, 93.6, 81.5, 72.7, 72.4, 68.9, 61.5, 60.8, 57.0, 52.3, 26.1, 25.9, 25.7, 18.4, 18.3, 18.1, −4.0, −4.6, −4.8; FAB HRMS for $C_{30}H_{53}IO_9Si_2Na$ (M + Na), calcd 763.2170, found 763.2221. Anal. Calcd for $C_{30}H_{53}IO_9Si_2$: C, 48.64; H, 7.21. Found: C, 48.85; H, 7.10.

4-(Hydroxymethyl)-6-iodo-2,3-dimethoxy-5-methylphenyl 6-Deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranoside (80). A solution of DIBAL-H (3.1 mL, 3.1 mmol, 1 M in cyclohexane) was added dropwise to a solution of methyl benzoate **79** (1.045 g, 1.4 mmol) in CH_2Cl_2 (140 mL) at −78 °C. After being stirred for 20 min at −78 °C, the reaction mixture was quenched with saturated aqueous $NaHCO_3$, warmed to room temperature, diluted with CH_2Cl_2 (300 mL), and washed with saturated aqueous $NaHCO_3$ (2 × 100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 90:10 to 70:30) to provide benzylic alcohol **80** (924 mg, 92%): white solid; mp 52 °C; $[\alpha]^{25}_D$ −38.6° (*c* 1.73, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3600, 3450, 3020, 2960, 2940, 2900, 2860, 1575, 1550, 1463, 1420, 1405, 1393, 1320, 1260, 1145, 1100, 1020, 950, 895, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 5.31 (d, 1 H, J = 1.9 Hz, H-1), 4.76 (s, 2 H, $HOCH_2Ar$), 4.48 (dd, 1 H, J = 2.5, 1.9 Hz, H-2), 4.18 (dq, 1 H, J = 8.9, 6.2 Hz, H-5), 3.90 (s, 3 H, $ArOCH_3$), 3.81 (s, 3 H, $ArOCH_3$), 3.69 (dd, 1 H, J = 9.1, 8.9 Hz, H-4), 3.55 (dd, 1 H, J = 9.1, 2.5 Hz, H-3), 3.41 (s, 3 H, OCH_3), 2.56 (s, 3 H, $ArCH_3$), 1.84 (s, 1 H, OH), 1.23 (d, 3 H, J = 6.2 Hz, CH_3), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.90 (s, 9 H, $SiC(CH_3)_3$), 0.13 (s, 3 H, $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.09 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 153.2, 151.1 143.6, 136.9, 128.8, 104.7, 83.9, 81.5, 77.2, 72.6, 72.3, 68.9, 61.4, 60.7, 58.4, 57.0, 26.1, 25.7, 25.3, 18.4, 18.3, 18.1, −4.0, −4.7, −4.8; FAB HRMS for $C_{29}H_{53}IO_8Si_2Na$ (M + Na), calcd 735.2221, found 735.2193. Anal. Calcd for $C_{29}H_{53}IO_8Si_2$: C, 48.87; H, 7.50. Found: C, 48.49; H, 7.42.

4-[(6-Deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzaldehyde (81). Dess−Martin periodinane (502 mg, 1.18 mmol) was added to a solution of benzylic alcohol **80** (649 mg, 0.91 mmol) in CH_2Cl_2 (50 mL) at 0 °C. After being stirred for 4 h at 0 °C, the reaction mixture was concentrated under reduced pressure, and the residue was purified by flash column chromatography (hexanes/EtOAc 96:4 to 94:6) to provide benzaldehyde **81** (641 mg, 99%): white amorphous solid; $[\alpha]^{25}_D$ −37.6° (*c* 0.94, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3000, 2960, 2940, 2890, 2860, 1685, 1565, 1545, 1413, 1420, 1380, 1310, 1260, 1145, 1200, 1010, 945, 895, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 10.31 (s, 1 H, CHO), 5.56 (d, 1 H, J = 1.9 Hz, H-1), 4.44 (dd, 1 H, J = 2.5, 1.9 Hz, H-2), 4.08 (dq, 1 H, J = 8.8, 6.2 Hz, H-5), 3.97 (s, 3 H, $ArOCH_3$), 3.84 (s, 3 H, $ArOCH_3$), 3.69 (dd, 1 H, J = 9.0, 8.8 Hz, H-4), 3.61 (dd, 1 H, J = 9.0, 2.5 Hz, H-3), 3.41 (s, 3 H, OCH_3), 2.73 (s, 3 H, $ArCH_3$), 1.22 (d, 3 H, J = 6.2 Hz, CH_3), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.907 (s, 9 H, $SiC(CH_3)_3$), 0.14 (s, 3 H, $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.10 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 190.9, 158.7, 154.8, 143.1, 140.1, 125.1, 104.4, 97.3, 81.3, 72.5, 72.4, 68.7, 62.1, 60.9, 57.1, 26.0, 25.8, 25.7, 18.3, 18.2, 18.1, −4.0, −4.7, −4.8; FAB HRMS for $C_{29}H_{51}IO_8Si_2Na$ (M + Na), calcd 733.2064, found 733.2099. Anal. Calcd for $C_{29}H_{51}IO_8Si_2$: C, 49.00; H, 7.23. Found: C, 49.30; H, 7.25.

4-[(6-Deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoic acid (82). $NaH_2PO_4 \cdot H_2O$ (1.6 g, 11.6 mmol) and $NaClO_2$ (1.5 g, 16.6 mmol) were sequentially added to a solution of aldehyde **81**

(625 mg, 0.88 mmol), BuOH (20 mL), 2-methyl-2-butene (10 mL), and water (20 mL). After being stirred for 30 min at room temperature, the layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (3 × 20 mL). The combined organic extracts were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/acetone/acetic acid 60:40:1 to 50:50:2) to provide benzoic acid **82** (626 mg, 98%): white amorphous solid; $[\alpha]^{25}_D$ −38.5° (*c* 1.645, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3100, 3010, 2960, 2940, 2900, 2860, 1705, 1550, 1460, 1405, 1255, 1145, 1110, 1090, 1010, 945, 840 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 5.40 (d, 1 H, J = 1.9 Hz, H-1), 4.46 (dd, 1 H, J = 2.5, 1.9 Hz, H-2), 4.14 (dq, 1 H, J = 8.8, 6.2 Hz, H-5), 3.94 (s, 3 H, $ArOCH_3$), 3.83 (s, 3 H, $ArOCH_3$), 3.69 (dd, 1 H, J = 9.0, 8.8 Hz, H-4), 3.57 (dd, 1 H, J = 9.0, 2.5 Hz, H-3), 3.41 (s, 3 H, OCH_3), 2.51 (s, 3 H, $ArCH_3$), 1.23 (d, 3 H, J = 6.2 Hz, CH_3), 0.92 (s, 9 H, $SiC(CH_3)_3$), 0.90 (s, 9 H, $SiC(CH_3)_3$), 0.14 (s, 3 H, $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.10 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 172.2, 152.5, 151.4, 143.3, 134.5, 124.3, 104.6, 94.1, 81.3, 72.4, 68.7, 61.7, 60.8, 57.1, 26.2, 26.1, 25.7, 18.3, 18.1, −4.0, −4.7, −4.8; FAB HRMS for $C_{29}H_{51}IO_9Si_2Na$ (M + Na), calcd 749.2013, found 749.2011. Anal. Calcd for $C_{29}H_{51}IO_9Si_2$: C, 47.93; H, 7.07. Found: C, 47.79; H, 7.24.

4-Hydroxy-2,3-dimethoxy-6-methylbenzonitrile (86). Trimethylsilyl cyanide (17.4 mL, 130 mmol) was added to a flask containing 2,3-dimethoxy-6-methyl-1,4-benzoquinone (**84**) (10.32 g, 56.65 mmol) and potassium cyanide−18-crown-6 complex (30 mg, 0.09 mmol). The reaction was covered from light and stirred overnight in a room temperature water bath. The crude trimethylsilyl cyanohydrin **85** was dissolved in THF (120 mL) and methanol (60 mL) and cooled to −78 °C. A solution of samarium(II) iodide in THF (0.1 M) was added via cannula into the reaction vessel until an abrupt color change from blue-green to light brown indicated the reaction was complete. The reaction was also monitored by TLC (hexanes/ethyl acetate 2:1). Saturated aqueous NH_4Cl (200 mL) was added to the reaction mixture, which was subsequently extracted with diethyl ether (4 × 150 mL). The combined organic layers were dried ($MgSO_4$), concentrated, and purified by flash column chromatography (20 → 25 → 50% ethyl acetate in hexanes) to provide the desired *p*-hydroxybenzonitrile **86** (8.95 g, 82%): tan solid; mp 115−116 °C; ^1H NMR (250 MHz, $CDCl_3$) δ 6.62 (s, 1 H, ArH), 6.17 (bs, 1 H, OH), 4.02 (s, 3 H, OCH_3), 3.91 (s, 3 H, OCH_3), 2.42 (s, 3 H, $ArCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 155.1, 153.7, 139.2, 137.3, 115.7, 112.4, 98.8, 61.3, 60.9, 20.2; IR (KBr) 3320, 2995, 2960, 2855, 2245, 1615, 1580, 1503, 1370, 1322, 1208, 1180, 1125, 1008 cm^{-1}; FAB HRMS for $C_{10}H_{11}NO_3H$ (M + H^+), calcd 194.0817, found 194.0818.

4-Hydroxy-5-iodo-2,3-dimethoxy-6-methylbenzonitrile (87). A solution of iodine monochloride (14.9 g, 91.8 mmol) in acetonitrile (50 mL) was added to phenol **86** (8.85 g, 45.8 mmol) in acetonitrile (150 mL) and covered from light. After being stirred for 1 h at room temperature, the reaction was diluted with CH_2Cl_2 (200 mL) and washed with saturated aqueous $Na_2S_2O_3$ (100 mL) and H_2O (100 mL). The organic layer was dried ($MgSO_4$), concentrated, and purified by flash column chromatography (25% ethyl acetate in hexanes) to give **87** (13.6 g, 93%): white solid; mp 105−106 °C; ^1H NMR (250 MHz, $CDCl_3$) δ 6.87 (bs, 1 H OH), 4.03 (s, 3 H, OCH_3), 3.94 (s, 3 H, OCH_3), 2.69 (s, 3 H, $ArCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 154.7, 153.6, 141.7, 136.3, 115.5, 99.8, 83.0, 61.5, 61.4, 26.7; IR (KBr) 3300, 2935, 2220, 1698, 1682, 1610, 1550, 1455, 1345, 1110, 995, 834 cm^{-1}; FAB HRMS for $C_{10}H_{10}INO_3H$ (M + H^+), calcd 319.9760, found 319.9757.

4-[(2-*O*-Acetyl-6-deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzonitrile (88). Boron trifluoride etherate (0.83 mL, 6.7 mmol) was added dropwise to a −48 °C solution of iodophenol **87** (9.90 g, 31.0 mmol) and trichloroacetimidate **74** in CH_2Cl_2 (130 mL). After 1 h, the solution was poured into saturated aqueous $NaHCO_3$ (150 mL) and extracted with CH_2Cl_2 (2 × 100 mL). The combined extracts were dried ($MgSO_4$) and concentrated, and the residue was purified by flash column chromatography (5 → 10 → 20% ethyl acetate in hexanes) to provide aryl glycoside **88** (13.6 g, 95%) as an inseparable mixture of anomers (21:1 α:β): colorless foam; R_f = 0.48 (hexanes/ethyl acetate 3:1); $[\alpha]^{25}_D$ −36.6° (*c* 1.7, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 5.67 (dd, 1 H, J = 3.2, 1.6 Hz, H-2), 5.65 (d, 1 H, J = 1.6 Hz, H-1), 4.06 (dq, 1 H, J = 9.2, 6.2 Hz, H-5), 4.00 (s, 3 H, $ArOCH_3$), 3.82 (s, 3 H, $ArOCH_3$), 3.77 (dd, 1 H, J = 9.2, 3.2 Hz, H-3), 3.56 (t, 1 H, J = 9.2 Hz, H-4), 3.37 (s, 3 H, OCH_3), 2.63 (s, 3 H, $ArCH_3$), 2.12 (s, 3 H, $COCH_3$), 1.24 (d, 3 H, J = 6.2 Hz, H-6), 0.88 (s, 9 H, $SiC(CH_3)_3$), 0.09 (s, 3 H, $SiCH_3$), 0.07 (s, 3 H, $SiCH_3$); ^{13}C NMR (75.5 MHz, $CDCl_3$) δ 170.0, 156.9, 153.9, 142.3, 141.5, 115.0, 103.7, 100.9, 92.0, 79.3, 72.5, 72.0, 67.7, 61.7, 61.2, 57.2, 27.5, 26.0, 20.9, 18.3, 18.2, −4.0, −4.8; IR (KBr) 2930, 2850, 2230, 1745, 1540, 1457, 1330, 867, 838, 803, 780 cm^{-1}; FAB HRMS for $C_{25}H_{38}INO_8SiNa$ (M + Na^+), calcd 658.1309, found 658.1323.

4-[(6-Deoxy-4-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzonitrile (89). A solution of sodium methoxide in methanol (1.40 mL, 6.12 mmol) was added to **88** (9.69 g, 15.25 mmol) in methanol (100 mL) at −10 °C. After 18 h, solid NH_4Cl (ca. 1 g) was added, and the reaction was stirred for 5 min. It was then poured into H_2O (100 mL) and extracted with CH_2Cl_2 (3 × 75 mL). The organic fractions were combined, dried ($MgSO_4$), concentrated, and chromatographed (flash column, 25% ethyl acetate in hexanes) to afford the deacylated aryl glycoside **89** (8.53 g, 94%): clear glass; R_f = 0.38 (hexanes/ethyl acetate 2:1); $[\alpha]^{25}_D$ −68.9° (*c* 1.9, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 5.81 (d, 1 H, J = 1.4 Hz, H-1), 4.41 (dd, 1 H, J = 3.1, 1.6 Hz, H-2), 4.01 (s, 3 H, $ArOCH_3$), 3.99 (dq, 1 H, J = 9.2, 6.3 Hz, H-5), 3.83 (s, 3 H, $ArOCH_3$), 3.71 (dd, 1 H, J = 8.9, 3.3 Hz, H-3), 3.56 (t, 1 H, J = 9.1 Hz, H-4), 3.46 (s, 3 H, OCH_3), 2.64 (s, 3 H, $ArCH_3$), 2.57 (bs, 1 H, OH), 1.20 (d, 3 H, J = 6.2 Hz, H-6), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.11 (s, 3 H, $SiCH_3$), 0.07 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 156.9, 153.9, 142.5, 141.4, 115.1, 103.5, 102.3, 92.2, 81.2, 72.0, 71.3, 67.2, 61.6, 61.1, 56.8, 27.5, 25.9, 18.1, 18.0, −4.1, −4.7; IR (KBr) 3535, 3430, 2950, 2930, 2895, 2855, 2235, 1460, 1418, 1400, 1340, 1250, 1135, 1100, 1007, 930, 842, 810, 782 cm^{-1}; FAB HRMS for $C_{23}H_{36}INO_7SiNa$ (M + Na^+), calcd 616.1204, found 616.1256.

4-[(6-Deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzonitrile (90). A solution of **89** (4.66 g, 7.85 mmol) in CH_2Cl_2 (30 mL) was cooled to 0 °C, and pyridine (4.0 mL, 49.5 mmol) and DMAP (1.85 g, 16.5 mmol) were added. *tert*-Butyldimethylsilyl trifluoromethanesulfonate (3.40 mL, 14.8 mmol) was added dropwise, and the reaction was allowed to slowly warm to room temperature. After 36 h, the solution was poured into saturated aqueous $NaHCO_3$ (50 mL) and extracted with CH_2Cl_2 (2 × 100 mL). The organic layers were combined, dried ($MgSO_4$), and concentrated. Purification by flash column chromatography (2 → 5 → 10% ethyl acetate in hexanes) provided **90** (5.55 g, 100%): white foam; R_f = 0.44 (hexanes/ethyl acetate 9:1); $[\alpha]^{25}_D$ −45.4° (*c* 1.9, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 5.50 (d, 1 H, J = 1.9 Hz, H-1), 4.39 (t, 1 H, J = 2.3 Hz, H-2), 4.01 (s, 3 H, $ArOCH_3$), 3.99 (dq, 1 H, J = 9.1, 6.2 Hz, H-5), 3.81 (s, 3 H, $ArOCH_3$), 3.67 (t, 1 H, J = 9.0 Hz, H-4), 3.56 (dd, 1 H, J = 9.0, 2.5 Hz, H-3), 3.39 (s, 3 H, OCH_3), 2.64 (s, 3 H, $ArCH_3$), 1.19 (d, 3 H, J = 6.2 Hz, H-6), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.12 (s, 3 H, $SiCH_3$), 0.10 (s, 3 H , $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$), 0.07 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 156.9, 154.8, 142.8, 141.5, 115.2, 104.5, 103.6, 92.6, 81.3, 72.6, 72.4, 68.7, 61.7, 61.1, 57.2, 27.6, 26.0, 25.7, 18.3, 18.1, −4.0, −4.7, −4.7, −4.8; IR (KBr) 2920, 2850, 2225, 1722, 1715, 1560, 1538, 1460, 1410, 1335, 1250, 1090, 940, 840, 778 cm^{-1}; FAB HRMS for $C_{29}H_{50}INO_7Si_2Na$ (M + Na^+), calcd 730.2068, found 730.2108.

4-[(6-Deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzaldehyde (81). Diisobutylaluminum hydride (1.5 M in toluene) was added very slowly to a solution of nitrile **90** (5.47 g, 7.73 mmol) in hexanes (80 mL) at 0 °C until the reaction was complete (ca. 1.2 equiv; TLC, toluene/ethyl acetate 12:1). The reaction was quenched with saturated aqueous NH_4Cl (50 mL), and the organic layer was removed. The aqueous layer was back extracted with diethyl ether (2 × 50 mL), and the combined organic fractions were dried ($MgSO_4$), concentrated, and purified by flash column chromatography (2 → 5% ethyl acetate in toluene) to provide benzaldehyde **81** (4.21 g, 77%).

2,4,6-Trideoxy-1-*O*-{[2-(trimethylsilyl)ethyl]amino}-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-β-D-*ribo*-hexopyranosyl 4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylthiobenzoate (91). Oxalyl chloride (3 mL) was added to a flask containing the neat acid

82 (200 mg, 0.275 mmol). After being stirred at room temperature for 2 h, the reaction mixture was concentrated under reduced pressure and azeotroped with benzene (2 × 1 mL). The resulting chloride **83** was dissolved in CH_2Cl_2 (5 mL) and cooled to 0 °C. DMAP (3 mg, 25 mmol) and triethylamine (350 mL, 2.5 mmol) were added to the reaction mixture at 0 °C, followed by thiol **65** (109 mg, 0.25 mmol) in CH_2Cl_2 (3 mL). After being stirred at 0 °C for 2 h, the reaction mixture was quenched with saturated aqueous $NaHCO_3$, diluted with CH_2Cl_2 (75 mL), and washed with saturated aqueous $NaHCO_3$ (20 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 95:5 to 88:12) to provide thiobenzoate **91** (246 mg, 86%): white amorphous solid; $[\alpha]^{25}_D$ −24.0° (*c* 1.175, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3360, 3010, 2950, 2930, 2890, 2850, 1745, 1710, 1670, 1460, 1255, 1190, 1095, 845 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.59 (s 1 H, NH), 5.36 (d, 1 H, *J* = 1.8 Hz, D-1), 5.13 (dd, 1 H, *J* = 9.8, 1.8 Hz, B-1), 4.46 (dd, 1 H, *J* = 2.5, 1.8 Hz, D-2), 4.32−4.23 (m, 3 H, B-3, OCH_2 (TEOC)), 4.16 (dq, 1 H, *J* = 9.1, 6.2 Hz, D-5), 4.04 (dq, 1 H, *J* = 10.6, 6.2 Hz, B-5), 3.87 (s, 3 H, $ArOCH_3$), 3.80 (s, 3 H, $ArOCH_3$), 3.78 (dd, 1 H, *J* = 10.6, 2.4 Hz, B-4), 3.69 (dd, 1 H, *J* = 9.1, 9.1 Hz, D-4), 3.53 (dd, 1 H, *J* = 9.1, 2.5 Hz, D-3), 3.40 (s, 3 H, OCH_3), 2.35 (s, 3 H, $ArCH_3$), 2.13 (ddd, 1 H, *J* = 13.2, 3.4, 1.8 Hz, B-2_{eq}), 1.80 (ddd, 1 H, *J* = 13.2, 9.8, 2.4 Hz, B-2_{ax}), 1.40 (d, 3 H, *J* = 6.2 Hz, B-6), 1.23 (d, 3 H, *J* = 6.2 Hz, D-6), 1.08−0.94 (m, 2 H, $SiCH_2$ (TEOC)), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.90 (s, 9 H, $SiC(CH_3)_3$), 0.896 (s, 9 H, $SiC(CH_3)_3$), 0.14 (s, 3 H, $SiCH_3$), 0.12 (s, 6 H, 2 × $SiCH_3$), 0.10 (s, 6 H, 2 × $SiCH_3$), 0.09 (s, 3 H, $SiCH_3$), 0.05 (s, 9 H, $Si(CH_3)_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 192.7, 157.2, 152.5, 150.5, 143.4, 133.4, 130.5, 104.7, 101.6, 93.9, 81.4, 72.5, 72.4, 70.5, 70.1, 68.7, 64.5, 61.5, 60.8, 57.1, 51.4, 37.5, 29.7, 26.1, 25.9, 25.8, 25.7, 25.3, 18.7, 18.3, 18.1, 18.0, 17.7, −1.5, −4.0, −4.7, −4.8, −5.0; FAB HRMS for $C_{47}H_{88}INO_{13}SSi_4Na$ (M + Na), calcd 1168.3995, found 1168.3977. Anal. Calcd for $C_{47}H_{88}INO_{13}SSi_4$: C, 49.24; H, 7.74; N, 1.22; S, 2.80. Found: C, 48.98; H, 7.87; N, 1.31; S, 3.02.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-4-phthalimido-3-*O*-methyl-α-L-*threo*-pentopyranosyl]-3-*O*-[(4-methoxyphenyl)methyl]-β-D-glucopyranoside (92). Sodium hydride (37 mg, 1.53 mmol, 60% dispersion in mineral oil) was added to a solution of carbamate **91** (715 mg, 0.62 mmol) in DMF (7 mL) at 0 °C. The reaction mixture was warmed to room temperature, stirred for 30 min at room temperature, and cooled to 0 °C. A solution of triflate **50** (354 mg, 0.51 mmol) in DMF (7 mL) was added via cannula. After being stirred at 0 °C for 10 min, the reaction mixture was quenched by syringe pump addition of acetic acid (500 μL) over 10 min, diluted with EtOAc (300 mL), and washed with saturated aqueous NH_4Cl (100 mL), brine (100 mL), saturated aqueous $NaHCO_3$ (100 mL), and brine (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 85:15 to 70:30) to provide aryltetrasaccharide **92** (704 mg, 81%): white amorphous solid; $[\alpha]^{25}_D$ −31.6° (*c* 1.90, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3010, 2950, 2930, 2850, 1770, 1710, 1680, 1610, 1510, 1460, 1390, 1250, 1090, 1040, 840 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 100 °C) δ 7.87−7.82 (m, 4 H, ArH (Phth)), 7.21−7.19 (m, 2 H, ArH (PMB)), 6.87−6.85 (m, 2 H, ArH (PMB)), 5.38 (d, 1 H, *J* = 1.9 Hz, D-1), 5.27 (m, 1 H, E-1), 5.14 (dd, 1 H, *J* = 10.0, 1.7 Hz, B-1), 4.66 (AB, 2 H, *J* = 10.8 Hz, Δν = 23.6 Hz, CH_2Ar), 4.53 (app t, 1 H, *J* = 11.3 Hz, E-5_{ax}), 4.48−4.42 (m, 1 H, E-3), 4.45 (dd, 1 H, *J* = 2.6, 1.3 Hz, D-2), 4.39 (m, 1 H, B-3), 4.30 (d, 1 H, *J* = 7.7 Hz, A-1), 4.25 (app t, 1 H, *J* = 9.9 Hz, A-3), 4.19 (AB of ABX_2, 2 H, *J* = 11.7, 8.4, 8.4 Hz, Δν = 38.9 Hz, OCH_2 (TEOC)), 4.09−4.03 (m, 1 H, E-4), 4.08 (dq, 1 H, *J* = 8.9, 6.2 Hz, D-5), 3.97 (dq, 1 H, *J* = 10.6, 6.2 Hz, B-5), 3.89−3.81 (m, 2 H, A-5, A-4), 3.81 (s, 3 H, $ArOCH_3$ (PMB)), 3.77 (s, 3 H, $ArOCH_3$), 3.74 (s, 3 H, $ArOCH_3$), 3.72 (dd, 1 H, *J* = 10.6, 2.4 Hz, B-4), 3.68 (app t, 1 H, *J* = 9.0 Hz, D-4), 3.55 (dd, 1 H, *J* = 8.9, 2.6 Hz, D-3), 3.46 (dd, 1 H, *J* = 10.7, 5.1 Hz, E-5_{eq}), 3.45 (s, 3 H, OCH_3), 3.43 (app t, 1 H, *J* = 8.2 Hz, A-2), 3.37 (s, 3 H, OCH_3), 3.11 (s, 3 H, OCH_3), 2.32 (s, 3 H, $ArCH_3$), 2.30 (b dd, 1 H, *J* = 13.1, 4.0 Hz, E-2_{eq}), 2.15 (b d, 1 H, *J* = 13.1 Hz, B-2_{eq}), 1.90 (ddd, 1 H, *J* = 13.1, 10.0, 2.5 Hz, B-2_{ax}), 1.47 (b dt, 1 H, *J* = 11.9, 3.8 Hz, E-2_{ax}), 1.39 (d, 3 H, *J* = 6.2 Hz, B-6), 1.21 (d, 3 H, *J* = 6.0 Hz, A-6), 1.16 (d, 3 H, *J* = 6.2 Hz, D-6), 0.98 (dd, 2 H, *J* = 8.4, 8.4 Hz, $SiCH_2$ (TEOC)), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.89 (s, 9 H, $SiC(CH_3)_3$, 0.86 (s, 9 H, $SiC(CH_3)_3$), 0.14 (s, 3 H, $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.115 (s, 3 H, $SiCH_3$), 0.10 (s, 3 H, $SiCH_3$), 0.09 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$), 0.03 (s, 9 H, $Si(CH_3)_3$); ^{13}C NMR (125 MHz, DMSO-d_6, 100 °C) δ 191.1, 167.2, 158.4, 151.4, 149.7, 142.6, 134.0, 132.1, 130.9, 130.3, 129.7, 128.3, 128.2, 122.6, 113.3, 103.3, 102.1, 97.4, 93.3, 80.6, 79.1, 78.2, 72.3, 72.0, 71.4, 70.7, 69.8, 69.6, 67.8, 67.4, 63.9, 60.9, 60.3, 58.0, 56.2, 55.8, 54.8, 54.7, 52.1, 50.9, 37.1, 35.3, 28.5, 25.6, 25.1, 25.0, 24.4, 18.0, 17.7, 17.5, 17.3, 17.2, 17.11, 17.09, −2.1, −4.5, −5.0, −5.2, −5.3, −5.4, −5.5; FAB HRMS for $C_{76}H_{121}IN_2O_{22}SSi_4Na$ (M + Na), calcd 1707.6149, found 1707.6092.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-4-amino-3-*O*-methyl-α-L-*threo*-pentopyranosyl]-3-*O*-[(4-methoxyphenyl)methyl]-β-D-glucopyranoside (93). Anhydrous hydrazine (380 μL, 11.8 mmol) was added to phthalimide **92** (200 mg, 0.12 mmol) in absolute EtOH (12 mL) at room temperature. After being stirred at 70 °C for 10 min, the reaction mixture was diluted with EtOAc (150 mL) and washed with saturated aqueous $NaHCO_3$ (2 × 50 mL) and brine (50 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc/MeOH 50:50:3 to 50:50:10) to provide amine **93** (175 mg, 95%): white amorphous solid; $[\alpha]^{25}_D$ −33.7° (*c* 2.20, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3010, 2950, 2930, 2850, 1670 (b), 1605, 1510, 1457, 1390, 1253, 1090, 1035, 840 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 100 °C) δ 7.19−7.16 (m, 2 H, ArH (PMB)), 6.87−6.84 (m, 2 H, ArH (PMB)), 5.39 (d, 1 H, *J* = 2.0 Hz, D-1), 5.15 (m, 1 H, E-1), 5.12 (dd, 1 H, *J* = 10.1, 2.0 Hz, B-1), 4.61 (AB, 2 H, *J* = 10.7 Hz, Δν = 23.5 Hz, CH_2Ar), 4.45 (dd, 1 H, *J* = 2.7, 2.0 Hz, D-2), 4.38 (m, 1 H, B-3), 4.23 (d, 1 H, *J* = 7.7 Hz, A-1), 4.20 (app t, 1 H, *J* = 8.5 Hz, A-3), 4.21−4.12 (m, 2 H, OCH_2 (TEOC)), 4.08 (dq, 1 H, *J* = 8.9, 6.2 Hz, D-5), 3.95 (dq, 1 H, *J* = 10.5, 6.2 Hz, B-5), 3.85−3.83 (m, 1 H, A-5), 3.82 (s, 3 H, $ArOCH_3$ (PMB)), 3.80−3.76 (m, 1 H, A-4), 3.78 (s, 3 H, $ArOCH_3$), 3.74 (s, 3 H, $ArOCH_3$), 3.70 (dd, 1 H, *J* = 10.7, 2.6 Hz, B-4), 3.68 (app t, 1 H, *J* = 8.9 Hz, D-4), 3.57 (app t, 1 H, *J* = 11.0 Hz, E-5_{ax}), 4.55 (dd, 1 H, *J* = 8.9, 2.7 Hz, D-3), 3.44 (dd, 1 H, *J* = 11.4, 5.1 Hz, E-5_{eq}), 3.41 (s, 3 H, OCH_3), 3.40 (app t, 1 H, *J* = 8.6 Hz, A-2), 3.37 (s, 3 H, OCH_3), 3.27 (s, 3 H, OCH_3), 3.25−3.20 (m, 1 H, E-3), 2.67−2.60 (m, 1 H, E-4), 2.32 (s, 3 H, $ArCH_3$), 2.15 (b d, 1 H, *J* = 13.4 Hz, B-2_{eq}), 2.09 (ddd, 1 H, *J* = 12.8, 4.5, 2.2 Hz, E-2_{eq}), 1.88 (ddd, 1 H, *J* = 13.4, 10.1, 2.3 Hz, B-2_{ax}), 1.36 (d, 3 H, *J* = 6.2 Hz, B-6), 1.34−1.28 (m, 1 H, E-2_{ax}), 1.20 (d, 3 H, *J* = 6.0 Hz, A-6), 1.16 (d, 3 H, *J* = 6.2 Hz, D-6), 0.97 (app t, 2 H, *J* = 8.4 Hz, $SiCH_2$ (TEOC)), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.85 (s, 9 H, $SiC(CH_3)_3$), 0.13 (s, 3 H, $SiCH_3$), 0.127 (s, 3 H, $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.10 (s, 6 H, 2 × $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$), 0.03 (s, 9 H, $Si(CH_3)_3$); FAB HRMS for $C_{68}H_{119}IN_2O_{20}SSi_4Na$ (M + Na), calcd 1555.6276, found 1555.6407.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-4-(ethylamino)-3-*O*-methyl-α-L-*threo*-pentopyranosyl]-3-*O*-[(4-methoxyphenyl)-methyl]-β-D-glucopyranoside (94). Excess acetaldehyde (3 drops) was added to a solution of amine **93** (175 mg, 0.11 mmol) in absolute MeOH (12 mL). After being stirred at room temperature for 5 min, $MgSO_4$ (143 mg, 1.1 mmol) and sodium cyanoborohydride (74 mg, 1.1 mmol) were added, and the heterogeneous reaction mixture was stirred at room temperature for 1 h. The reaction mixture was then diluted with EtOAc (150 mL) and washed with saturated aqueous NH_4Cl (50 mL), saturated aqueous $NaHCO_3$ (50 mL), and brine (50 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc/MeOH 60:40:0 to 0:90:10) to provide ethylamine **94** (169 mg, 95%): white amorphous solid; $[\alpha]^{25}_D$ −38.3° (*c* 0.575, $CHCl_3$); IR

($CHCl_3$) ν_{max} 2950, 2930, 2850, 1710 (b), 1670 (b), 1510, 1455, 1250, 1090 (b), 1035, 910, 840 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 100 °C) δ 7.18−7.16 (m, 2 H, ArH (PMB)), 6.87−6.84 (m, 2 H, ArH (PMB)), 5.39 (d, 1 H, J = 2.0 Hz, D-1), 5.14−5.11 (m, 2 H, E-1, B-1), 4.60 (AB, 2 H, J = 10.8 Hz, $\Delta\nu$ = 32.5 Hz, CH_2Ar), 4.45 (app t, 1 H, J = 2.3 Hz, D-2), 4.39−4.38 (m, 1 H, B-3), 4.23 (d, 1 H, J = 7.7 Hz, A-1), 4.19 (app t, 1 H, J = 8.9 Hz, A-3), 4.24−4.11 (m, 2 H, OCH_2 (TEOC)), 4.08 (dq, 1 H, J = 9.0, 6.2 Hz, D-5), 3.95 (dq, 1 H, J = 10.6, 6.2 Hz, B-5), 3.86−3.83 (m, 1 H, A-5), 3.82 (s, 3 H, $ArOCH_3$), 3.81 (app t, 1 H, J = 11.3 Hz, E-5_{ax}), 3.78 (s, 3 H, $ArOCH_3$), 3.74 (s, 3 H, $ArOCH_3$), 3.73−3.68 (m, 1 H, A-4), 3.70 (dd, 1 H, J = 10.6, 2.5 Hz, B-4), 3.68 (app t, 1 H, J = 9.1 Hz, D-4), 3.63 (app dt, 1 H, J = 9.9, 4.9 Hz, E-3), 3.55 (dd, 1 H, J = 9.0, 2.5 Hz, D-3), 3.40 (s, 3 H, OCH_3), 3.37 (s, 3 H, OCH_3), 3.37 (app t, 1 H, J = 8.0 Hz, A-2), 3.35 (dd, 1 H, J = 10.0, 5.4 Hz, E-5_{eq}), 2.65 (AB of ABX_3, 2 H, J = 13.2, 7.0 Hz, $\Delta\nu$ = 24.1 Hz, CH_2N), 2.64−2.57 (m, 1 H, E-4). 2.32 (s, 3 H, $ArCH_3$), 2.15 (b d, 1 H, J = 12.2 Hz, E-2_{eq}), 2.14 (b d, 1 H, J = 12.7 Hz, B-2_{eq}), 1.88 (ddd, 1 H, J = 12.7, 10.0, 2.3 Hz, B-2_{ax}), 1.36 (d, 3 H, J = 6.2 Hz, B-6), 1.32 (ddd, 1 H, J = 12.2, 9.9, 3.9 Hz, E-2_{ax}), 1.19 (d, 3 H, J = 6.0 Hz, A-6), 1.16 (d, 3 H, J = 6.2 Hz, D-6), 0.98 (dd, 3 H, J = 7.0, 7.0 Hz, CH_3-CH_2N), 0.99−0.93 (m, 2 H, $SiCH_2$ (TEOC)), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.85 (s, 9 H, $SiC(CH_3)_3$), 0.13 (s, 6 H, 2 × $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.10 (s, 6 H, 2 × $SiCH_3$), 0.81 (s, 3 H, $SiCH_3$), 0.02 (s, 9 H, $Si(CH_3)_3$).

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-4-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-4-(ethylamino)-3-*O*-methyl-α-L-*threo*-pentopyranosyl]-β-D-glucopyranoside (95). DDQ (121 mg, 0.53 mmol) was added to a solution of PMB ether **94** (169 mg, 107 μmol) in CH_2Cl_2/H_2O (20:1, 5 mL). After the mixture was stirred at room temperature for 24 h, THF (5 mL) and saturated aqueous $NaHCO_3$ (5 mL) were added. The reaction mixture was stirred at room temperature for 30 min, diluted with EtOAc (150 mL), and washed with saturated aqueous $NaHCO_3$ (3 × 50 mL) and brine (50 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc/MeOH 50:50:2 to 50:50:10) to provide alcohol **95** (125 mg, 80%): white amorphous solid; $[\alpha]^{25}_D$ −26.5° (*c* 1.12, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3500, 2950, 2930, 2855, 1715, 1670, 1460, 1390, 1255, 1100, 845, cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 100 °C) δ 5.38 (d, 1 H, J = 1.9 Hz, D-1), 5.30 (app t, 1 H, J = 2.8 Hz, E-1), 5.14 (dd, 1 H, J = 10.0, 1.8 Hz, B-1), 4.45 (app t, 1 H, J = 2.4 Hz, D-2), 4.45−4.42 (b, 1 H, OH), 4.37 (m, 1 H, B-3), 4.27−4.21 (m, 1 H, OCH-H (TEOC)), 4.19 (d, 1 H, J = 7.7 Hz, A-1), 4.18−4.11 (m, 2 H, A-3, OCH-H (TEOC)), 4.08 (dq, 1 H, J = 9.3, 6.2 Hz, D-5), 4.05 (dq, 1 H, J = 10.7, 6.2 Hz, B-5), 3.81 (s, 3 H, $ArOCH_3$), 3.78 (s, 3 H, $ArOCH_3$), 3.71−3.66 (m, 1 H, A-5), 3.681 (dd, 1 H, J = 10.7, 2.5 Hz, B-4), 3.679 (app t, 1 H, J = 9.0 Hz, D-4), 3.58 (app t, 1 H, J = 11.2 Hz, E-5_{ax}), 3.55 (dd, 1 H, J = 8.9, 2.3 Hz, D-3), 3.52 (dd, 1 H, J = 11.2, 5.0 Hz, E-5_{eq}), 3.41−3.33 (m, 2 H, E-3, A-4), 3.39 (s, 3 H, OCH_3), 3.37 (s, 3 H, OCH_3), 3.31 (app t, 1 H, J = 8.2 Hz, A-2), 3.27 (s, 3 H, OCH_3), 2.64−2.57 (m, 2 H, CH_2N), 2.51−2.48 (m, 1 H, E-4), 2.32 (s, 3 H, $ArCH_3$), 2.16 (dd, 1 H, J = 10.4, 4.4, 2.2 Hz, E-2_{eq}), 2.08 (app dt, 1 H, J = 13.2, 2.6 Hz B-2_{eq}), 1.81 (ddd, 1 H, J = 13.2, 10.0, 2.5 Hz, B-2_{ax}), 1.39 (ddd, 1 H, J = 12.6, 10.4, 3.6 Hz, E-2_{ax}), 1.33 (d, 3 H, J = 6.2 Hz, B-6), 1.16 (d, 3 H, J = 6.2 Hz, D-6), 1.13 (d, 3 H, J = 6.1 Hz, A-6), 1.01 (app t, 3 H, J = 7.0 Hz, CH_3-CH_2N), 1.04−0.92 (m, 2 H, $SiCH_2$ (TEOC)), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 0.886 (s, 9 H, $SiC(CH_3)_3$), 0.132 (s, 3 H, $SiCH_3$), 0.127(s, 3 H, $SiCH_3$), 0.12 (s, 3 H, $SiCH_3$), 0.103 (s, 3 H, $SiCH_3$), 0.098 (s, 3 H, $SiCH_3$), 0.08 (s, 3 H, $SiCH_3$), 0.05 (s, 9 H, $Si(CH_3)_3$); FAB HRMS for $C_{62}H_{116}IN_2O_{19}SSi_4$ (M + H), calcd1463.6014, found 1463.6094.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]-thio}-β-D-*ribo*-hexopyranosyl)oxy]amino}-2-*O*-[2,4-dideoxy-4-(ethylamino)-3-*O*-methyl-α-L-*threo*-pentopyranosyl]-β-D-glucopyranoside (13). Tetrabutylammonium fluoride (105 μL, 105 μmol, 1 M in THF) was added to a solution of silylated compound **95** (38.6 mg, 26.4 μmol) in THF (5 mL) at 0 °C. After being stirred for 10 days at 0 °C, with addition of TBAF (53 μL, 53 μmol) every 24 h, the reaction mixture was diluted with EtOAc (75 mL) and washed with saturated aqueous $NaHCO_3$ (25 mL) and brine (25 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography ($CHCl_3$/MeOH 92:8 to 85:15) to provide methyl glycoside **13** (15.4 mg, 60%): white amorphous solid; $[\alpha]^{25}_D$ −33.6° (*c* 0.35, $CHCl_3$); IR ($CHCl_3$) ν_{max} 3550, 3020, 2930, 2850, 1725, 1675, 1460, 1415, 1375, 1320, 1240, 1100, 1070, 990, 920 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 6.25 (b, 1 H, NH-O), 5.75 (d, 1 H, J = 1.3 Hz, D-1), 5.43 (m, 1 H, E-1), 5.06 (dd, 1 H, J = 10.0, 1.7 Hz, B-1), 4.49 (m, 1 H, D-2), 4.33 (m, 1 H, B-3), 4.23 (d, 1 H, J = 7.7 Hz, A-1), 4.21 (dq, 1 H, J = 9.7, 6.2 Hz, D-5), 4.08 (dq, 1 H, J = 10.7, 6.2 Hz, B-5), 4.01 (app t, 1 H, J = 9.7 Hz, A-3), 3.90 (s, 3 H, $ArOCH_3$), 3.85 (s, 3 H, $ArOCH_3$), 3.85 (dd, 1 H, J = 8.9, 3.5 Hz, B-4), 3.78−3.72 (m, 3 H, D-3, E-5_{eq}, E-5_{ax}), 3.66 (dq, 1 H, J = 9.3, 6.2 Hz, A-5), 3.65 (app t, 1 H, J = 9.6 Hz, D-4), 3.59 (s, 3 H, OCH_3), 3.53 (s, 3 H, OCH_3), 3.52−3.48, (m, 1 H, E-3), 3.50 (dd, 1 H, J = 9.4, 7.7 Hz, A-2), 3.39 (s, 3 H, OCH_3), 2.72−2.60 (m, 3 H, E-4, CH_2N), 2.37 (s, 3 H, $ArCH_3$), 2.35 (app t, 1 H, J = 9.8 Hz, A-4), 2.34−2.29 (m, 1 H, E-2_{eq}), 2.04 (b d, 1 H, J = 13.3 Hz, B-2_{eq}), 1.79 (ddd, 1 H, J = 13.3, 10.0, 2.8 Hz, B-2_{ax}), 1.65−1.55 (m, 1 H, E-2_{ax}), 1.43 (d, 3 H, J = 6.2 Hz, B-6), 1.35 (d, 3 H, J = 6.2 Hz, A-6), 1.32 (d, 3 H, J = 6.2 Hz, D-6), 1.13 (app t, 3 H, J = 7.1 Hz, CH_3-CH_2N); ^{13}C NMR (125 MHz, $CDCl_3$) δ 192.0, 151.6, 150.7, 143.0, 133.4, 130.3, 102.7, 102.6, 99.8, 98.3, 93.5, 80.9, 78.3, 77.2, 76.3, 71.1, 70.5, 69.0, 68.41, 68.36, 68.2, 67.1, 61.7, 60.9, 59.1, 57.2, 56.8, 56.1, 51.7, 41.9, 36.9, 33.9, 30.3, 29.7, 25.3, 19.0, 17.7, 17.6, 15.1; FAB HRMS for $C_{38}H_{62}N_2IO_{17}S$ (M + H), calcd 977.2814, found 977.2878.

Methyl 6-Deoxy-2-*O*-[1,1-dimethylethyl)dimethylsilyl]-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (96). A solution of *tert*-butyldimethylsilyl chloride (95 mg) in DMF (2.0 mL) was added to a solution of **47** (175 mg) and Et_3N (250 μL) in DMF (5.0 mL) at 0 °C. The mixture was stirred for 2 h at 0 °C, followed by 3 h at room temperature. The mixture was added to 30 mL of EtOAc and washed with 15 mL of saturated aqueous $NaHCO_3$ and 3 × 10 mL of H_2O. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 7:3) to give 140 mg (58%) of **96**: $[\alpha]^{25}_D$ −13.0° (*c* 1.055, $CHCl_3$); IR ($CHCl_3$) 3640, 3020, 2960, 2930, 1610, 1515, 1250, 1080 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.34−7.28 (m, 2 H, ArH), 6.94−6.85 (m, 2 H, ArH), 4.60 (AB, 2 H, J = 11.2 Hz, $\Delta\nu$ = 14.6 Hz, $ArCH_2$), 4.06 (d, 1 H, J = 7.6 Hz, H-1), 3.73 (s, 3 H, $ArOCH_3$), 3.69−3.65 (m, 1 H, H-4), 3.62 (dd, 1 H, J = 9.3, 7.6 Hz, H-2), 3.52 (dq, 1 H, J = 6.4, 1.1 Hz, H-5), 3.49 (s, 3 H, OCH_3), 3.35 (dd, 1 H, J = 9.3, 3.4 Hz, H-3), 2.30 (bs, 1 H, OH), 1.38 (d, 3 H, J = 6.4 Hz, 3 H-6), 0.94 (s, 9 H, CMe_3), 0.11 (s, 3 H, $SiCH_3$), 0.10 (s, 3 H, $SiCH_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 159.2, 129.9, 129.6, 113.7, 104.6, 81.8, 71.7, 71.6, 69.7, 69.0, 56.6, 55.1, 25.8, 18.2, 16.3, −4.6, −4.7.

Methyl 6-Deoxy-2-*O*-[1,1-dimethylethyl)dimethylsilyl]-3-*O*-[(4-methoxyphenyl)methyl]-4-*O*-(trifluoromethanesulfonyl)-β-D-galactopyranoside (97). Trifluoromethanesulfonic anhydride (65 μL) was added to a solution of **96** (140 mg) and pyridine (80 μL) in CH_2Cl_2 (5 mL) at 0 °C. After 1 h, the mixture was warmed to room temperature, added to 25 mL of CH_2Cl_2, and washed with 2 × 10 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 8:2) to give 185 mg (100%) of **97**: ^1H NMR (250 MHz, $CDCl_3$) δ 7.26−7.19 (m, 2 H, ArH), 6.81−6.75 (m, 2 H, ArH), 4.81 (d, 1 H, J = 2.7 Hz, H-4), 4.55 (AB, 2 H, J = 11.2 Hz, $\Delta\nu$ = 53.9 Hz, $ArCH_2$), 4.02 (d, 1 H, J = 7.4 Hz, H-1), 3.72 (s, 3 H, $ArOCH_3$), 3.61 (q, 1 H, J = 6.4 Hz, H-5), 3.58 (dd, 1 H, J = 9.5, 7.5 Hz, H-2), 3.41 (s, 3 H, OCH_3), 3.34 (dd, 1 H, J = 9.5 , 2.8 Hz, H-3), 1.26 (d, 3 H, J = 6.5 Hz, 3 H-6), 0.79 (s, 9 H, CMe_3), −0.01 (s, 3 H, $SiCH_3$), −0.05 (s, 3 H, $SiCH_3$).

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl)]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-[(4-methoxyphenyl)methyl]-β-D-glucopyranoside (98). Sodium hydride (60% dispersion in mineral oil, 25 mg) was added to a solution of carbamate **50** (353 mg) in DMF (4.0 mL) at 0 °C. The mixture was warmed to room temperature for 30 min and then cooled to 0 °C. A solution of triflate **97** (185 mg) in DMF (3.0 mL) was

added dropwise, and the mixture was stirred at 0 °C for 30 min. The reaction mixture was quenched by the slow addition of 300 μL of AcOH at 0 °C. The resulting mixture was added to 50 mL of EtOAc and washed with 20 mL of saturated aqueous NH_4Cl, 3 × 20 mL H_2O, and 20 mL of saturated aqueous NaCl. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 9:1) to provide 352 mg (74%) of **98**: $[\alpha]^{25}_D$ −17.6° (*c* 1.145, $CHCl_3$); IR ($CHCl_3$) 3020, 2960, 2930, 1690, 1510, 1460, 1255, 1090 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 7.28−7.19 (m, 2 H), 6.95−6.88 (m, 2 H), 5.37 (d, 1 H, *J* = 2.0 Hz), 5.21−5.12 (m, 1 H), 4.83−4.75 (m, 1 H), 4.75−4.66 (m, 1 H), 4.47 (t, 1 H, *J* = 2.0 Hz), 4.32 (bs, 1 H), 4.22−4.08 (m, 4 H), 4.05−3.95 (m, 1 H), 3.93−3.87 (m, 1 H), 3.88 (s, 3 H), 3.85−3.76 (m, 1 H), 3.81 (s, 3 H), 3.79 (s, 3 H), 3.71 (t, 1 H, *J* = 9.0 Hz), 3.58−3.50 (m, 3 H), 3.50 (s, 3 H), 3.41 (s, 3 H), 2.43−2.35 (m, 1 H), 2.36 (s, 3 H), 1.93−1.85 (m, 1 H), 1.50−1.42 (m, 3 H), 1.35−1.28 (m, 3 H), 1.25 (d, 3 H, *J* = 6.2 Hz), 1.05−0.95 (m, 2 H), 0.92 (s, 9 H), 0.90 (s, 18 H), 0.22−0.08 (m, 18 H), 0.05 (s, 9 H); FAB HRMS for $C_{68}H_{122}INO_{18}SSi_5Na$ (M + Na^+), calcd 1562.6170, found 1562.6184.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl)]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[(1,1-dimethylethyl)dimethylsilyl]-β-D-glucopyranoside (99). A mixture of **98** (267 mg), DDQ (50 mg), H_2O (0.5 mL), and CH_2Cl_2 (6 mL) was vigorously stirred at room temperature for 18 h. The mixture was added to 50 mL of CH_2Cl_2 and washed with 20 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 9:1) to give 217 mg (88%) of **99**: $[\alpha]^{25}_D$ −16.6° (*c* 1.16, $CHCl_3$); IR ($CHCl_3$) 3500, 3020, 2960, 2935, 1720, 1680, 1460, 1390, 1255, 1090, 845 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 5.38 (d, 1 H, *J* = 2.0 Hz), 5.31−5.21 (m, 1 H), 4.47 (t, 1 H, *J* = 2.0 Hz), 4.32 (m, 1 H), 4.29−4.20 (m, 2 H), 4.19−4.14 (m, 1 H), 4.16 (d, 1 H, *J* = 7.6 Hz), 4.13−4.05 (m, 1 H), 3.93−3.86 (m, 1 H), 3.87 (s, 3 H), 3.85−3.76 (m, 2 H), 3.81 (s, 3 H), 3.71 (t, 1 H, *J* = 9.3 Hz), 3.70−3.64 (m, 1 H), 3.54 (dd, 1 H, *J* = 9.3, 2.9 Hz), 3.52 (s, 3 H), 3.46 (dd, 1 H, *J* = 9.1, 7.4 Hz), 3.41 (s, 3 H), 2.38 (s, 3 H), 2.22−2.12 (m, 1 H), 1.83−1.74 (m, 1 H), 1.41 (d, 3 H, *J* = 6.2 Hz), 1.25 (d, 3 H, *J* = 6.3 Hz), 1.24−1.20 (m, 3 H), 1.05−0.95 (m, 2 H), 0.94 (s, 9 H), 0.92 (s, 18 H), 0.22−0.10 (m, 18 H), 0.08 (s, 9 H); FAB HRMS for $C_{60}H_{114}INO_{17}SSi_5Na$ (M + Na^+), calcd 1441.5595, found 1441.5696.

Methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-β-D-*ribo*-hexopyranosyl)oxy]amino}-β-D-glucopyranoside (100). Tetrabutylammonium fluoride (1.0 M in THF, 600 μL) was added to a solution of **99** (87.1 mg) in THF (3.0 mL) at 0 °C. After being stirred for 72 h at 0 °C, the reaction was quenched by the addition of 1 mL of saturated aqueous NH_4Cl. The mixture was added to 25 mL of EtOAc and washed with 20 mL of saturated aqueous NH_4Cl. The aqueous phase was reextracted with 10 mL of EtOAc. The combined organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel ($CHCl_3$/MeOH 95:5 to 90:10) to provide 23.4 mg (47%) of **100**: $[\alpha]^{25}_D$ −28.1° (*c* 0.595, $CHCl_3$), IR ($CHCl_3$) 3590, 3020, 1675, 1455, 1415, 1330, 1070, 925 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 5.73 (d, 1 H, *J* = 1.5 Hz, H-1D), 5.07 (dd, 1 H, *J* = 10.2, 1.9 Hz, H-1B), 4.48 (dd, 1 H, *J* = 3.2, 1.7 Hz, H-2D), 4.32 (m, 1 H, H-3B), 4.22 (d, 1 H, *J* = 7.7 Hz, H-1A), 4.20 (dq, 1 H, *J* = 9.6, 6.3 Hz, H-5B), 4.08 (dq, 1 H, *J* = 10.8, 6.3 Hz, H-5D), 3.95 (t, 1 H, *J* = 9.6 Hz, H-3A), 3.89 (s, 3 H, $ArOCH_3$), 3.85 (s, 3 H, $ArOCH_3$), 3.84 (dd, 1 H, *J* = 9.2, 3.3 Hz, H-4B), 3.74 (dd, 1 H, *J* = 10.7, 2.7 Hz, H-3D), 3.72 (dq, 1 H, *J* = 9.6, 6.2 Hz, H-5A), 3.65 (t, 1 H, *J* = 9.4 Hz, H-4D), 3.70−3.60 (m, 1 H, OH), 3.58 (s, 3 H, OCH_3), 3.57 (s, 3 H, OCH_3), 3.44 (dd, 1 H, *J* = 9.4, 7.7 Hz, H-2A), 2.50−2.20 (m, 3 H, 3 OH), 2.40 (t, 1 H, *J* = 9.7 Hz, H-4A), 2.37 (s, 3 H, $ArCH_3$), 2.04 (ddd, 1 H, *J* = 13.5, 3.3, 2.1 Hz, H-2B_{eq}), 1.79 (ddd, 1 H, *J* = 13.3, 10.2, 3.0 Hz, H-2B_{ax}), 1.43 (d, 3 H, *J* = 6.3 Hz, 3 H-6B), 1.38 (d, 3 H, *J* = 6.2 Hz, 3 H-6A), 1.31 (d, 3 H, *J* = 6.2 Hz, 3 H-6D); ^{13}C NMR (490 MHz, $CDCl_3$) δ 191.8, 151.5, 150.6, 143.0, 133.4, 130.3, 103.4, 102.6, 99.8, 93.5, 80.9, 74.5, 71.1, 70.4, 69.9, 69.0, 68.9, 68.3, 67.7, 67.0, 61.7, 60.9, 57.2, 57.0, 51.8, 36.8, 25.3, 19.1, 17.7, 17.6; FAB HRMS for $C_{30}H_{47}INO_{15}S$ (M + H^+), calcd 820.1711, found 820.1746.

(4-Methoxyphenyl)methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl)]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)dimethylsilyl]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl]-3-*O*-[(4-methoxyphenyl)methyl]-β-D-glucopyranoside (101). Sodium hydride (40 mg, 0.65 mmol, 60% dispersion in mineral oil) was added to a solution of carbamate **91** (412 mg, 0.36 mmol) in DMF (5 mL) at 0 °C. The reaction mixture was warmed to room temperature, stirred 30 min at room temperature, and cooled to 0 °C. A solution of triflate **61** (260 mg, 0.33 mmol) in DMF (5 mL) was added via cannula. After being stirred at 0 °C for 10 min, the reaction mixture was quenched by syringe pump addition of acetic acid (500 μL) over 10 min, diluted with EtOAc (300 mL), and washed with saturated aqueous NH_4Cl (100 mL), brine (100 mL), saturated aqueous $NaHCO_3$ (100 mL), and brine (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 80:20 to 60:40) to provide aryltetrasaccharide **101** (476 mg, 81%): $[\alpha]^{25}_D$ −39.1° (*c* 1.805, $CHCl_3$); IR ($CHCl_3$) 3020, 2960, 1715, 1680, 1610, 1515, 1460, 1390, 1255 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$) δ 7.88−7.84 (m, 2 H), 7.78−7.73 (m, 2 H), 7.36−7.31 (m, 2 H), 7.28−7.20 (m, 2 H), 6.88−6.82 (m, 2 H), 6.71−6.66 (m, 2 H), 5.44−5.35 (m, 1 H), 5.37 (d, 1 H, *J* = 1.6 Hz), 5.24−5.15 (m, 1 H), 4.74 (AB, 2 H, *J* = 11.4 Hz, Δν = 123.6 Hz), 4.83−4.77 (m, 1 H), 4.69−4.58 (m, 2 H), 4.55−4.46 (m, 3 H), 4.35 (bs, 1 H), 4.29−4.12 (m, 5 H), 4.08−4.00 (m, 1 H), 3.88 (s, 3 H), 3.82 (s, 3 H), 3.80 (s, 3 H), 3.87−3.75 (m, 3 H), 3.71 (t, 1 H, *J* = 9.0 Hz), 3.70−3.65 (m, 1 H), 3.61 (s, 3 H), 3.53 (dd, 1 H, *J* = 9.0, 2.9 Hz), 3.42 (s, 3 H), 3.23 (s, 3 H), 3.25−3.20 (m, 1 H), 2.37 (s, 3 H), 2.38−2.35 (m, 1 H), 2.30−2.20 (m, 1 H), 1.98−1.88 (m, 1 H), 1.65−1.55 (m, 2 H), 1.48 (m, 3 H), 1.35 (m, 3 H), 1.24 (d, 3 H, *J* = 6.2 Hz), 0.93 (s, 9 H), 0.91 (s, 18 H), 1.00−0.90 (m, 2 H), 0.16 (s, 6 H), 0.14 (s, 6 H), 0.12 (s, 3 H), 0.10 (s, 3 H), 0.04 (s, 9 H); FAB HRMS for $C_{83}H_{127}IN_2O_{23}SSi_4Na$ (M + Na^+), calcd 1813.6568, found 1813.6833.

4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)-dimethylsilyl]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl]-D-glucopyranose (102). DDQ (207 mg, 0.9 mmol) was added to a solution of diPMB ether **101** (326 mg, 182 μmol) in CH_2Cl_2/H_2O (20:1, 9 mL). After being stirred at room temperature for 16 h, the reaction mixture was diluted with EtOAc (200 mL) and washed with saturated aqueous $NaHCO_3$ (3 × 70 mL) and brine (70 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 60:40 to 50:50) to provide **102** (265 mg, 94%): white amorphous solid; $[\alpha]^{25}_D$ −16.3° (*c* 1.285, $CHCl_3$); IR ($CHCl_3$) 3500, 3010, 2945, 2925, 1710, 1675, 1455, 1390, 1255, 1090, 840 cm^{-1}; ^1H HMR (490 MHz, $CDCl_3$) δ 7.88−7.82 (m), 7.75−7.70 (m), 5.65 (bs), 5.53 (m), 5.37 (d, *J* = 1.6 Hz), 5.35−5.25 (br m), 5.31 (d, *J* = 3.6 Hz), 4.79 (dd, *J* = 7.5, 4.9 Hz), 4.67 (t, *J* = 11.1 Hz), 4.64−4.56 (m), 4.46 (t, *J* = 2.4 Hz), 4.40 (t, *J* = 10.8 Hz), 4.37−4.29 (m), 4.28−4.21 (m), 4.16 (dq, *J* = 9.5, 6.5 Hz), 4.17−4.09 (m), 3.87 (s), 3.88−3.79 (m), 3.81 (s), 3.70 (t, *J* = 9.5 Hz), 3.67−3.56 (m), 3.53 (dd, *J* = 9.1, 2.6 Hz), 3.41 (s), 3.28 (s), 3.27 (s), 2.57 (dd, *J* = 13.1, 4.9 Hz), 2.51 (dd, *J* = 12.7, 4.9 Hz), 2.36 (s), 2.35 (s), 2.21−2.09 (m), 1.88−1.79 (m), 1.66−1.60 (m), 1.45 (d, *J* = 6.2 Hz), 1.23 (d, *J* = 6.2 Hz), 1.18 (d, *J* = 6.2 Hz), 1.12−1.03 (m), 0.92 (s), 0.90 (s), 0.21−0.09 (m), 0.06 (s); FAB HRMS for $C_{83}H_{127}IN_2O_{23}SSi_4Na$ (M + Na^+), calcd 1813.6568, found 1813.6833.

4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-2,4-*O*,*O*-bis[(1,1-dimethylethyl)dimethylsilyl]-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-[(1,1-dimethylethyl)-dimethylsilyl]-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-[2,4-dideoxy-3-*O*-methyl-4-phthalimido-α-L-*threo*-pentopyranosyl]-α-D-glucopyranosyl Trichloroacetimidate (103). A solution of **102** (32.4 mg), DBU (10 μL), and trichloroacetonitrile (50 μL) in CH_2Cl_2 (3.0 mL) was stirred at room temperature for 24 h. The solution was concentrated to 0.5 mL total volume and chromatographed on silica gel (hexane/EtOAc 9:1 to 7:3)

to give 17.6 mg (50%) of **103** along with 5.2 mg (15%) of the faster-eluting β anomer. **103**: ^{1}H NMR (490 MHz, $CDCl_3$) δ 8.96 (s, 1 H, NH), 7.88−7.82 (m, 2 H, ArH), 7.75−7.69 (m, 2 H, ArH), 6.48 (d, 1 H, J = 3.6 Hz, H-1A), 5.48 (d, 1 H, J = 2.9 Hz, H-1E), 5.38 (d, 1 H, J = 2.0 Hz, H-1D), 5.40−5.30 (m, 1 H, H-1B), 4.54 (dt, 1 H, J = 11.1, 4.6 Hz, H-4E), 4.47 (t, 1 H, J = 2.0 Hz, H-2D), 4.50−4.43 (m, 1 H), 4.40−4.34 (m, 2 H), 4.33−4.21 (m, 3 H), 4.20−4.06 (m, 2 H), 3.98 (dd, 1 H, J = 10.6, 3.9 Hz), 3.94−3.80 (m, 3 H), 3.88 (s, 3 H, $ArOCH_3$), 3.82 (s, 3 H, $ArOCH_3$), 3.71 (t, 1 H, J = 9.0 Hz, H-4D), 3.58 (dd, 1 H, J = 10.1, 4.7 Hz, H-4B), 3.54 (dd, 1 H, J = 9.0, 2.4 Hz, H-3D), 3.42 (s, 3 H, OCH_3), 3.24 (s, 3 H, OCH_3), 2.56−2.51 (m, 1 H, H-$2E_{eq}$), 2.38 (s, 3 H, $ArCH_3$), 2.20−2.02 (m, 1 H, H-$2B_{eq}$), 1.83 −1.76 (m, 1 H, H-$2B_{ax}$), 1.65−1.55 (m, 1 H, H-$2E_{ax}$), 1.48 (d, 3 H, J = 6.2 Hz, 3 H-6B), 1.28 (d, 3 H, J = 6.2 Hz, 3 H-6A), 1.20 (d, 3 H, J = 6.1 Hz, 3 H-6D), 1.14−1.09 (m, 2 H, CH_2Si), 0.93 (s, 18 H, 2 Si-*t*-Bu), 0.92 (s, 9 H, Si-*t*-Bu), 0.20−0.10 (m, 18 H, 6 $SiCH_3$), 0.08 (s, 9 H, $SiMe_3$).

Glycoside 105. Imidate **103** (5.9 mg) and azide (−)-**104** (6.0 mg) were combined and dried by coevaporating with benzene. Diethyl ether (0.5 mL) and CH_2Cl_2 (0.3 mL) were added along with 4 Å molecular sieves, and the mixture was stirred at room temperature for 30 min. The mixture was cooled to −78 °C, and a solution of $BF_3{\cdot}Et_2O$ in Et_2O (10 μL, 0.1 M) was added. The mixture was stirred at −78 °C for 20 min, after which the reaction was quenched by adding 1 mL of saturated aqueous $NaHCO_3$, followed by warming to room temperature. The mixture was added to 15 mL of CH_2Cl_2 and washed with 3 × 5 mL of saturated aqueous $NaHCO_3$. The organics were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (hexane/EtOAc 7:3 to 1:1) to give 1.8 mg (28%) of **105** along with the corresponding α anomer (3:1). **105:** ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.90−7.60 (m, ArH), 6.05 (d, J = 1.0 Hz, aglycon propargylic CH), 5.58 (dd, J = 9.6, 1.1 Hz, aglycon C=CH), 5.55−5.50 (m), 5.35 (d, J = 9.6 Hz, aglycon C=CH), 5.38−5.28 (m), 5.15−5.00 (m), 4.67 (d, J = 7.9 Hz, H-1A), 4.53 (t, J = 11.6 Hz), 4.46 (m), 4.39−4.34 (m), 4.32−4.09 (m), 3.87 (s, $ArOCH_3$), 3.80 (s, $ArOCH_3$), 3.79−3.68 (m), 3.70 (t, J = 10.0 Hz), 3.58−3.50 (m), 3.41 (s, OCH_3), 3.37 (s, OCH_3), 2.75 (app d, J = 14.6 Hz, one of aglycon CH_2), 2.75−2.58 (m), 2.35 (s, $ArCH_3$), 2.28 (app d, J = 14.6 Hz, one of aglycon CH_2), 2.15−1.95 (m), 1.42 (d, J = 6.5 Hz, 3 × H-6B), 1.23 (app d, J = 6.3 Hz, 3 × H-6A and 3 × H-6D), 1.20−1.10 (m, CH_2Si), 0.90 (s, 2 × $SiCMe_3$), 0.88 (s, $SiCMe_3$), 0.18−0.10 (m, s × $SiMe_3$), 0.04 (s, $SiMe_3$).

Methyl 4-Azido-2,4-dideoxy-3-*O*-methyl-α-L-*threo*-pentopyranoside (107). Sodium azide (19.5 g, 298 mmol) was added to a solution of mesylate **106** (35.95 g, 149 mmol) in DMSO at room temperature. After being stirred for 12 h at 100 °C, the reaction mixture was cooled to room temperature, diluted with ether (500 mL), and washed with brine (3 × 200 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/ether 80:20 to 70:30) to provide volatile azide **107** (26.58 g, 95%): colorless oil; $[\alpha]^{25}_D$ −174.4° (*c* 2.43, $CHCl_3$); FT-IR (MIDAC, $CHCl_3$) ν_{max} 3012, 2938, 2911, 2836, 2109, 1464, 1444, 1374, 1264, 1143, 1128, 1105, 1051, 998, 969, 948, 902 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 4.77 (dd, 1 H, J = 3.5, 1.8 Hz, H-1), 3.69−3.63 (m, 1 H, H-5), 3.58−3.53 (m, 1 H, H-3), 3.47−3.38 (m, 2 H, H-4, H-5′), 3.43 (s, 3 H, OCH_3), 3.32 (s, 3 H, OCH_3), 2.24 (ddd, 1 H, J = 13.1, 4.8, 1.8 Hz, H-2_{eq}), 1.55 (ddd, 1 H, J = 13.1, 10.8, 3.5 Hz, H-2_{ax}); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 98.6, 76.8, 61.2, 60.1, 56.5, 54.6, 34.4. Anal. Calcd for $C_7H_{13}N_3O_3$: C, 44.91; H, 7.00; N, 22.45. Found: C, 45.20; H, 7.12; N, 22.51.

Methyl 4-Acetamido-2,4-dideoxy-3-*O*-methyl-α-L-*threo*-pentopyranoside (108). A solution of azide **107** (10 g, 53.4 mmol) in EtOAc (100 mL) was stirred for 30 min at room temperature under 1 atm of H_2. Acetic anhydride (25 mL, 267 mmol) and 10% Pd/C (3 g) were added. After the mixture was stirred for 48 h at room temperature under 1 atm of H_2, Celite was added, and the reaction mixture was filtered through Celite. The filtering pad was rinsed with hot MeOH, and the combined filtrates were concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 50:50 to 0:100, then $CHCl_3$/MeOH 95:5 to 90:10 to provide acetamide **108** (9.77 g, 90%); white needles; mp 113−114 °C; $[\alpha]^{25}_D$ −69.6° (*c* 2.89, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3437, 3010, 2937, 1671, 1510, 1370, 1252, 1147, 1128, 1096, 1048, 1035 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 5.78 (b s, 1 H, NH), 4.65 (dd, 1 H, J = 6.3, 2.9 Hz, H-1), 3.97 (dd, 1 H, J = 11.6, 3.4 Hz, H-5_{eq}), 3.93 (m, 1 H, H-4), 3.55 (m, 2 H, H-5_{ax}, H-3), 3.42 (s, 3 H, OCH_3), 3.38 (s, 3 H, OCH_3), 1.99 (s, 3 H, Ac), 1.88 (ddd, 1 H, J = 13.7, 6.3, 3.9 Hz, H-2_{ax}), 1.80 (ddd, 1 H, J = 13.7, 6.25, 2.9 Hz, H-2_{eq}); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 169.9, 99.1, 75.1, 62.2, 56.0, 55.2, 48.3, 33.1, 23.0; FAB HRMS for $C_9H_{18}NO_4$ (M + H), calcd 204.1236, found 204.1239. Anal. Calcd for $C_9H_{17}NO_4$: C, 53.19; H, 8.43; N, 6.89. Found: C, 53.18; H, 8.64; N, 6.86.

Methyl 2,4-Dideoxy-4-(ethylamino)-α-L-*threo*-pentopyranoside (109). Lithium aluminum hydride (3.1 g, 81 mmol) was added in three portions over 30 min to a solution of acetamide **108** (5.49 g, 27 mmol) in dry ether (270 mL) at room temperature. After completion of the addition, the reaction mixture was refluxed for 24 h, cooled to room temperature, and quenched with EtOAc until effervescence subsided. The aluminate salts were then precipitated by sequential addition of water (3.2 mL), 15% aqueous NaOH (3.1 mL), and water (9.3 mL). After being stirred at room temperature for 45 min, the white precipitate was filtered and rinsed with EtOAc. The combined filtrates were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (EtOAc/MeOH 100:0 to 80:20) to provide ethylamine **109** (4.58, 90%): colorless oil; $[\alpha]^{25}_D$ −57.1° (*c* 2.26, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3670, 3300, 2969, 2937, 2834, 1466, 1445, 1376, 1127, 1097, 1051, 991, 957, 900 cm^{-1}; ^{1}H NMR (490 MHz, $CDCl_3$) δ 4.79 (dd, 1 H, J = 3.5, 2.2 Hz, H-1), 3.74 (dd, 1 H, J = 11.1, 4.7 Hz, H-5_{eq}), 3.48−3.43 (m, 2 H, H-3, H-5_{ax}), 3.35 (s, 3 H, OCH_3), 3.32 (s, 3 H, OCH_3), 2.66 (m, 1 H, H-4), 2.65 (AB of ABX_3, 2 H, J = 11.1, 7.2, 7.2 Hz, $\Delta\nu$ = 38 Hz, CH_2N), 2.20 (ddd, 1 H, J = 12.9, 4.6, 2.2 Hz, H-2_{eq}), 2.02 (b s, 1 H, NH), 1.52 (ddd, 1 H, J = 12.9, 10.5, 3.5 Hz, H-2_{ax}), 1.12 (dd, 3 H, J = 7.2, 7.2 Hz, CH_3-CH_2N); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 98.9, 76.6, 61.6, 58.8, 55.9, 54.4, 41.8, 33.6, 15.3; FAB HRMS for $C_9H_{20}NO_3$ (M + H), calcd 190.1443, found 190.1449.

Methyl 2,4-Dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)-amino]-3-*O*-methyl-α-L-*threo*-pentopyranoside (110). A solution of K_2CO_3 (10 g, 72.6 mmol) in water (100 mL) was added to a stirring solution of ethylamine **109** (4.58 g, 24.2 mmol) in THF (200 mL) at room temperature. The reaction mixture was cooled to 0 °C, and 9-fluorenylmethyl chloroformate (9.4 g, 36.3 mmol) was added in three portions over 30 min. After being stirred at 0 °C for 10 more minutes, the reaction mixture was warmed slowly to 10 °C in the course of 1 h. The layers were separated, and the aqueous layer was extracted with EtOAc (3 × 50 mL). The combined organic extracts were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/ether 50:50 to 20:80) to provide carbamate **110** (9.48 g, 95%): colorless syrup; $[\alpha]^{25}_D$ −61.2° (*c* 2.32, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3023, 3011, 2937, 2835, 1692, 1452, 1424, 1277, 1193, 1139, 1128, 1049 cm^{-1}; ^{1}H NMR (490 MHz, DMSO-d_6, 140 °C) δ 7.83 (d, 2 H, J = 7.5 Hz, ArH), 7.63 (d, 2 H, J = 7.5 Hz, ArH), 7.39 (dd, 2 H, J = 7.5, 7.5 Hz, ArH), 7.31 (dd, 2 H, J = 7.5, 7.5 Hz, ArH), 4.73 (dd, 1 H, J = 3.3, 1.6 Hz, H-1), 4.47 (AB of ABX, 2 H, J = 10.8, 6.1, 6.0 Hz, $\Delta\nu$ = 17.6 Hz, OCH_2 (FMOC)) 4.27 (dd, 1 H, J = 6.1, 6.0 Hz, CH (FMOC)), 3.81 (ddd, 1 H, J = 10.1, 10.1, 4.9 Hz, H-3), 3.66 (dd, 1 H, J = 10.5, 10.1 Hz, H-5_{ax}), 3.57 (ddd, 1 H, J = 10.1, 10.1, 4.7 Hz, H-4), 3.65 (dd, 1 H, J = 10.5, 4.7 Hz, H-5_{eq}), 3.26 (s, 3 H, OCH_3), 3.17 (s, 3 H, OCH_3), 3.09 (AB of ABX_3, 2 H, J = 14.5, 7.0, 7.0 Hz, $\Delta\nu$ = 36.2 Hz, CH_2N), 2.19 (ddd, 1 H, J = 13.1, 4.9, 1.6 Hz, H-2_{eq}), 1.41 (ddd, 1 H, J = 13.1, 10.1, 3.3 Hz, H-2_{ax}), 0.94 (dd, 3 H, J = 7.0, 7.0 Hz, CH_3-CH_2N); ^{13}C NMR (125 MHz, DMSO-d_6, 140 °C) δ 154.5, 143.4, 140.3, 126.6, 126.1, 123.9, 119.0 97.8, 71.3, 65.5, 58.7, 58.0, 54.2, 53.33, 53.3, 46.6, 34.4, 13.5; FAB HRMS for $C_{24}H_{29}NO_5Na$ (M + Na), calcd 434.1943, found 434.1958. Anal. Calcd for $C_{24}H_{29}NO_5$: C, 70.05; H, 7.10; N, 3.40. Found: C, 69.81; H, 7.23; N, 3.36.

Phenyl 2,4-Dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)-amino]-3-*O*-methyl-1-thio-α-L-*threo*-pentopyranoside (111α) and Phenyl 2,4-Dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)-amino]-3-*O*-methyl-1-thio-β-L-*threo*-pentopyranoside (111β). Thiophenol (7.1 mL, 68.6 mmol) and boron trifluoride etherate (4.25 mL, 34.3 mmol) were added sequentially to a solution of methyl glycoside **110** (9.40 g, 22.9 mmol) in CH_2Cl_2 (200 mL) at −20 °C. After being stirred at −20 °C for 1 h, the reaction mixture was warmed slowly to room

temperature over the course of 1 h and quenched with saturated aqueous $NaHCO_3$. The mixture was diluted with EtOAc (400 mL) and washed with saturated aqueous $NaHCO_3$ (200 mL) and brine (200 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 80:20 to 65:35) to provide phenyl thioglycosides **111α** (5.28 g, 47%) and **111β** (5.37 g, 48%). **111α**SPCLN white amorphous solid; $[\alpha]^{25}_D$ −173.2° (*c* 2.15, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3066, 3031, 3010, 1692, 1479, 1451, 1424, 1277, 1198, 1154, 1137, 1108, 1048, 1011 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 130 °C) δ 7.83 (d, 2 H, *J* = 7.6 Hz, ArH (FMOC)), 7.64 (d, 2 H, *J* = 7.6 Hz, ArH (FMOC)), 7.44−7.42 (m, 2 H, ArH (SPh_{ortho})), 7.39 (dd, 2 H, *J* = 7.6, 7.6 Hz, ArH (FMOC)), 7.34−7.30 (m, 4 H, ArH (FMOC, SPh_{meta})), 7.28−7.24 (m, 1 H, ArH (SPh_{para})), 5.65 (dd, 1 H, *J* = 5.3, 2.3 Hz, H-1), 4.50 (d, 2 H, *J* = 5.8 Hz, OCH_2 (FMOC)), 4.29 (t, 1 H, *J* = 5.8 Hz, CH (FMOC)), 4.11 (dd, 1 H, *J* = 11.2, 10.0 Hz, H-5_{ax}), 3.83 (ddd, 1 H, *J* = 10.4, 9.9, 4.6 Hz, H-3), 3.58 (ddd, 1 H, *J* = 10.0, 9.9, 5.1 Hz, H-4), 3.49 (dd, 1 H, *J* = 11.2, 5.1 Hz, H-5_{eq}), 3.21 (s, 3 H, OCH_3), 3.14 (AB of ABX_3, 2 H, *J* = 14.2, 7.0, 7.0 Hz, Δν = 36 Hz, CH_2N), 2.40 (ddd, 1 H, *J* = 13.5, 4.6, 2.3 Hz, H-2_{eq}), 1.86 (ddd, 1 H, *J* = 13.5, 10.4, 5.3 Hz, H-2_{ax}), 0.96 (dd, 3 H, *J* = 7.0, 7.0 Hz, CH_3-CH_2N); ^{13}C NMR (125 MHz, DMSO-d_6, 120 °C) δ 154.3, 143.4, 140.3, 133.9, 130.3, 128.2, 126,8, 126.3, 126.2, 124.0, 119.2, 83.1, 72.0, 65.6, 60.0, 58.0, 54.7, 46.6, 35.2, 13.7; FAB HRMS for $C_{29}H_{32}NO_4S$ (M + H), calcd 490.2052, found 490.2082. Anal. Calcd for $C_{29}H_{31}NO_4S$: C, 71.14; H, 6.38; N, 2.86; S, 6.55. Found: C 71.07; H, 6.37; N, 2.80; S, 6.47. **111β**SPCLN white amorphous solid; $[\alpha]^{25}_D$ 117.1° (*c* 3.03, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3068, 3041, 2978, 2936, 1690, 1479, 1465, 1452, 1440, 1434, 1276, 1251, 1181, 1105, 1076, 1024 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 150 °C) δ 7.76 (d, 2 H, *J* = 7.5 Hz, ArH (FMOC)), 7.41 (d, 2 H, *J* = 7.5 Hz, ArH (FMOC)), 7.62 (dd, 2 H, *J* = 7.5, 7.5 Hz, ArH (FMOC)), 7.45 (d, 2 H, *J* = 8 Hz, ArH (SPh_{ortho})), 7.37 (dd, 2 H, *J* = 7.5, 7.5 Hz ArH (FMOC)), 7.35−7.26 (m, 3 H, ArH ($SPh_{meta, para}$), 4.61 (AB of ABX, 2 H, *J* = 11.0, 4.8, 4.8 Hz, Δν = 14.4 Hz, OCH_2 (FMOC)), 4.54 (dd, 1 H, *J* = 11.3, 1.7 Hz, H-1), 4.27 (dd, 1 H, *J* = 4.8, 4.8 Hz, CH (FMOC)), 3.52 (dd, 1 H, *J* = 10.0, 3.9 Hz, H-5_{eq}), 3.34−3.31 (m, 1 H, H-3), 3.23−3.15 (m, 1 H, H-4), 3.14−3.06 (m, 1 H, H-5_{ax}), 3.11 (q, 2 H, *J* = 7.0 Hz, CH_2N), 2.21 (ddd, 1 H, *J* = 11.3, 8.9, 1.7 Hz, H-2_{eq}), 1.32 (ddd, 1 H, *J* = 11.3, 11.3, 11.3 Hz, H-2_{ax}), 0.92 (t, 3 H, *J* = 7.0 Hz, CH_3-CH_2N); ^{13}C NMR (125 MHz, DMSO-d_6, 150 °C) δ 154.3, 143.51, 143.47, 140.3, 140.2, 133.0, 130.6, 127.94, 127.90, 126.6, 126.5 126.4, 126.3, 126.2, 126.1, 123.73, 123.65, 118.95, 118.9, 81.2, 74.3, 65.7, 65.04, 65.0, 58.7, 54.7, 54.6, 46.5, 40.94, 40.9, 36.3, 13.0; FAB HRMS for $C_{29}H_{32}NO_4S$ (M + H), calcd 490.2052, found 490.2045. Anal. Calcd for $C_{29}H_{31}NO_4S$: C, 71.14; H, 6.38; N, 2.86; S, 6.55. Found: C, 70.93; H, 6.39; N, 2.82; S, 6.50.

1,5-Anhydro-2,4-dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)amino]-3-*O*-methyl-L-*threo*-pent-1-enitol (112). (i) **From 111α.** Oxone (5.6 g, 9.12 mmol) was added to a solution of sulfide **111α** (2.23 g, 4.56 mmol) in MeOH/THF/H_2O (6:2:2, 225 mL) at 0 °C. After being stirred at 0 °C for 20 min, the reaction mixture was quenched with 10% aqueous $NaHSO_3$. The mixture was diluted with EtOAc (200 mL) and washed with 10% aqueous $NaHSO_3$ (2 × 100 mL), saturated aqueous $NaHCO_3$ (100 mL), and brine (100 mL). the organic layer was dried over Na_2SO_4 and filtered. Toluene (50 mL) was added to the filtrate, and the solution was concentrated under reduced pressure until toluene started to evaporate. This solution was azeotroped twice with toluene (100 mL), leaving each time *ca.* 50 mL of toluene in the flask. Toluene (170 mL) was added to this concentrated solution, and the resulting solution was heated at 90 °C for 1 h. The reaction mixture was cooled to room temperature, diluted with EtOAc (100 mL), and washed with saturated aqueous $NaHCO_3$ (100 mL) and brine (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 80:20 to 70:30) to provide glycal **112** (1.42 g, 82%).

(ii) **From 111β.** Oxone (11.15 g, 18.12 mmol) was added to a solution of sulfide **111β** (4.43 g, 9.06 mmol) in MeOH/THF/H_2O (6:2:2, 450 mL) at 0 °C. After being stirred at 0 °C for 5 min, the reaction mixture was warmed slowly to room temperature over the course of 30 min and quenched with 10% aqueous $NaHSO_3$. Same treatment as for **111α** was then followed to provide glycal **112** (2.79 g, 82%): colorless syrup; $[\alpha]^{25}_D$ 68.66° (*c* 2.37, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3070, 3025, 3016, 2980, 2935, 2826, 1690, 1647, 1479, 1452, 1422, 1273, 1248, 1166, 1148, 1086 cm^{-1}; ^1H NMR (490 MHz, $CDCl_3$, −10 °C) δ 7.78−7.76 (m, 3 H, ArH (FMOC)), 7.73 (d, 1 H, *J* = 7.4 Hz, ArH (FMOC)), 7.60−7.55 (m, 4 H, ArH (FMOC)), 7.42−7.37 (m, 4 H, ArH (FMOC)), 7.36−7.31 (m, 4 H, ArH), 6.46 (dd, 1 H, *J* = 6.2, 0.8 Hz, H-1 (rotamer 1)), 6.18 (dd, 1 H, *J* = 6.0, 0.6 Hz, H-1 (rotamer 2)), 4.93 (dd, 1 H, *J* = 6.2, 3.4 Hz, H-2 (rotamer 1)), 4.70 (AB of ABX, 2 H, *J* = 10.6, 3.8, 3.8 Hz, Δν = 65.5 Hz, OCH_2 (FMOC, rotamer 2)), 4.55 (dd, 1 H, *J* = 6.0, 2.4 Hz, H-2 (rotamer 2)), 4.48 (AB of ABX, 2 H, *J* = 10.6, 6.4, 6.1 Hz, Δν = 14.3 Hz, OCH_2 (FMOC, rotamer 1)), 4.27−4.23 (m, 2 H, CH (FMOC, rotamer 1, rotamer 2)), 4.17 (dd, 1 H, *J* = 11.2, 7.1 Hz, H-5_{ax} (rotamer 1)), 4.05−4.02 (m, 1 H, H-4 (rotamer 1)), 3.96 (dd, 1 H, *J* = 11.2, 3.8 Hz, H-5_{eq} (rotamer 1)), 3.93−3.91 (m, 1 H, H-3 (rotamer 1)), 3.37 (dd, 1 H, *J* = 10.6, 3.9 Hz, H-5_{eq} (rotamer 2)), 3.36 (s, 3 H, OCH_3 (rotamer 1)), 3.30 (dq, 1 H, *J* = 14.2, 7.1 Hz, H-CHN (rotamer 2)), 3.22−3.19 (m, 1 H, H-4 (rotamer 2)), 3.16 (q, 2 H, *J* = 7.0 Hz, CH_2N (rotamer 1)), 3.13 (dq, 1 H, *J* = 14.2, 7.0 Hz, H-CHN (rotamer 2)), 3.07 (b d, 1 H, *J* = 7.8 Hz, H-3 (rotamer 2)), 2.88 (s, 3 H, OCH_3 (rotamer 2)), 2.84 (dd, 1 H, *J* = 10.6, 10.6 Hz, H-5_{ax} (rotamer 2)), 1.01 (dd, 3 H, *J* = 7.1, 7.0 Hz, CH_3-CH_2N (rotamer 2), 0.95 (t, 3 H, *J* = 7.0 Hz, CH_3-CH_2N (rotamer 1)); ^{13}C NMR (125 MHz, $CDCl_3$, −10 °C) δ 155.7, 155.2, 145.9, 144.4, 143.77, 143.73, 143.65, 141.3, 141.11, 141.08, 127.4, 127.3, 127.02, 126.99, 126.8, 124.61, 124.59, 124.0, 123.9, 120.1, 119.8, 100.6, 72.6, 71.4, 66.7, 66.3, 65.5, 65.4, 56.7, 56.0, 55.5, 53.9, 46.9, 46.6, 43.5, 40.5, 15.1, 13.8; FAB HRMS for $C_{23}H_{25}NO_4Na$ (M + Na), calcd 402.1681, found 402.1686.

4-[(2-*O*-Acetyl-6-deoxy-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzonitrile (113). Tetrabutylammonium fluoride (5.1 mL, 1.0 M in THF) was slowly added to a 0 °C solution of aryl glycoside **88** (1.62 g, 2.55 mmol) in THF (50 mL). After being stirred for 5 h, the solution was added to saturated aqueous $NaHCO_3$ (75 mL) and extracted with CH_2Cl_2 (3 × 50 mL). The organic layers were combined, dried ($MgSO_4$), concentrated, and purified by flash column chromatography (33 → 50% ethyl acetate in hexanes) to give **113** (1.32 g, 2.54 mmol, 99%): white amorphous solid; R_f = 0.24 (1:1 hexanes/ethyl acetate); $[\alpha]^{25}_D$ −13.8° (*c* 1.9, CH_2Cl_2); ^1H NMR (400 MHz, $CDCl_3$) δ 5.74 (d, 1 H, *J* = 1.7 Hz, H-1), 5.69 (dd, 1 H, *J* = 3.2, 1.9 Hz, H-2), 4.17 (dq, 1 H, *J* = 9.5, 6.2 Hz, H-5), 4.02 (s, 3 H, $ArOCH_3$), 3.92 (dd, 1 H, *J* = 9.6, 3.2 Hz, H-3), 3.84 (s, 3 H, $ArOCH_3$), 3.63 (br t, 1 H, H-4), 3.49 (s, 3 H, OCH_3), 2.65 (s, 3 H, $ArCH_3$), 2.54 (d, 1 H, *J* = 1.5 Hz, OH), 2.15 (s, 3 H, $COCH_3$), 1.31 (d, 3 H, *J* = 6.2 Hz, H-6); ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.0, 156.9, 153.6, 142.2, 141.6, 115.0, 103.8, 100.9, 92.0, 79.0, 71.2, 71.1, 67.1, 61.8, 61.3, 57.5, 27.5, 20.9, 17.6; IR (neat) 3470, 2936, 1744, 1565, 1547, 1461, 1414, 1231, 1100, 947 cm^{-1}; EI HRMS for $C_{19}H_{24}INO_8H$ (M + H^+), calcd 522.0625, found 522.0631.

4-[(6-Deoxy-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzonitrile (114). A solution of sodium methoxide in methanol (0.70 mL, 3.06 mmol) was added to a −20 °C solution of glycoside **113** (1.97 g, 3.78 mmol) in methanol (60 mL). After 13 h, solid NH_4Cl (ca. 0.2 g) was added, and the reaction was stirred for 10 min. The cold reaction mixture was poured into H_2O (40 mL) and extracted with CH_2Cl_2 (3 × 50 mL). The organic fractions were combined, dried ($MgSO_4$), concentrated, and chromatographed (flash column, 50 → 75 → 100% ethyl acetate in hexanes) to afford aryl glycoside **114** (1.71 g, 94%): white solid; $[\alpha]^{25}_D$ −52.4° (*c* 3.3, CH_2Cl_2); ^1H NMR (400 MHz, $CDCl_3$) δ 5.85 (d, 1 H, *J* = 1.45 Hz, H-1), 4.43 (dd, 1 H, *J* = 2.9, 1.6 Hz, H-2), 4.07 (dq, 1 H, *J* = 9.6, 6.2 Hz, H-5), 4.01 (s, 3 H, $ArOCH_3$), 3.84 (dd, 1 H, *J* = 9.3, 2.9 Hz, H-3), 3.84 (s, 3 H, $ArOCH_3$), 3.64 (t, 1 H, *J* = 9.5 Hz, H-4), 3.56 (s, 3 H, OCH_3), 2.70 (br s, 1 H, OH), 2.63 (s, 3 H, $ArCH_3$), 2.63 (br s, 1 H, OH), 1.27 (d, 3 H, *J* = 6.2 Hz, H-6); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.9, 153.6, 142.4, 141.5, 115.1, 103.6, 102.4, 92.2, 80.8, 70.9, 70.6, 66.9, 61.7, 61.2, 57.2, 27.5, 17.5; IR (neat) 3420, 2938, 1558, 1542, 1460, 1415, 1339, 1246, 1152, 1097, 1002, 948, 805, 757 cm^{-1}; EI HRMS for $C_{17}H_{22}INO_7$ (M^+), calcd 479.0441, found 479.0432.

4-[(6-Deoxy-3-*O*-methyl-2,4-*O*,*O*-bis(triethylsilyl)-3-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzonitrile (115). A solution of diol **114** (1.27 g, 2.65 mmol) in CH_2Cl_2 (50 mL) was cooled

to 0 °C, and pyridine (4.0 mL, 32.2 mmol) and DMAP (1.36 g, 12.1 mmol) were added. Triethylsilyl trifluoromethanesulfonate (2.40 mL, 10.6 mmol) was added dropwise, and the reaction was allowed to slowly warm to room temperature. After 14 h, the solution was poured into saturated aqueous $NaHCO_3$ (30 mL) and extracted with CH_2Cl_2 (2 × 25 mL). The organic layers were combined, dried ($MgSO_4$), and concentrated. Purification by flash column chromatography (2 → 5 → 10% ethyl acetate in hexanes) provided **115** (1.87 g, 100%): white foam; R_f = 0.44 (9:1 hexanes/ethyl acetate); $[\alpha]^{25}_D$ −40.0° (*c* 1.9, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.56 (d, *J* = 2.0 Hz, H-1), 4.40 (t, 1 H, *J* = 2.4 Hz, H-2), 4.02 (s, 3 H, $ArOCH_3$), 3.93 (dq, 1 H, *J* = 9.2, 6.2 Hz, H-5), 3.81 (s, 3 H, $ArOCH_3$), 3.73 (t, 1 H, *J* = 9.1 Hz, H-4), 3.59 (dd, 1 H, *J* = 9.0, 2.6 Hz, H-3), 3.42 (s, 3 H, OCH_3), 2.65 (s, 3 H, $ArCH_3$), 1.21 (d, 3 H, *J* = 6.2 Hz, H-6), 0.97 (t, 9 H, *J* = 8.0 Hz, $Si(CH_2CH_3)_3$), 0.97 (t, 9 H, *J* = 8.0 Hz, $Si(CH_2CH_3)_3$), 0.68−0.60 (m, 12 H, 2 × $Si(CH_2CH_3)_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.9, 154.6, 142.6, 141.5, 115.2, 104.5, 103.5, 92.6, 81.4, 72.6, 72.2, 68.5, 61.7, 61.1, 57.3, 27.6, 18.0, 6.9, 6.7, 5.2, 4.8; IR (neat) 2953, 2912, 2876, 2226, 1568, 1543, 1461, 1415, 1398, 1336, 1320, 1242, 1142, 1096, 1005, 937, 912, 881, 803, 777, 742 cm^{-1}; EI HRMS for $C_{29}H_{50}INO_7Si_2H$ (M + H$^+$), calcd 708.2249, found 708.2218.

4-[(6-Deoxy-3-*O*-methyl-2,4-*O*,*O*-bis(triethylsilyl)-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzaldehyde (116). Diisobutylaluminum hydride (1.5 M in toluene) was added very slowly to a solution of nitrile **115** (2.80 g, 3.96 mmol) in hexanes (50 mL) at 0 °C until the reaction was complete (approximately 1.2 equiv; TLC, 12:1 toluene/ethyl acetate). The reaction was quenched with saturated aqueous NH_4Cl (20 mL), and the organic layer was removed. The aqueous layer was reextracted with ethyl acetate (2 × 30 mL), and the combined organic fractions were dried ($MgSO_4$), concentrated, and purified by flash column chromatography (2 → 5% ethyl acetate in toluene) to provide benzaldehyde **116** (2.38 g, 84%): white amorphous solid; $[\alpha]^{25}_D$ −29.7° (*c* 2.4, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.30 (s, 1 H, CHO), 5.60 (d, 1 H, *J* = 2.0 Hz, H-1), 4.42 (t, 1 H, *J* = 2.4 Hz, H-2), 4.08 (dq, 1 H, *J* = 9.1, 6.2 Hz, H-5), 3.96 (s, 3 H, $ArOCH_3$), 3.83 (s, 3 H, $ArOCH_3$), 3.74 (t, 1 H, *J* = 9.1 Hz, H-4), 3.63 (dd, 1 H, *J* = 9.1, 2.6 Hz, H-3), 3.43 (s, 3 H, OCH_3), 2.72 (s, 3 H, $ArCH_3$), 1.22 (d, 3 H, *J* = 6.2 Hz, H-6), 0.97 (t, 9 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.97 (t, 9 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.68−0.60 (m, 12 H, 2 × $Si(CH_2CH_3)_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 191.1, 158.8, 154.7, 142.9, 140.1, 125.0, 104.4, 97.2, 81.3, 72.5, 72.3, 68.5, 62.1, 60.9, 57.3, 25.9, 18.0, 6.9, 6.7, 5.1, 4.8; IR (neat) 2952, 2875, 1694, 1558, 1540, 1457, 1418, 1377, 1311, 1236, 1141, 1094, 1006, 937, 911, 881, 805, 765, 740 cm^{-1}; EI HRMS for $C_{29}H_{51}IO_8Si_2$ (M$^+$), calcd 710.2167, found 710.2131.

4-[(6-Deoxy-2,4-*O*,*O*-bis(triethylsilyl)-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoic acid (117). Monobasic sodium phosphate ($NaH_2PO_4 \cdot H_2O$, 4.60 g, 33.3 mmol) and sodium chlorite ($NaClO_2$, 6.04 g, 66.8 mmol) were sequentially added to a solution of aldehyde **116** (2.38 g, 3.34 mmol) in a 1:2:2 mixture of 2-methyl-2-butene (37 mL), *tert*-butyl alcohol (75 mL), and water (75 mL). After the mixture was stirred for 30 min at room temperature, the layers were separated, and the aqueous layer was extracted with CH_2Cl_2 (3 × 50 mL). The combined organic extracts were dried over $MgSO_4$, filtered, and concentrated. The residue was purified by flash column chromatography (33% → 50% → 67% ether in CH_2Cl_2 or 50:50:1 ethyl acetate/hexanes/acetic acid → 99:1 ethyl acetate/acetic acid → 90:10:1 ethyl acetate/methanol/acetic acid) to provide benzoic acid **117** (2.24 g, 92%): white amorphous solid; $[\alpha]^{25}_D$ −31.8° (*c* 1.95, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.5−7.5 (bs, 1 H, COOH), 5.43 (d, 1 H, *J* = 1.9 Hz, H-1), 4.45 (t, 1 H, *J* = 2.3 Hz, H-2), 4.12 (dq, 1 H, *J* = 9.1, 6.2 Hz, H-5), 3.93 (s, 3 H, $ArOCH_3$), 3.83 (s, 3 H, $ArOCH_3$), 3.75 (t, 1 H, *J* = 9.2 Hz, H-4), 3.59 (dd, 1 H, *J* = 9.1, 2.6 Hz, H-3), 3.43 (s, 3 H, OCH_3), 2.49 (s, 3 H, $ArCH_3$), 1.24 (d, 3 H, *J* = 6.2 Hz, H-6), 0.98 (t, 9 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.97 (t, 9 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.66 (q, 6 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.64 (q, 6 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.8, 152.4, 151.4, 143.1, 134.4, 124.2, 104.6, 94.0, 81.3, 72.4, 72.3, 68.7, 61.7, 60.8, 57.3, 26.2, 18.0, 6.9, 6.7, 5.1, 4.8; IR (neat) 2953, 2876, 1735, 1705, 1555, 1458, 1404, 1319, 1282, 1241, 1142, 1114, 1087, 1061, 1006, 942, 881, 803, 742 cm^{-1}; FAB HRMS for $C_{29}H_{51}IO_9Si_2Na$ (M + Na$^+$), calcd 749.2014, found 749.2004.

1,5-Anhydro-2,4,6-trideoxy-3-*O*-(triethylsilyl)-4-(2,4-dinitrophenyl)thio]-D-*ribo*-hex-1-enopyranose (119). Glycal **45** (1.26 g, 4.04 mmol) was dissolved in CH_2Cl_2 (40 mL) and stirred at 0 °C. Pyridine (1.96 mL, 24.2 mmol), DMAP (0.968 g, 8.1 mmol), and triethylsilyl trifluoromethanesulfonate (1.83 mL, 8.1 mmol) were sequentially added to the solution. The reaction mixture was slowly warmed to room temperature. After 5 h, the solution was washed with saturated aqueous $NaHCO_3$ (100 mL), dried ($MgSO_4$), concentrated, and chromatographed (flash column, 12% ethyl acetate in hexanes) to provide **119** (1.65 g, 96%): dark yellow oil; $[\alpha]^{25}_D$ +264° (*c* 3.4, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.00 (d, 1 H, *J* = 2.5 Hz, ArH), 8.34 (dd, 1 H, *J* = 9.0, 2.5 Hz, ArH), 7.76 (d, 1 H, *J* = 9.1 Hz, ArH), 6.49 (d, 1 H, *J* = 6.0 Hz, H-1), 4.97 (t, 1 H, *J* = 5.7 Hz, H-2), 4.38 (dd, 1 H, *J* = 5.5, 3.3 Hz, H-3), 4.34 (dq, 1 H, *J* = 10.8, 6.5 Hz, H-5), 3.55, (dd, 1 H, *J* = 10.8, 3.3 Hz, H-4), 1.37 (d, 3 H, *J* = 6.5 Hz, H-6), 0.98 (t, 9 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.63 (q, 6 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$); ^{13}C NMR (62.9 MHz, $CDCl_3$) δ 146.4, 145.7, 145.4, 144.0, 128.9, 126.4, 121.5, 103.0, 70.8, 63.2, 52.9, 18.6, 6.7, 5.0; IR (neat) 3097, 2955, 2876, 1642, 1592, 1530, 1461, 1413, 1382, 1342, 1302, 1232, 1146, 1090, 1047, 1000, 954, 9 17, 881, 832, 734 cm^{-1}; FAB HRMS for $C_{18}H_{26}N_2O_6SSiNa$ (M + Na$^+$), calcd 449.1179, found 449.1145.

[(2,4,6-Trideoxy-4-[(2,4-dinitrophenyl)thio]-3-*O*-(triethylsilyl)-β-D-*ribo*-hexopyranosyl)oxy[2-(trimethylsilyl)ethoxycarbonyl]amine (120). Triphenylphosphine hydrobromide (61 mg, 0.179 mmol) was added to a solution of **119** (1.53 g, 3.58 mmol) and TEOC-NHOH (1.58 g, 8.95 mmol) in CH_2Cl_2 (72 mL). After being stirred for 20 min at room temperature, the mixture was diluted with CH_2Cl_2 (100 mL) and washed with saturated aqueous $NaHCO_3$ (3 × 100 mL). The aqueous extracts were combined and reextracted with CH_2Cl_2 (100 mL). The combined organic layers were dried over $MgSO_4$, filtered, concentrated, and chromatographed on silica gel (1.5% ether in CH_2Cl_2, then 25 → 33% ethyl acetate in hexanes) to give **120** (0.756 g, 35%) along with 39% of the β-*N*-glycosylated compound and 5% of the α-*O*-glycosylated compound. **120**: yellow solid; $[\alpha]^{25}_D$ +25.6° (*c* 1.8, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.98 (d, 1 H, *J* = 2.5 Hz, ArH), 8.33 (dd, 1 H, *J* = 9.0, 2.5 Hz, ArH), 7.92 (bs, 1 H, NH), 7.75 (d, 1 H, *J* = 9.1 Hz, ArH), 5.17 (dd, 1 H, *J* = 9.9, 2.0 Hz, H-1), 4.43 (m, 1 H, H-3), 4.26 (m, 2 H, CH_2O (TEOC)), 4.19 (dq, 1 H, *J* = 10.2, 6.4 Hz, H-5), 3.36 (dd, 1 H, *J* = 10.2, 2.2 Hz, H-4), 2.17 (ddd, 1 H, *J* = 13.4, 3.5, 2.3 Hz, H-2_{eq}), 1.81 (ddd,1 H, *J* = 13.3, 10.0, 2.5 Hz, H-2_{ax}), 1.31 (d, 3 H, *J* = 6.4 Hz, H-6), 1.03 (m, 2 H, $SiCH_2$ (TEOC)), 0.96 (t, 9 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.63 (q, 6 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.04 (s, 9 H, $SiCH_3$ (TEOC)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.2, 146.2, 145.1, 144.0, 128.4, 126.7, 121.7, 101.6, 70.5, 69.0, 64.6, 53.8, 37.7, 19.2, 17.6, 6.8, 4.8, −1.6; IR (neat) 3274, 2954, 1716, 1700, 1684, 1593, 1522, 1457, 1340, 1249, 1151, 1086, 1034, 986, 916, 834, 735 cm^{-1}; FAB HRMS for $C_{24}H_{41}N_3O_9SSi_2Na$ (M + Na$^+$), calcd 626.2000, found 626.2054.

2-(Trimethylsilyl)ethyl [(2,4,6-Trideoxy-3-*O*-(triethylsilyl)-4-thio-β-D-*ribo*-hexopyranosyl)oxy]carbamate (121). Ethanethiol (1.48 mL, 20.1 mmol) and K_2CO_3 (1.11 g, 8.0 mmol) were added to a solution of dinitrophenyl sulfide **120** (242 mg, 0.40 mmol) in MeOH (8.0 mL) at room temperature. After being stirred for 10 min, the reaction mixture was diluted with ethyl acetate (100 mL) and washed with saturated aqueous $NaHCO_3$ (30 mL) and brine (30 mL). The organic layer was dried over $MgSO_4$, filtered, and concentrated. The residue was purified by flash column chromatography (1% ether in CH_2Cl_2, then 15% ethyl acetate in hexanes) to provide thiol **121** (156 mg, 89%): light yellow oil; $[\alpha]^{25}_D$ −30.3° (*c* 1.2, CH_2Cl_2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (bs, 1 H, NH), 5.05 (dd, 1 H, *J* = 10.0, 1.8 Hz, H-1), 4.22 (m, 2 H, CH_2O (TEOC)), 4.16 (m, 1 H, H-3), 3.76 (dq, 1 H, *J* = 10.1, 6.2 Hz, H-5), 2.47, (dt, 1 H, *J* = 10.5, 2.3 Hz, H-4), 2.10 (ddd, 1 H, *J* = 13.2, 3.2, 2.2 Hz, H-2_{ax}), 2.10 (ddd, 1 H, *J* = 13.2, 10.1, 2.4 Hz, H-2_{eq}), 1.62 (d, 1 H, *J* = 10.8 Hz, SH), 1.36 (d, 3 H, *J* = 6.2 Hz, H-6), 0.97−1.03 (m, 2 H, SiCH (TEOC)), 0.98 (t, 9 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.65 (q, 6 H, *J* = 7.9 Hz, $Si(CH_2CH_3)_3$), 0.02 (s, 9 H, $SiCH_3$ (TEOC)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.2, 101.6, 72.6, 60.5, 64.4, 47.2, 38.1, 19.6, 17.6, 6.9, 4.9, −1.6; IR (neat) 3276, 2955, 2910, 2877, 1757, 1718, 1458, 1413, 1383, 1368, 1339, 1323, 1250, 1155, 1087, 1038, 992, 966, 861, 838, 795, 742, 698 cm^{-1}. FAB HRMS for $C_{18}H_{39}NO_5SSi_2H$ (M + H$^+$), calcd 438.2166, found 438.2156.

2,4,6-Trideoxy-1-*O*-{[2-(trimethylsilyl)ethyl]amino}-3-*O*-triethylsilyl)-4-β-D-*ribo*-hexopyranosyl 4-[(6-deoxy-2,4-*O*,*O*-bis(triethylsilyl)-3-*O*-methyl-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylthiobenzoate (122). Oxalyl chloride (0.61 mL) in CH_2Cl_2 (2.0 mL) was added to a flask containing the acid **117** (0.101 g, 0.139 mmol) in CH_2Cl_2 (1.0 mL). After being stirred at room temperature for 2 h, the reaction mixture was concentrated under reduced pressure and azeotroped with benzene (3 × 1 mL). The crude acid chloride **118** was dissolved in CH_2Cl_2 (2.8 mL) and cooled to 0 °C. DMAP (2 mg, 16 μmol) and triethylamine (0.192 mL, 1.4 mmol) were added to the reaction mixture, followed by thiol **121** (39.5 mg, 0.090 mmol) in CH_2Cl_2 (1.2 mL). After being stirred at 0 °C for 90 min, the reaction mixture was quenched with saturated aqueous $NaHCO_3$, diluted with CH_2Cl_2 (30 mL), and washed with saturated aqueous $NaHCO_3$ (10 mL). The organic layer was dried ($MgSO_4$), filtered, and concentrated. The residue was purified by flash column chromatography (10% ethyl acetate in hexanes) to provide thiobenzoate **122** (63.6 mg, 62%): white amorphous solid; $[\alpha]^{25}_D$ −21.5° (*c* 2.70, CH_2Cl_2); ^1H NMR (400 MHz, $CDCl_3$) δ 7.64 (s, 1 H, NH), 5.40 (d, 1 H, *J* = 1.9 Hz, D-1), 5.13 (dd, 1 H, *J* = 9.9, 1.7 Hz, B-1), 4.44 (t, 1 H, *J* = 2.2 Hz, D-2), 4.33 (m, 1 H, B-3), 4.26 (m, 2 H, CH_2O (TEOC)), 4.12 (dq, 1 H, *J* = 9.1, 6.2 Hz, D-5), 4.05 (dq, 1 H, *J* = 10.6, 6.3 Hz, B-5), 3.86 (s, 3 H, $ArOCH_3$), 3.80 (s, 3 H, $ArOCH_3$), 3.77 (dd, 1 H, *J* = 10.6, 2.4 Hz, B-4), 3.74 (t, 1 H, *J* = 9.1 Hz, D-4), 3.42 (s, 3 H, OCH_3), 2.34 (s, 3 H, $ArCH_3$), 2.11, (ddd, 1 H, *J* = 12.8, 2.4, 1.7 Hz, B-2_{eq}), 1.85 (ddd, 1 H, *J* = 12.8, 10.4, 2.3 Hz, B-2_{ax}), 1.39 (d, 3 H, *J* = 6.3 Hz, B-6), 1.23 (d, 3 H, *J* = 6.2 Hz, D-6), 1.03 (m, 2 H, CH_2Si (TEOC)), 1.00−0.94 (m, 27 H, 3 × $Si(CH_2CH_3)_3$), 0.68−0.60 (m, 18 H, 3 × $Si(CH_2CH_3)_3$), 0.04 (s, 9 H, $Si(CH_3)_3$ (TEOC)); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.9, 157.2, 152.3, 150.5, 143.2, 133.3, 130.4, 104.7, 101.6, 93.8, 81.4, 72.4, 72.3, 70.5, 70.0, 68.6, 64.5, 61.5, 60.8, 57.3, 51.4, 37.6, 25.3, 18.6, 18.0, 17.7, 7.0, 6.9, 6.8, 5.2, 4.9, 4.9, −1.5; IR (neat) 3283, 2953, 2876, 1681, 1456, 1414, 1319, 1239, 1086, 1004, 935, 908, 881, 836, 741 cm^{-1}. FAB HRMS for $C_{47}H_{88}INO_{13}SSi_4Na$ (M + Na^+), calcd 1168.3998, found 1168.4050.

(4-Methoxyphenyl)methyl 6-Deoxy-3-*O*-[(4-methoxyphenyl)methyl]-4-*O*-(trimethylsilyl)-β-D-galactopyranoside (123). Pyridine (850 μL, 10.6 mmol) and trimethylsilyl trifluoromethanesulfonate (1 mL, 5.3 mmol) were sequentially added to a solution of diol **58** (430 mg, 1.06 mmol) in CH_2Cl_2 (20 mL) at room temperature. After being stirred for 15 min at room temperature, the reaction mixture was diluted with EtOAc (150 mL) and washed with saturated aqueous NH_4Cl (50 mL) and brine (50 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was dissolved in MeOH (20 mL), and K_2CO_3 (150 mg, 1.06 mmol) was added. After being stirred for 90 min at room temperature, the reaction mixture was diluted with EtOAc (150 mL) and washed with saturated aqueous NH_4Cl (50 mL) and brine (50 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 75:25 to 50:50) to provide monosily lether **123** (430 mg, 85%), disilyl ether (29 mg, 5%), and diol **58** (43 mg, 10%). **123**: colorless oil; $[\alpha]^{25}_D$ −21.1° (*c* 2.68, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3591, 2957, 2937, 2883, 2838, 1612, 1587, 1514, 1303, 1250, 1181, 1174, 1106, 1083, 1064, 1035, 860, 844 cm^{-1}; ^1H NMR (250 MHz, $CDCl_3$) δ 7.31−7.27 (m, 4 H, ArH (PMB)), 6.88−6.85 (m, 4 H, ArH (PMB)), 4.71 (AB, 2 H *J* = 11.7 Hz, Δν = 82.2 Hz, CH_2Ar), 4.64 (AB, 2 H, *J* = 11.6 Hz, Δν = 21.8 Hz, CH_2Ar), 4.23 (d, 1 H, *J* = 7.7 Hz, H-1), 3.84 (dd, 1 H, *J* = 9.7, 7.7 Hz, H-2), 3.80 (s, 6 H, 2 $ArOCH_3$), 3.75 (b d, 1 H, *J* = 2.9 Hz, H-4), 3.48 (b q, 1 H, *J* = 6.3 Hz, H-5), 3.24 (dd, 1 H, *J* = 9.7, 2.9 Hz, H-3), 2.22−2.17 (m, 1 H, OH), 1.25 (d, 3 H, *J* = 6.3 Hz, CH_3), 0.11 (s, 9 H, $Si(CH_3)_3$); ^{13}C NMR (62.5 MHz, $CDCl_3$) δ 159.8, 159.1, 130.4, 129.7, 129.5, 113.8, 113.7, 107.0, 101.7, 80.7, 72.4, 71.5, 71.1, 71.0, 70.3, 55.2, 16.9, 0.6; FAB HRMS for $C_{25}H_{36}O_7SiNa$ (M + Na), calcd 499.2128, found 499.2131. Anal. Calcd for $C_{25}H_{36}O_7Si$: C, 63.00; H, 7.61. Found: C, 62.91; H, 7.76.

(4-Methoxyphenyl)methyl 6-Deoxy-2-*O*-{2,4-dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)amino]-2-iodo-3-*O*-methyl-α-L-*lyxo*-pentopyranosyl}-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (124). Molecular sieves (4 Å) were added to a solution of alcohol **123** (210 mg, 0.44 mmol) and glycal **112** (250 mg, 0.66 mmol) in CH_2Cl_2 (10 mL) at room temperature. After the mixture was stirred at room temperature for 30 min, I(*sym*-collidine)$_2ClO_4$ (352 mg, 0.75 mmol) was added, and the reaction mixture was stirred in the dark at room temperature for 2 h. The mixture was filtered through Celite, and the filtered pad was rinsed with EtOAc. The combined filtrates were diluted with EtOAc (100 mL) and washed with 10% aqueous $Na_2S_2O_3$ (3 × 30 mL), 10% aqueous $CuSO_4$ (2 × 30 mL), and brine (2 × 30 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was dissolved in THF/AcOH/H_2O (1:6:3, 22 mL). After being stirred at room temperature for 30 min, the reaction mixture was diluted with EtOAc (150 mL) and washed with water (2 × 50 mL), saturated aqueous $NaHCO_3$ (2 × 50 mL), and brine (50 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 60:40 to 40:60) to provide disaccharide **124** (360 mg, 90%): white amorphous solid; $[\alpha]^{25}_D$ −13.5° (*c* 2.16, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3557, 3012, 2935, 2837, 1692, 1612, 1514, 1452, 1426, 1303, 1293, 1250, 1194, 1173, 1142, 1112, 1071, 1040, 992 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 140 °C) δ 7.82 (d, 2 H, *J* = 7.5 Hz, ArH (FMOC)), 7.63 (d, 2 H, *J* = 7.5 Hz, ArH (FMOC)), 7.39 (dd, 2 H, *J* = 7.5, 7.5 Hz, ArH (FMOC)), 7.35−7.28 (m, 4 H, ArH (FMOC, PMB)), 7.25−7.22 (m, 2 H, ArH (PMB)), 6.93−6.89 (m, 2 H, ArH (PMB)), 6.86−6.83 (m, 2 H, ArH (PMB)), 5.48 (d, 1 H, *J* = 0.9 Hz, H-1′), 4.64 (d, 1 H, *J* = 11.5 Hz, H-CHAr), 4.62 (AB, 2 H, *J* = 11.7 Hz, Δν = 60.4 Hz, CH_2-Ar), 4.55 (dd, 1 H, *J* = 3.9, 0.9 Hz, H-2′), 4.413 (d, 1 H, *J* = 11.5 Hz, H-CHAr), 4.408 (AB of ABX, 2 H, *J* = 10.9, 6.2, 6.2 Hz, Δν = 29.3 Hz, OCH_2 (FMOC)), 4.39 (d, 1 H, *J* = 7.7 Hz, H-1), 4.25 (dd, 1 H, *J* = 6.2, 6.2 Hz, CH (FMOC)), 4.05 (dd, 1 H, *J* = 10.8, 10.4 Hz, H-5′$_{ax}$), 4.0−3.85 (m, 1 H, H-4′), 3.80 (d, 1 H, *J* = 3.2 Hz, H-4), 3.77 (s, 3 H, $ArOCH_3$), 3.73 (s, 3 H, $ArOCH_3$), 3.69 (dd, 1 H, *J* = 9.5, 7.7 Hz, H-2), 3.56 (q, 1 H, *J* = 6.4 Hz, H-5), 3.53 (dd, 1 H, *J* = 9.5, 3.2 Hz, H-3), 3.23 (dd, 1 H, *J* = 10.4, 4.9 Hz, H-5′$_{eq}$), 3.12 (s, 3 H, OCH_3), 3.06−3.02 (m, 1 H, H-3′), 2.96 (AB of ABX_3, 2 H, *J* = 14.4, 7.0, 7.0 Hz, Δν 23.4 Hz, CH_2N), 1.23 (d, 3 H, *J* = 6.4 Hz, CH_3), 0.86 (dd, 3 H, *J* = 7.0, 7.0 Hz, CH_3-CH_2N); ^{13}C NMR (125 MHz, DMSO-d_6, 100 °C) δ 158.6, 158.5, 154.7, 143.5, 140.4, 130.0, 129.4, 129.0 128.6, 127.0, 126.4, 124.3, 119.4, 113.5, 113.3, 101.4, 99.5, 81.3, 74.1, 71.4, 69.6, 69.5, 68.9, 68.6, 66.8, 66.0, 59.5, 54.73, 54.68, 54.0, 46.6, 39.2, 35.7, 15.8, 13.7; FAB HRMS for $C_{45}H_{52}INO_{11}Na$ (M + Na), calcd 932.2483, found 932.2543. Anal. Calcd for $C_{45}H_{52}INO_{11}$: C, 59.41; H, 5.76; N, 1.54. Found: C, 59.40; H, 5.77; N, 1.47.

(4-Methoxyphenyl)methyl 6-Deoxy-2-*O*-{2,4-dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)amino]-3-*O*-methyl-α-L-*threo*-pentopyranosyl}-3-*O*-[(4-methoxyphenyl)methyl]-β-D-galactopyranoside (125). Triphenyltin hydride (171 μL, 0.67 mmol) and AIBN (13 mg, 0.08 mmol) were added to a degassed solution (argon) of disaccharide **124** (381 mg, 0.42 mmol) at room temperature. The reaction mixture was refluxed for 20 min, cooled to room temperature, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 50:50 to 30:70) to provide disaccharide **125** (325 mg, 99%): white amorphous solid; $[\alpha]^{25}_D$ −41.2° (*c* 1.92, $CHCl_3$); FT-IR ($CHCl_3$) 3500, 3025, 2939, 2875, 2838, 1690, 1612, 1514, 1478, 1465, 1452, 1424, 1304, 1250, 1173, 1069, 1039, 995 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 130 °C) δ 7.82 (d, 2 H, *J* = 7.6 Hz, ArH (FMOC)), 7.62−7.59 (m, 2 H, ArH (FMOC)), 7.38 (dd, 2 H, *J* = 7.6, 7.6 Hz, ArH (FMOC)), 7.32−7.27 (m, 4 H, ArH (FMOC, PMB)), 7.25−7.22 (m, 2 H, ArH (PMB)), 6.92−6.89 (m, 2 H, ArH (PMB)), 6.86−6.83 (m, 2 H, ArH (PMB)), 5.23 (dd, 1 H, *J* = 3.6, 1.3 Hz, H-1′), 4.63 (d, 1 H, *J* = 11.6 Hz, H-CHAr), 4.61 (AB, 2 H, *J* = 11.8 Hz, Δν = 61.3 Hz, CH_2Ar), 4.49−4.38 (m, 2 H, OCH_2 (FMOC)), 4.42 (d, 1 H, *J* = 11.6 Hz, H-CHAr), 4.37 (d, 1 H, *J* = 7.6 Hz, H-1), 4.25 (dd, 1 H, *J* = 6.1, 6.1 Hz, CH (FMOC)), 3.98 (b, 1 H, OH), 3.92 (dd, 1 H, *J* = 10.8, 10.8 Hz, H-5′$_{ax}$), 3.77 (s, 3 H, $ArOCH_3$), 3.76 (d, 1 H, *J* = 3.3 Hz, H-4), 3.73 (s, 3 H, $ArOCH_3$), 3.73−3.69 (m, 1 H, H-3′), 3.68 (dd, 1 H, *J* = 9.5, 7.8 Hz, H-2), 3.64 (ddd, 1 H, *J* = 10.8, 10.8, 4.8 Hz, H-4′), 3.54 (q, 1 H, *J* = 6.4 Hz, H-5), 3.48 (dd, 1 H, *J* = 9.5, 3.3 Hz, H-3), 3.14 (s, 3 H, OCH_3), 3.135 (dd, 1 H, *J* = 10.8, 4.8 Hz, H-5′$_{eq}$), 2.92 (AB of ABX_3, 2 H, *J* = 14.7, 7.0, 7.0 Hz, Δν = 30 Hz, CH_2N), 2.14 (ddd, 1 H, *J* = 12.8, 4.6, 1.3 Hz, H-2′$_{eq}$), 1.30 (ddd, 1 H, *J* = 12.8, 10.6, 3.6 Hz, H-2′$_{ax}$), 1.22 (d, 3 H, *J* = 6.4 Hz, CH_3), 0.82 (dd, 3 H, *J* = 7.0, 7.0 Hz, CH_3-CH_2N); ^{13}C NMR (125 MHz, DMSO-d_6, 110 °C) δ 158.5, 158.4, 154.6, 143.5, 140.4, 130.2, 129.6, 128.6, 128.5, 126.9, 126.3, 124.2, 119.3, 113.3,

113.2, 99.8, 97.0, 81.7, 73.0, 71.1, 69.5, 69.1, 68.5, 67.0, 65.7, 59.0, 57.4 (b), 54.7, 54.6, 54.1, 46.6, 39.0 (b), 34.5, 15.7, 13.8; FAB HRMS for $C_{45}H_{53}NO_{11}Na$ (M + Na), calcd 806.3516, found 806.3542. Anal. Calcd for $C_{45}H_{53}NO_{11}$: C, 68.95; H, 6.81; N, 1.77. Found: C, 68.84; H, 6.82; N, 1.77.

(4-Methoxyphenyl)methyl 6-Deoxy-2-*O*-{2,4-dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)amino]-3-*O*-methyl-α-L-*threo*-pentopyranosyl}-3-*O*-[(4-methoxyphenyl)methyl]-4-*O*-(trifluoromethanesulfonyl)-β-D-galactopyranoside (126). Trifluoromethanesulfonic anhydride (280 μL, 1.66 mmol) was added to a solution of alcohol **125** (325 mg, 0.42 mmol) and pyridine (270 μL, 3.32 mmol) in CH_2Cl_2 (20 mL) at −20 °C. After being stirred for 1 h at −20 °C and 90 min at room temperature, the reaction mixture was quenched with saturated aqueous $NaHCO_3$, diluted with EtOAc (200 mL), and washed with saturated aqueous $NaHCO_3$ (70 mL), 10% aqueous CuSO4 (2 × 70 mL), and brine (2 × 70 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 50:50 to 40:60) to provide triflate **126** (350 mg, 93%).

(4-Methoxyphenyl)methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-3-*O*-methyl-2,4-*O*,*O*-bis(triethylsilyl)-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-(triethylsilyl)-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-{2,4-dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)amino]-3-*O*-methyl-α-L-*threo*-pentopyranosyl}-3-*O*-[(4-methoxyphenyl)methyl]-β-D-glucopyranoside (127). Sodium hydride (46 mg, 1.14 mmol, 60% dispersion in mineral oil) was added to a solution of carbamate **122** (480 mg, 0.42 mmol) in DMF (5 mL) at 0 °C. The reaction mixture was warmed to room temperature, stirred 45 min at room temperature, and cooled to 0 °C. A solution of triflate **126** (350 mg, 0.38 mmol) in DMF (5 mL) was added via cannula. After being stirred at 0 °C for 10 min, the reaction mixture was quenched by syringe pump addition of acetic acid (1 mL) over 10 min, diluted with EtOAc (300 mL), and washed with saturated aqueous NH_4Cl (100 mL), brine (100 mL), saturated aqueous $NaHCO_3$ (100 mL), and brine (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 80:20 to 70:30) to provide aryltetrasaccharide **127** (500 mg, 68%): white amorphous solid; $[\alpha]^{25}_D$ −33.3° (*c* 2.21, $CHCl_3$); FT-IR ($CHCl_3$) ν_{max} 3008, 2957, 2937, 2912, 2876, 1689, 1613, 1515, 1456, 1417, 1251, 1140, 1088, 1065, 1036, 963, 909 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 130 °C) δ 7.83 (d, 2 H, *J* = 7.5 Hz, ArH (FMOC)), 7.60 (dd, 2 H, *J* = 7.5, 1.9 Hz, ArH (FMOC)), 7.38 (dd, 2 H, *J* = 7.5, 7.5 Hz, ArH (FMOC)), 7.29 (ddd, 2 H, *J* = 7.5, 7.5, 1.9 Hz, ArH (FMOC)), 7.27−7.23 (m, 2 H, ArH (PMB)), 7.19−7.17 (m, 2 H, ArH (PMB)), 6.87−6.84 (m, 4 H, ArH (PMB)), 5.40 (d, 1 H, *J* = 2.1 Hz, D-1), 5.20 (m, 1 H, E-1), 5.11 (dd, 1 H, *J* = 10.1, 1.8 Hz, B-1), 4.63 (AB, 2 H, *J* = 11.7 Hz, Δν = 66.6 Hz, CH_2Ar), 4.62 (AB, 2 H, *J* = 10.8 Hz, Δν = 32.8 Hz, CH_2-Ar), 4.43−4.36 (m, 6 H, A-1, A-3, B-3, D-2, OCH_2 (FMOC)), 4.25 (app t, 1 H, *J* = 6.1 Hz, CH (FMOC)), 4.22−4.12 (m, 3 H, E-4, OCH_2 (TEOC)), 4.05 (dq, 1 H, *J* = 9.0, 6.2 Hz, D-5), 3.95 (dq, 1 H, *J* = 10.7, 6.2 Hz, B-5), 3.92−3.83 (m, 2 H, A-5, E-5_{ax}), 3.82 (s, 3 H, $ArOCH_3$ (PMB)), 3.78 (s, 3 H, $ArOCH_3$ (PMB)), 3.76−3.70 (m, 2 H, E-3, A-4), 3.74 (s, 3 H, $ArOCH_3$), 3.73 (s, 3 H, $ArOCH_3$), 3.71 (dd, 1 H, *J* = 9.0, 8.9 Hz, D-4), 3.69 (dd, 1 H, *J* = 10.7, 2.4 Hz, B-4), 3.57 (dd, 1 H, *J* = 8.9, 2.6 Hz, D-3), 3.47 (app t, 1 H, *J* = 8.2 Hz, A-2), 3.40 (s, 3 H, OCH_3), 3.16 (dd, 1 H, *J* = 11.0, 4.8 Hz, E-5_{eq}), 3.13 (s, 3 H, OCH_3), 2.93−2.88 (m, 2 H, CH_2N), 2.32 (s, 3 H, $ArCH_3$), 2.21 (b dd, 1 H, *J* = 13.1, 4.0 Hz, E-2_{eq}), 2.11 (b d, 1 H, *J* = 13.0 Hz, B-2_{eq}), 1.89 (ddd, 1 H, *J* = 13.2, 10.1, 2.2 Hz, B-2_{ax}),1.36−1.29 (m, 1 H, E-2_{ax}), 1.34 (d, 3 H, *J* = 6.2 Hz, B-6), 1.21 (d, 3 H, *J* = 5.8 Hz, A-6), 1.17 (d, 3 H, *J* = 6.2 Hz, D-6), 0.99−0.90 (m, 29 H, 3 × Si-$(CH_2$-$CH_3)_3$, $SiCH_2$ (TEOC)), 0.89−0.81 (b m, 3 H, CH_3-CH_2N), 0.67−0.59 (m, 18 H, 3 × $Si(CH_2$-$CH_3)_3$), 0.03 (s, 9 H, $Si(CH_3)_3$); ^{13}C NMR (125 MHz, C_6D_6, 75 °C) δ 191.9, 160.0, 159.8, 158.5, 155.8, 152.6, 151.5, 145.0, 144.9, 143.9, 141.9, 133.9, 131.9, 131.4, 130.5, 130.0, 129.1, 128.5, 127.7, 127.3, 125.4, 120.1, 114.3, 104.9, 102.8, 101.2, 98.8, 94.4, 82.2, 80.7, 79.1, 73.4, 73.3, 73.0, 72.8, 71.3, 71.1, 70.4, 69.4, 69.2, 67.1, 64.9, 61.6, 61.0, 60.6, 57.1, 55.4, 55.0, 54.9, 52.2, 48.2, 38.6, 36.5, 25.6, 19.2, 18.5, 18.4, 18.3, 14.9, 7.2, 7.0, 6.9, 5.9, 5.6, 5.4, −1.6; FAB HRMS for $C_{92}H_{139}IN_2O_{23}SSi_4Na$ (M + Na), calcd 1933.7507, found 1933.7371.

(4-Methoxyphenyl)methyl 4,6-Dideoxy-4-{[(2,4,6-trideoxy-4-{[4-[(6-deoxy-3-*O*-methyl-2,4-*O*,*O*-bis(triethylsilyl)-α-L-mannopyranosyl)oxy]-5-iodo-2,3-dimethoxy-6-methylbenzoyl]thio}-3-*O*-(triethylsilyl)-β-D-*ribo*-hexopyranosyl)oxy][2-(trimethylsilyl)ethoxycarbonyl]amino}-2-*O*-{2,4-dideoxy-4-[ethyl(9*H*-fluoren-9-ylmethoxycarbonyl)amino]-3-*O*-methyl-α-L-*threo*-pentopyranosyl}-3-*O*-[(4-methoxyphenyl)methyl]-α-D-glucopyranoside (128). DDQ (240 mg, 1.05 mmol) was added to a solution of diPMB ether **127** (403 mg, 211 μmol) in CH_2Cl_2/pH 7 buffer solution (20:1, 21 mL). After being stirred at room temperature for 24 h, the reaction mixture was diluted with EtOAc (300 mL) and washed with saturated aqueous $NaHCO_3$ (3 × 100 mL) and brine (100 mL). The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified by flash column chromatography (hexanes/EtOAc 70:30 to 40:60) to provide lactol **128** (280 mg, 80%), along with the compound which was desilylated at O-4 of the rhamnose moiety (62 mg, 19%). **128:** white amorphous solid; $[\alpha]^{25}_D$ −13.9° (*c* 1.78, $CHCl_3$); FT-IR (MIDAC, $CHCl_3$) ν_{max} 3500, 3015, 2957, 2877, 1684, 1457, 1416, 1393, 1276, 1252, 1239, 1140, 1087, 1066, 1015 cm^{-1}; ^1H NMR (490 MHz, DMSO-d_6, 100 °C) δ 7.84 (d, 2 H, *J* = 7.5 Hz, ArH (FMOC)), 7.64 (b d, 2 H, *J* = 7.5 Hz, ArH (FMOC)), 7.39 (dd, 2 H, *J* = 7.5, 7.5 Hz, ArH (FMOC)), 7.31 (ddd, 2 H, *J* = 7.5, 7.5, 1.1 Hz, ArH (FMOC)), 5.40 (d, 1 H, *J* = 2.1 Hz, D-1), 5.18−5.11 (m, 2 H, B-1, E-1), 5.01 (d, 0.5 H, *J* = 3.6 Hz, A-1 (α)), 4.44−4.42 (m, 4 H, D-2, A-3, OCH_2 (FMOC)), 4.40−4.36 (m, 1 H, B-3), 4.30−4.13 (m, 4 H, CH (FMOC), E-3, OCH_2 (TEOC)), 4.22 (d, 0.5 H, *J* = 8.2 Hz, A-1 (β)), 4.12−3.99 (m, 3 H, B-5, A-5, E-5_{ax}), 3.88−3.76 (m, 1 H, A-4), 3.81 (2 s, 2 × 1.5 H, $ArOCH_3$ (α/β)), 3.78 (s, 3 H, $ArOCH_3$), 3.73 (app t, 1 H, *J* = 8.9 Hz, D-4), 3.70−3.67 (m, 1 H, E-4), 3.68 (dd, 1 H, *J* = 10.5, 2.5 Hz, B-4), 3.57 (dd, 1 H, *J* = 9.0, 2.7 Hz, D-3), 3.40 (s, 3 H, OCH_3), 3.37−3.30 (m, 1 H, E-5_{eq}), 3.26−3.21 (m, 1 H, A-2 (α/β)), 3.17 (2 s, 2 × 1.5 H, OCH_3 (α/β)), 3.17−2.98 (m, 2 H, CH_2N), 2.38−2.33 (m, 1 H, E-2_{eq}), 2.32 (2 s, 2 × 1.5 H, $ArCH_3$ (α/β)), 2.07−2.03 (m, 1 H, B-2_{eq}), 1.91−1.83 (m, 1 H, B-2_{ax}), 1.39−1.33 (m, 1 H, E-2_{ax}), 1.32 (2 d, 2 × 1.5 H, *J* = 6.1 Hz, B-6 (α/β)), 1.17 (d, 3 H, *J* = 6.1 Hz, D-6), 1.11 (d, 1.5 H, *J* = 6.0 Hz, A-6), 1.08 (d, 1.5 H, *J* = 6.3 Hz, A-6), 1.04−1.01 (m, 2 H, $SiCH_2$ (TEOC)), 0.98−0.90 (m, 30 H, 3 $Si(CH_2$-$CH_3)_3$, CH_3-CH_2N), 0.67−0.59 (m, 18 H, 3 $Si(CH_2$-$CH_3)_3$), 0.05 (s, 9 H, $Si(CH_3)_3$); ^{13}C NMR (125 MHz, C_6D_6, 75 °C) δ 191.9, 191.8, 158.7, 156.0, 155.7, 152.6, 152.5, 151.5, 145.03, 144.97, 144.8, 144.7, 143.8, 142.0, 133.9, 133.85, 131.3, 131.2, 128.4, 123.3, 127.9, 127.7, 127.6, 127.5, 127.4, 127.3, 127.2, 125.4, 125.3, 120.1, 104.9, 100.8, 100.7, 100.1, 99.0, 97.1, 94.4, 94.35, 93.2, 82.2, 80.5, 79.6, 73.4, 73.0, 72.6, 72.4, 72.2, 71.4, 71.3, 70.5, 69.3, 68.6, 68.4, 68.1, 67.1, 66.8, 65.0, 64.8, 64.7, 61.5, 60.6, 57.1, 55.8, 55.6, 52.01, 51.99, 48.2, 38.0, 37.9, 36.0, 25.6, 18.8, 18.5, 18.2, 17.7, 14.9, 14.6, 7.15, 7.0, 6.9, 5.9, 5.6, 5.4, −1.7; FAB HRMS for $C_{76}H_{123}IN_2O_{21}SSi_4Na$ (M + Na), calcd 1693.6357, found 1693.6327.

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