Synthesis of the Central Portion of Cycloviracin

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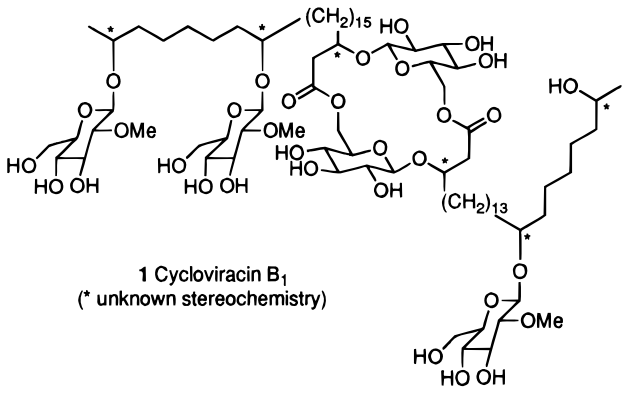
Introduction

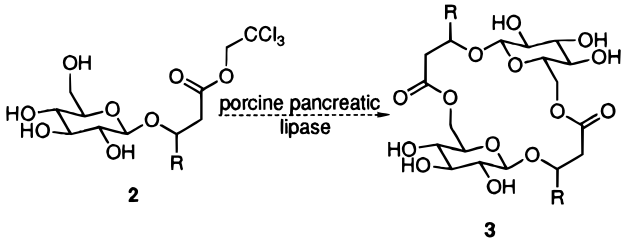
Cycloviracin B_1 (**1**) was recently isolated from a soil microorganism and discovered to have activity against Herpes simplex virus.[1] The interesting structure of the cycloviracins reveals the presence of a "core" portion composed of two glucose molecules as part of the macrolactone.[2] Attached to the glycosidic core are two alkyl side chains with several 2-methylglucopyranosides. The stereogenic centers of the alkyl group at the site of attachment to the macrolactone portion and those along the alkyl side chains are currently unknown. To help elucidate the various stereogenic centers and because of the unique structure and antiviral activity, we set out to synthesize the core region of cycloviracin. In this paper, we wish to communicate our results in preparing a suitably protected glycoside intermediate **16** that served as a precursor for the stepwise construction of the cycloviracin core. This effort should aid in the determination of the two unknown stereogenic centers of the core.



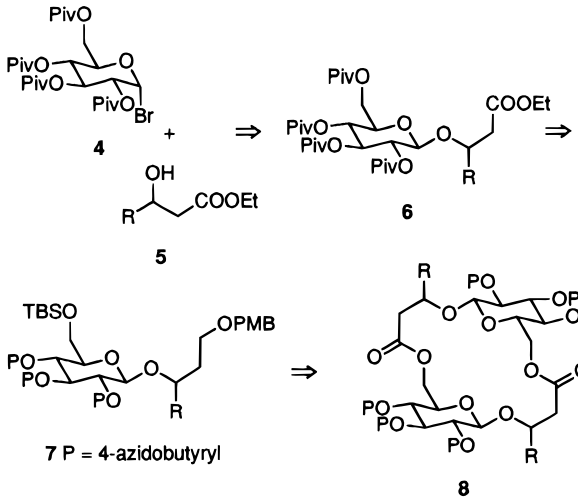
Results And Discussion

An examination of the cycloviracin core reveals a macrolactone consisting of two nearly identical glycosidic esters with the core reminiscent of crown ethers.[3] As the cycloviracin core is composed of two glucose molecules acylated at the 6-position, we initially investigated enzymatic methods for esterifying a glucopyranoside at the 6-position with an appropriate activated ester. An enzymatic approach would have allowed for a facile entry of the core region in one step from a suitable intermediate, such as **2** (Scheme 1). We reasoned that an enzymatic approach would "dimerize" glucopyranoside **2** to **3** using porcine pancreatic lipase (PPL) or chromobacterium viscosum lipase (CVL).[4] Early results with a simple model system (methyl β-glucopyranoside) were discouraging as acylations with simple trichloroethyl esters did not yield the desired 6-acylated monosaccharide. These results prompted us to employ a different approach.

Scheme 1



Scheme 2



Retrosynthetic analysis identified the needed components and reduced the problem to glucopyranoside **7** (Scheme 2), which may be available from **4** and **5** via **6**. The goal became preparation of glycoside **7** that is both suitably functionalized and protected to allow for a stepwise construction of the core region. The presence of the pivolates on the glucopyranosyl bromide **4** suggested the need for conversion of the carboxylic ester to a protected *p*-methoxybenzyl ether that is stable to the base-catalyzed removal of the pivolates yet can be oxidatively removed. We arbitrarily choose the *S*-configuration for the β-hydroxy ester as **9** can be obtained from the Bakers' yeast reduction of ethyl acetoacetate.[5] The β-hydroxy ester can also be obtained by ruthenium−BINAP reduction of β-keto esters.[6] Reductions of various β-keto esters using Bakers' yeast typically give 70−90% ee and in our hands, β-hydroxy ester **9** of 85% ee was obtained. The enantiomeric purity was determined by

† Undergraduate research participant.

(1) Tsunakawa, M.; Komiyama, N.; Tenmyo, O.; Tomita, K.; Kawano, K.; Kotake, C.; Konishi, M.; Oki, T. *J. Antibiot.* **1992**, *45*, 1467−1471.

(2) Tsunakawa, M.; Kotake, C.; Yamasaki, T.; Moriyama, T.; Komishi, M.; Oki, T. *J. Antibiot.* **1992**, *45*, 1472−1480.

(3) For an example of crown ethers: Lein, G. M.; Cram, D. J. *J. Am. Chem. Soc.* **1985**, *107*, 448−455. McDaniel, C. W.; Bradshaw, J. S.; Izath, R. M. *Heterocycles* **1990**, *30*, 665−706. Aza-crown ethers: Krakowiak, K. E.; Bradshaw, J. S.; Zamecka-Krakowiak, D. J. *Chem. Rev.* **1989**, *89*, 929−972. Aza-crown ethers incorporating a carbohydrate: Bako, P.; Fenichel, L.; Toke, L.; Davison, B. E. *J. Chem. Soc., Perkin Trans. 1* **1989**, 2514−2516.

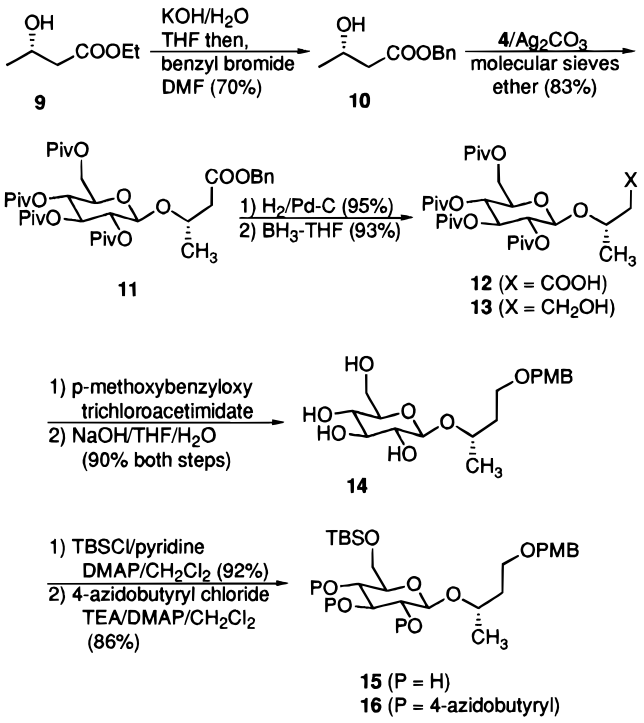
(4) Therisod, M.; Klibanov, A. M. *J. Am. Chem. Soc.* **1986**, *108*, 5638−5640. Therisod, M.; Klibanov, A. M. *J. Am. Chem. Soc.* **1987**, *109*, 3977−3981. Riva, S.; Chopineau, J.; Kieboom, A. P. G.; Klibanov, A. M. *J. Am. Chem. Soc.* **1988**, *110*, 584−589.

(5) Seebach, D.; Sutter, M. A.; Weber, R. H.; Züger, M. F. *Org. Synth.* **1984**, *63*, 1−9. Nakamura, K.; Kawai, Y.; Oka, S.; Ohno, A. *Bull. Chem. Soc. Jpn.* **1989**, *62*, 875−879. Crump, D. R. *Aust. J. Chem.* **1982**, *35*, 1945−1948.

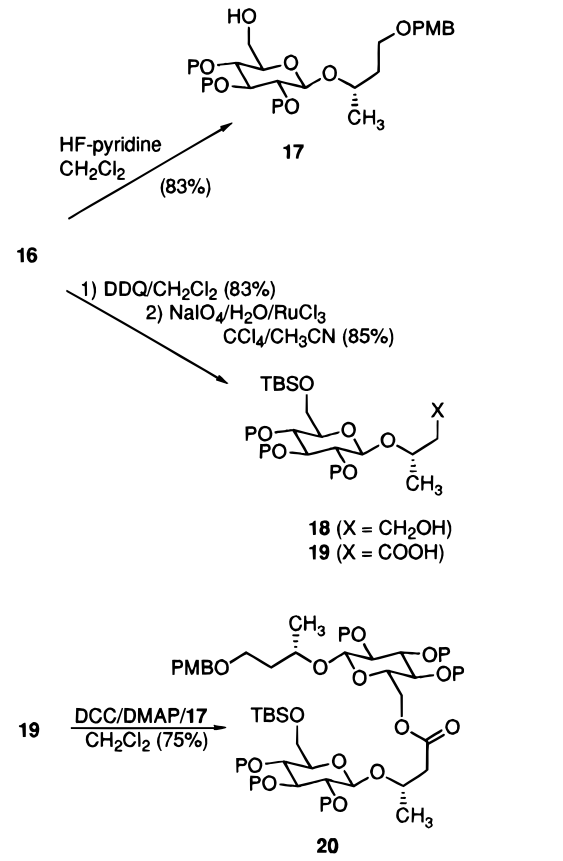
(6) Keck, G. E.; Murry, J. A. *J. Org. Chem.* **1991**, *56*, 6606−6611. Noyori, R.; Ohkuma, T.; Kitamura, M.; Sayo, N.; Kumobayashi, H.; Akutagawa, S. *J. Am. Chem. Soc.* **1987**, *109*, 5856−5858.

S0022-3263(96)01623-4 CCC: $12.00

Scheme 3



Scheme 4



conversion to the *O*-methylmandelate[7] and Mosher's ester[8] followed by examination of ^{1}H- and ^{19}F-NMR spectral data, respectively. Saponification of ethyl ester **9** and benzylation afforded **10**.[9]

When α-glucopyranosyl bromide **4** was employed as the glycosylation reagent[10] glycoside **11** was obtained in good yield and anomeric control (Scheme 3). Spectral analysis of **11** revealed that the anomeric integrity was maintained. A closer examination showed the presence of a small amount (~5%) of the diastereomer resulting from the inefficient Bakers' yeast reduction of the *β*-keto ester; however, we anticipated removal of the unwanted diastereomer at latter stages. Reductive removal of the benzyl ester afforded the crystalline acid **12** and following diborane reduction in the presence of the pivolates yielded alcohol **13**. Protection of **13** (PMBO−trichloroacetimidate/triflic acid catalyst)[11] followed by pivolate removal cleanly afforded glycoside **14**. Spectral examination of **14** (^{1}H- and ^{13}C-NMR) showed removal of the unwanted diastereomer by flash chromatography. Silylation of **14** occurred regioselectively[12] to place the *tert*-butyldimethylsilyl protecting group at the 6-position, affording **15**. Esterification of the remaining hydroxyl groups with 4-azidobutyryl chloride[13] yielded **16**, which gave spectral data (^{1}H, ^{13}C-NMR, COSY, and NOE) that were consistent with the correct placement of protecting groups. Intermediate **16** was then ready for divergence to the two coupling partners **17** and **19** for the stepwise construction of the core region (Scheme 4). Desilylation of **16** afforded **17**, whereas oxidative removal of the PMB group from **16** followed by $RuCl_3$-mediated oxidation yielded acid **19**.

The two components were coupled (DCC/DMAP) to yield **20**, and after oxidative removal of the *p*-methoxybenzyl ether, oxidation of the alcohol to the acid, and desilylation ((a) DDQ; (b) $NaIO_4/RuCl_3/CCl_4-CH_3CN-$water; (c) HF−pyridine), precursor **23** was obtained (Scheme 5). Disaccharide **23** was submitted to the Yamaguchi macrocyclization[14] to give protected **24** in 73% yield. We were quite pleased with the cyclization because few side products were obtained as judged by TLC analysis. The last step, reductive removal of the azidobutryrate groups to give **25**, was initially troublesome. The product was finally obtained by employing distilled ethanol in both the reduction and thermolysis to **25** and the pyrrolidinone byproduct. Purification by column chromatography (30% MeOH−$CHCl_3$) yielded a white solid whose spectral data (^{1}H, ^{13}C, HMBC, HMQC, MS) indicated >95% purity. A minor side product isolated and identified was the ethyl ester of the monosaccharide.

Synthetic lactone **25** was nearly consistent with cycloviracin. The ^{13}C, HMBC, HMQC, and HRMS were exceedingly useful in confirming **25**; however, two of the

(7) Trost, B. M.; Belletire, J. L.; Godleski, S.; McDougal, P. G.; Balkovec, J. M.; Baldwin, J. J.; Christy, M. E.; Ponticello, G. S.; Varga, S. L.; Springer, J. P. *J. Org. Chem.* **1986**, *51*, 2370−2374. Bonner, W. A. *J. Am. Chem. Soc.* **1951**, *73*, 3126−3132.

(8) Dale, J. A.; Mosher, H. S. *J. Am. Chem. Soc.* **1973**, *95*, 512−519. König, W. A.; Nippe, K.-S.; Mischnick, P. *Tetrahedron Lett.* **1990**, *31*, 6867−6868.

(9) Sakaki, J.-i.; Kobayashi, S.; Sato, M.; Kaneko, C. *Chem Pharm. Bull.* **1989**, *37*, 2952−2960.

(10) Schmidt, R. R. *Angew. Chem., Int. Ed. Engl.* **1986**, *25*, 212−235. Paulsen, H. *Angew. Chem., Int. Ed. Engl.* **1982**, *21*, 155−173. Mori, K.; Qian, Z.-H. *Leibigs Ann. Chem.* **1994**, 291−295. Kunz, H.; Harreus, A. *Liebigs Ann. Chem.* **1982**, 41−48. Collins, P.; Ferrier, R. *Monosaccharides−Their Chemistry and Their Roles in Natural Products*; Wiley: New York, 1995; pp 60−184.

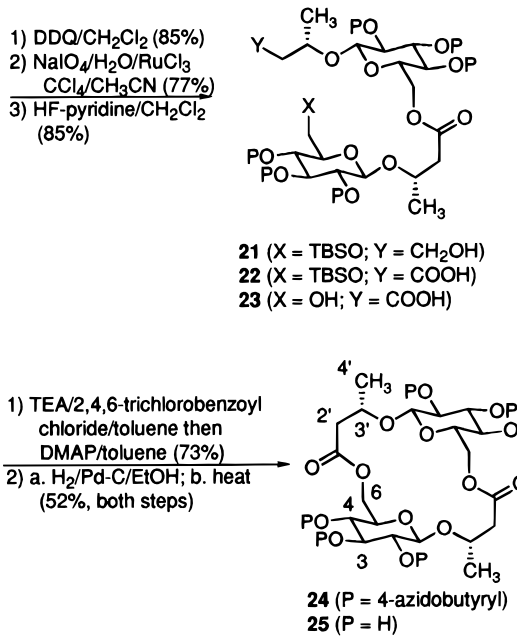
(11) Nakajima, N.; Horita, K.; Abe, R.; Yonemitsu, O. *Tetrahedron Lett.* **1988**, *29*, 4139−4142.

(12) Hanessian, S.; Lavalee, P. *Can. J. Chem.* **1975**, *53*, 2975−2977. Franke, F.; Guthrie, R. D. *Aust. J. Chem.* **1977**, 639−647.

(13) Kucumoto, S.; K. Sakai, K.; Shiba, T. *Bull. Chem. Soc. Jpn.* **1986**, *59*, 1296−1298. Goel, O. P.; Seamans, R. E. *Synthesis* **1973**, 538−539.

(14) Inanaga, J.; Hirata, K.; Saeki, H.; Katsuki, T.; Yamuguchi, M. *Bull. Chem. Soc. Jpn.* **1979**, *52*, 1989−1993.

Scheme 5



carbon atoms, C-3′ and C-1 (anomeric), were slightly different (<4 ppm). All of the other carbons were within 1 ppm with authentic cycloviracin. We are currently examining **25** and another simple analog of cycloviracin in order to determine the configuration of the two stereogenic centers at the β-hydroxy glycosidic portion. Our findings will be reported in the future.

Experimental Section

General Methods. All solvents were distilled from calcium hydride prior to use except for tetrahydrofuran (THF), which was distilled from molten potassium, and ethyl ether, which was distilled from sodium−benzophenone. Methanol and ethanol were distilled from Mg turnings. All reagents were used as obtained from commercial suppliers unless otherwise noted. Thin layer chromatography was performed with glass-backed precoated plates (Si-254F). Column chromatography utilized silica gel 230−400 mesh, 60 Å. The following deuterated solvents and their following internal reference points were used: deuteriochloroform ($CDCl_3$) with tetramethylsilane (TMS) referenced to TMS (0.000 ppm ^{1}H) or chloroform (77.00 ppm ^{13}C), methanol-d_4 referenced to methanol (3.48 ppm ^{1}H and 39.00 ppm ^{13}C), and pyridine-d_5 referenced to pyridine (7.22 ppm ^{1}H and 123.5 ppm ^{13}C). Melting points are uncorrected. Elemental analyses were performed by Atlantic Microlab (Norcross, GA). Mass spectroscopy (FAB) was performed at the Nebraska Center for Mass Spectroscopy and Washington University Resource for Biomedical and Bioorganic Mass Spectrometry.

2,3,4,6-Tetra-*O*-pivaloyl-α-D-glucopyranosyl Bromide (4). This compound was prepared in two steps from D-glucose and pivoyl chloride, according to a literature procedure.[10] Glucose was first converted to 1,2,3,4,6-penta-*O*-pivaloyl-β-D-glucopyranose [mp 145−149 °C; R_f = 0.43 (12% EtOAc/hexane); ^{1}H ($CDCl_3$) δ 1.1 (s, 18H), 1.13 (s, 9H), 1.15 (s, 9H), 1.18 (s, 9H), 3.8−3.9 (m, 1H), 4.1−4.2 (m, 2H), 5.1−5.2 (m, 2H), 5.3−5.4 (t, 1H, J = 9.4 Hz), 5.7 (d, 1H, J = 8.3 Hz)], which was then treated with HBr in acetic acid to give **4** as a white solid: mp = 145 °C; R_f = 0.53 (12% EtOAc/hexane); ^{1}H ($CDCl_3$) δ 1.1 (s, 9H), 1.14 (s, 9H), 1.15 (s, 9H), 1.2 (s, 9H), 4.1 (m, 2H), 4.2−4.3 (dt, 1H, J = 3.2 Hz, 10.5 Hz), 4.7−4.8 (dd, 1H, J = 4.1 Hz, 9.9 Hz), 5.2 (t, 1H, J = 9.9 Hz), 5.6 (t, 1H, J = 9.7 Hz), 6.6 (d, 1H, J = 4.0 Hz); ^{13}C ($CDCl_3$) δ 177.9, 177.3, 176.8, 176.4, 86.9, 72.6, 70.9, 69.6, 66.6, 60.9, 38.9, 38.8, 38.680, 27.2, 27.1.

(3*S*)-Benzyl 3-[(2,3,4,6-Tetra-*O*-pivaloyl-β-D-glucopyranosyl)oxy]butanoate (11). A solution of 200 mg (1.00 mmol) of **10**, 1.19 g (2.1 mmol, 2.00 equiv) of **4**, 568 mg (2.1 mmol) of Ag_2CO_3, 2.50 g of 4 Å molecular sieves, and 50 mL of ether was stirred in the dark, under N_2, for 2 d. The mixture was filtered through Celite and the solvent removed under reduced pressure. The residue was purified by column chromatography (25% EtOAc/hexane) to give 1.3 g (83% yield) of **11** as a colorless viscous oil that slowly crystallized upon standing: mp 76−77 °C; R_f = 0.54 (25% EtOAc/hexane); $[\alpha]^{24}_D$ +12.6° (c 12.5, $CHCl_3$); ^{1}H($CDCl_3$) δ 1.0, 1.1, 1.13, 1.18 (4s, 36H), 1.2 (d, 3H, J = 6.0 Hz), 2.3 (dd, 1H, J = 5.5, 16.5 Hz), 2.5 (dd, 1H, J = 7.7, 16.5 Hz), 3.5−3.6 (m, 1H), 3.9 (dd, 1H, J = 6.0, 12.1 Hz), 4.1−4.2 (m, 1H, methine), 4.1−4.2 (m, 1H), 4.6 (d, 1H, J = 8.2 Hz), 4.8−5.0 (m, 3H), 5.1−5.2 (m, 2H), 7.3−7.4 (m, 5H); ^{13}C ($CDCl_3$) δ 177.9, 177.0, 176.4, 176.3, 170.6, 135.5, 128.6, 128.4, 128.4, 100.1, 72.2, 72.1, 71.9, 71.2, 68.2, 66.3, 62.0, 41.9, 38.7, 38.6, 38.6, 27.0 (overlapping signals), 21.8. Anal. Calcd for $C_{37}H_{56}O_{12}$ (692.84): C, 64.14; H, 8.15. Found: C, 63.89; H, 8.21.

(3*S*)-3-[(2,3,4,6-Tetra-*O*-pivaloyl-β-D-glucopyranosyl)oxy]-butanoic Acid (12). A solution containing 4.46 g (6.43 mmol) of **11**, 200 mL of methanol, and 400 mg of Pd−C (5% Pd) was hydrogenated for 5 h using a Parr hydrogenation apparatus. Filtration of the mixture through a pad of Celite and evaporation of solvent *in vacuo* left a viscous oil that was further purified by column chromatography (50% EtOAc/hexane followed by 50% EtOAc/methanol) to give 3.67 g (95% yield) of **12** as a white solid: R_f = 0.1 (25% EtOAc/hexane); mp 171.5−173 °C; $[\alpha]^{24}_D$ +7.8° (c 17.7, $CHCl_3$); ^{1}H($CDCl_3$) δ 1.1, 1.11, 1.13, 1.2 (4s, 36H), 1.3 (d, 3H, J = 6.3 Hz), 2.4 (dd, 1H, J = 5.5, 16.7 Hz), 2.6 (dd, 1H, J = 7.1, 16.5 Hz), 3.7−3.8 (m, 1H), 3.9 (dd, 1H, J = 6.3, 12.1 Hz), 4.15 (m, 1H), 4.2 (dd, 1H, J = 1.9, 12.1 Hz), 4.7 (d, 1H, J = 8.0 Hz), 4.94−5.1 (m, 2H), 5.3 (t, 1H, $J \approx$ 9.4 Hz); ^{13}C ($CDCl_3$) δ 178.1, 177.2, 176.6, 176.5, 176.1, 100.6, 72.4, 72.2, 71.4, 68.3, 62.1, 41.5, 38.9, 38.8, 38.7, 38.7, 27.1 (overlapping signals), 21.9. Anal. Calcd for $C_{30}H_{50}O_{12}$ (602.72): C, 59.78; 8.36. Found: C, 59.67; H, 8.37.

(3*S*)-3-[(2,3,4,6-Tetra-*O*-pivaloyl-β-D-glucopyranosyl)oxy]-1-butanol (13). A solution of 2.52 g (4.19 mmol) of **12**, 30 mL of THF, and 8.4 mL (1 M, 8.4 mmol) of BH_3−THF was allowed to stir at 0 °C for 30 min, followed by warming to rt for an additional 30 min. The reaction was slowly quenched by dropwise addition of 16 mL of water. The mixture was poured into a separatory funnel containing Et_2O/water. The aqueous layer was extracted with ether (2 × 20 mL), and the combined organic layers were washed with saturated aqueous $NaHCO_3$ (2 × 30 mL) and then dried over $MgSO_4$. Filtration and evaporation of solvent *in vacuo* left a solid that was further purified by column chromatography (50% EtOAc/hexane) to give 2.92 g (93% yield) of **13** as a white solid: R_f = 0.68 (50% EtOAc/hexane); mp 125−127 °C; $[\alpha]^{24}_D$ +10.1° (c 25.6, $CHCl_3$); ^{1}H ($CDCl_3$) δ 1.1, 1.12, 1.13, 1.2 (4s, 36H), 1.23 (d, 3H, J = 6.4 Hz), 1.6−1.8 (m, 2H), 3.6 (pent, 1H), 3.66−3.7 (m, 2H), 3.9 (m, 1H), 3.95 (dd, 1H, J = 6.4, 12.1 Hz), 4.6 (d, 1H, J = 7.7 Hz), 4.9−5.1 (m, 2H), 5.3 (t, 1H, J = 9.5 Hz); ^{13}C ($CDCl_3$) δ 181.1, 177.1, 176.6, 176.5, 100.5, 75.2, 72.4, 72.1, 71.6, 68.3, 62.2, 59.3, 39.4, 38.8, 38.7, 38.7, 27.1, 27.1, 27.1, 27.0, 21.5. Anal. Calcd for $C_{30}H_{52}O_{11}\cdot 1/2H_2O$: C, 60.28; H, 8.94. Found: C, 60.28; H, 8.94.

1-[(*p*-Methoxybenzyl)oxy]-(3*S*)-3-((β-D-glucopyranosyl-oxy)butane (14). A solution of 4.16 g (7.07 mmol) of **13**, 3.0 g (10.6 mmol, 1.50 equiv) of 4-methoxybenzyl 2,2,2-trichloroacetimidate, 50 mL of Et_2O, and one drop (from a microliter syringe) of trifluoromethanesulfonic acid (TfOH) was stirred under N_2 at rt until TLC analysis showed complete consumption of starting material (about 2 h). The reaction mixture was poured into a separatory funnel containing aqueous saturated $NaHCO_3$ and ether. The aqueous phase was washed with ether (2 × 50 mL), and the combined organic layers were dried over $MgSO_4$. Filtration and evaporation of solvent *in vacuo* left a viscous oil that was further purified by column chromatography (25% EtOAc/hexane) to give a solid that by ^{1}H-NMR showed the product and excess 4-methoxybenzyl alcohol (obtained by the hydrolysis of the trichloroacetimidate during workup). HPLC analysis showed a 4:1 ratio of product over 4-methoxybenzyl alcohol. The product was not fully characterized but carried on to the next step: R_f = 0.46 (25% EtOAc/hexane); ^{1}H ($CDCl_3$) δ 1.1, 1.15, 1.17, 1.21 (4s, 36H), 1.2 (d, 3H), 1.6−1.8 (m, 2H), 3.4−3.5 (m, 2H), 3.6 (m, 1H), 3.8 (s, 3H), 4.0 (dd, 1H, J = 6.6, 12.1 Hz), 4.2 (dd, 1H, J = 1.9, 12.1 Hz), 4.9−5.5.1 (m, 2H), 5.2 (t, 1H, $J \approx$ 9.5 Hz), 6.9 (d, 2H, J = 8.7), 7.25 (d, 2H, J = 8.7 Hz) for selected peaks. A solution made up of the crude glucoside, 30 mL of a 3% NaOH solution, and 80 mL of ethanol was stirred

until TLC analysis showed complete comsumption of starting material (about 36 h). The reaction mixture was quenched by the addition of 4 g of Amberlite until pH 7. The solution was filtered and the Amberlite washed with MeOH. Evaporation of solvent *in vacuo* gave a viscous oil that was further purified by column chromatography (10% MeOH/$CHCl_3$) to give 2.39 g (90.8% from **13**) of **14** as a viscous oil that slowly crystallized upon standing: mp 75−76 °C; R_f = 0.13 (10% MeOH/$CHCl_3$); $[\alpha]^{24}_D$ −10.6° (*c* 12.6, $CHCl_3$); ^{1}H ($CDCl_3$) δ 1.2 (d, 3H, *J* = 4.2 Hz), 1.6−1.70 (m, 1H), 1.8−1.85 (m, 1H), 3.2 (d, 1H, *J* = 6.9 Hz), 3.4−3.52 (m, ∼2H), 3.53−3.63 (m, ∼3H), 3.7−3.8 (t, 1H, *J* = 6.1 Hz), 3.74 (s, 3H), 3.76 (br s, ∼1H), 3.87 (sext, 1H), 4.3 (d, 1H, *J* = 5.40 Hz), 4.34−4.4 (AB quartet, 2H, *J* ≈ 8.8 Hz), 6.84 (d, 2H, *J* = 6.3 Hz), 7.2 (d, 2H, *J* = 6.3 Hz); ^{13}C ($CDCl_3$) δ 159.1, 130.2, 129.4, 113.8, 102.8, 76.4, 75.5, 74.9, 73.5, 72.4, 69.4, 66.3, 61.5, 55.2, 36.4, 21.8. Anal. Calcd for $C_{18}H_{28}O_8$: C, 58.05; H, 7.58 (372.41). Found: C, 58.11; H, 7.58.

1-[(*p*-Methoxybenzyl)oxy]-(3*S*)-3-[[6-*O*-(*tert*-butyldimethylsilyl)-*β*-D-glucopyranosyl]oxy]butane (15). A solution of 1.69 g (4.53 mmol) of **14**, 650 mg (9.52 mmol, 2.10 equiv) of imidazole, and 30 mL of CH_2Cl_2 was stirred at 0 °C. To this solution was added in a single portion 752 mg (5.00 mmol, 1.1 equiv) of *tert*-butyldimethylsilyl chloride dissolved in 5 mL of CH_2Cl_2. After the mixture was stirred for 1 d at 0 °C, TLC analysis showed complete conversion of starting material. The solvent was removed under reduced pressure, and the residue was directly applied to a column (10% MeOH/$CHCl_3$) to give 2.0 g (92% yield) of **15** as a viscous oil: R_f = 0.40 (10% MeOH/$CHCl_3$); $[\alpha]^{24}_D$ −11.6° (*c* 7.1, $CHCl_3$); ^{1}H ($CDCl_3$) δ 0.05, 0.06 (2s, 6H), 0.9 (s, 9H), 1.22 (d, 3H, *J* = 6.6 Hz), 1.70−1.80 (m, 2H), 3.26−3.33 (m, 2H), 3.39−3.53 (m, 3H), 3.56−3.62 (m, 1H), 3.77 (s, 3H), 3.75−3.80 (m, 1H), 3.84−3.93 (m, 2H), 4.04 (br s, 3H), 4.26 (d, 1H, *J* = 7.8 Hz), 4.40 (s, 2H), 6.86 (d, 2H, *J* = 8.4 Hz), 7.23 (d, 2H, *J* = 8.4 Hz); ^{13}C ($CDCl_3$) δ 159.1, 130.1, 129.4, 113.7, 102.7, 76.4, 75.1, 74.9, 73.6, 72.4, 71.6, 66.2, 64.0, 55.1, 36.4, 25.8, 21.8, 18.1, −5.5. Anal. Calcd for $C_{24}H_{42}O_8Si$ (486.68): C, 59.23; H, 8.70. Found: C, 59.04; H, 8.74.

1-[(4-Methoxybenzyl)oxy]-(3*S*)-3-[[2,3,4-tris-*O*-(4-azidobutanoyl)-6-*O*-(*tert*-butyldimethylsilyl)-*β*-D-glucopyranosyl]oxy]butane (16). A solution of 2.38 g (4.90 mmol) of glycoside **15**, 30 mL of CH_2Cl_2, 2.4 mL (29.4 mmol, 6 equiv) of pyridine, and 4.34 g (29.4 mmol, 6 equiv) of 4-azidobutyryl chloride was stirred at 0 °C for 6 h under N_2. The reaction mixture was poured into a separatory funnel containing water and CH_2Cl_2. The product was extracted with three (10 mL) portions of CH_2Cl_2. The organic layers were combined, washed with saturated $NaHCO_3$ and brine, and dried over $MgSO_4$. Filtration and evaporation of solvent *in vacuo* left a viscous oil that was further purified by column chromatography (25% EtOAc/hexane) to give 3.5 g (86% yield) of **16** as a viscous oil: R_f = 0.35 (25% EtOAc/hexane); $[\alpha]^{24}_D$ +15.4° (*c* 6.4, THF); ^{1}H ($CDCl_3$) δ 0.04, 0.057 (2s, 6H), 0.9 (s, 9H), 1.23 (d, 3H, *J* = 5.1 Hz), 1.67−1.74 (m, 2H), 1.8−1.89 (m, 6H), 2.3−2.39 (m, 6H), 3.3−3.35 (m, 6H), 3.4−3.5 (m, 3H), 3.66−3.68 (m, 2H), 3.8 (s, 3H), 3.86−3.9 (m, 1H), 4.37 (d, 1H, *J* = 11.6 Hz), 4.44 (d, 1H, *J* = 8.4 Hz), 4.5 (d, 1H, *J* = 11.6 Hz), 4.9 (dd, 1H, *J* ≈ 9.4 Hz), 5.05 (t, 1H, *J* ≈ 9.8 Hz), 5.1 (t, 1H, *J* = 9.6 Hz), 6.9 (d, 2H, *J* = 6.6 Hz), 7.25 (d, 2H, *J* = 6.3 Hz); ^{13}C ($CDCl_3$) δ 172.1, 171.1, 171.0, 159.2, 130.4, 129.3, 113.9, 100.6, 74.4, 74.4, 73.6, 72.5, 72.0, 69.0, 65.9, 62.3, 55.3, 50.4, 50.4, 50.3, 37.1, 30.9, 30.9, 30.8, 24.0, 23.9, 21.9, 18.2, −5.4, −5.5. Anal. Calcd for $C_{36}H_{57}N_9O_{11}Si$ (819.98): C, 52.73; H, 7.01; N, 15.37. Found: C, 52.64; H, 7.03; N, 15.26.

(3*S*)-1-[(4-Methoxybenzyl)oxy]-3-[[2,3,4-tris-*O*-(4-azidobutanoyl)-*β*-D-glucopyranosyl]oxy]butane (17). A solution of 2.95 g (3.61 mmol) of **16**, 30 mL of dry THF, and excess HF−pyridine (added *via* pipet) was stirred overnight at rt. The reaction was extracted three times from saturated aqueous $NaHCO_3$ and EtOAc. The organic layers were combined and dried over $MgSO_4$. Filtration and evaporation of solvent *in vacuo* left a pale yellow oil and was further purified by column chromatography (50% EtOAc/hexane) to afford 2.11 g (83%) of **17**: R_f = 0.27 (50% EtOAc/hexane); $[\alpha]^{24}_D$ +11.7° (*c* 2.55, THF); ^{1}H ($CDCl_3$) δ 1.23 (d, 3H, *J* = 6 Hz), 1.6−1.9 (m, 9H), 2.0 (br s, 1H), 2.3−2.43 (m, ∼6H), 3.3−3.35 (m, 6H), 3.4−3.6 (m, 3H), 3.72 (dd, 1H, *J* = 2.4, 12.3 Hz), 3.82 (s, 3H), 3.87−3.9 (m, 1H), 4.35 (d, 1H, *J* = 11.5 Hz), 4.47 (d, 1H, *J* = 11.5 Hz), 4.5 (d, 1H, *J* = 8.1), 4.9−5.0 (dd, 1H, *J* = 7.8, 9.6 Hz), 5.05 (t, 1H, *J* = 9.6 Hz), 5.2 (t, 1H, *J* = 9.3 Hz), 6.9 (d, 2H, *J* = 8.6 Hz), 7.25 (d, 2H, *J* = 8.4 Hz); ^{13}C ($CDCl_3$) δ 171.9, 171.8, 171.0, 159.3, 130.3, 129.3, 113.9, 100.4, 74.5, 73.8, 73.1, 72.6, 71.9, 68.9, 65.8, 61.4, 55.2, 50.3, 50.3, 37.0, 30.9, 30.8, 30.7, 24.0, 22.0. Anal. Calcd for $C_{30}H_{43}N_9O_{11}$ (705.72): C, 51.06; H, 6.14; N, 17.86. Found: C, 50.99; H, 6.16; N, 17.80.

(3*S*)-3-[[2,3,4-Tris-*O*-(4-azidobutanoyl)-6-*O*-(*tert*-butyldimethylsilyl)-*β*-D-glucopyranosyl]oxy]-1-butanol (18). To a solution of 2.40 g (2.93 mmol) of **16** in 35 mL of CH_2Cl_2/water (18:1) at 5 °C was added in one portion (730 mg, 3.22 mmol, 1.1 equiv) of DDQ. The reaction was allowed to proceed for 4 h and then quenched by addition of saturated $NaHCO_3$. The product was extracted with several portions of EtOAc. The organic layers were combined, washed once with water, and dried over $MgSO_4$. Filtration and evaporation of solvent *in vacuo* left a viscous oil and was further purified by column chromatography (50% EtOAc/hexane) to give 1.75 g (83%) of **18**: R_f = 0.38 (50% EtOAc/hexane); $[\alpha]^{24}_D$ +7.57° (*c* 2.7, THF); ^{1}H ($CDCl_3$) δ 0.04, 0.06 (2s, 6H), 0.9 (s, 9H), 1.3 (d, 3H, *J* = 6.6 Hz), 1.6−1.75 (m, 4H), 1.8−1.92 (m, 6H), 2.3−2.4 (m, 6H), 3.3−3.37 (m, 6H), 3.5−3.6 (m, 1H), 3.6−3.75 (m, 4H), 3.9−4.0 (m, 1H), 4.6 (d, 1H, *J* = 8.1 Hz), 4.9−4.98 (dd, 1H, *J* = 7.8, 9.3 Hz), 5.0−5.1 (t, 1H, *J* ≈ 9.6 Hz), 5.17−5.2 (t, 1H, *J* = 9.3 Hz); ^{13}C ($CDCl_3$) δ 172.1, 171.3, 171.2, 100.7, 76.1, 74.5, 73.5, 72.0, 68.9, 62.2, 59.3, 50.3, 39.1, 30.9, 30.8, 30.6, 25.8, 25.7, 25.6, 24.0, 23.9, 23.8, 21.8, 18.2, −5.47, −5.50. Anal. Calcd for $C_{28}H_{49}N_9O_{10}Si$ (699.84): C, 48.05; H, 7.06; N, 18.01. Found: C, 47.78; H, 7.02; N, 17.86.

(3*S*)-3-[[2,3,4-Tris-*O*-(4-azidobutanoyl)-6-*O*-(*tert*-butyldimethylsilyl)-*β*-D-glucopyranosyl]oxy]-1-butanoic Acid (19). A two-phase solution of **18** (177 mg, 0.253 mmol), 120 mg (0.760 mmol) of $KMnO_4$, 40 mL of water, 30 mL of benzene, and 245 mg (0.760 mmol) of tetrabutylammonium bromide (Bu_4NBr) was stirred until TLC analysis showed complete consumption of **18** (about 3 d). The reaction was quenched by addition of saturated $NaHSO_3$ and Amberlite. Filtration left a solution that was extracted with several portions of EtOAc. The organic layers were combined and washed with brine and dried over $MgSO_4$. Filtration and evaporation of solvent *in vacuo* left a viscous oil that was further purified by column chromatography (50% EtOAc/hexane) to give 108 mg (60%) of **19** as a visous oil: R_f = 0.32 (50% EtOAc/hexane); $[\alpha]^{24}_D$ +2.17° (*c* 2.0, THF); ^{1}H ($CDCl_3$) δ 0.04, 0.06 (2s, 6H), 0.9 (s, 9H), 1.25 (br s, 1H), 1.3 (d, 3H, *J* = 6.6 Hz), 1.8−1.9 (m, 6H), 2.3−2.5 (m, 7H), 2.53−2.61 (dd, 1H, *J* = 8.7, 16.2 Hz), 3.3−3.37 (m, 6H), 3.5−3.6 (m, 1H), 3.64−3.73 (m, 2H), 4.2−4.23 (m, 1H), 4.6 (d, 1H, *J* = 7.8 Hz), 4.9−4.95 (dd, 1H, *J* = 8.4, 9.5 Hz), 5.1 (t, 1H, *J* ≈ 9.6 Hz), 5.2 (t, 1H, *J* ≈ 9.6 Hz); ^{13}C ($CDCl_3$) δ 175.0, 172.1, 171.2, 171.1, 101.1, 74.4, 74.1, 73.5, 71.7, 68.9, 62.2, 50.4, 41.6, 30.9, 30.8, 30.4, 25.7, 24.0, 23.9, 23.7, 21.9, 18.2, −5.4, −5.5. Anal. Calcd for $C_{28}H_{47}N_9O_{11}Si$ (713.82): C, 47.11; H, 6.64; N, 17.66. Found: C, 46.83; H, 6.56; N 17.82. Alternatively, compound **19** was obtained using the $NaIO_4/RuCl_3$ method. From 1.18 g (1.68 mmol) of **18**, 20 mL of acetonitrile, 35 mL of CCl_4, 25 mL of water, 1.48 g (6.91 mmol, 4.1 equiv) of $NaIO_4$, and 22 mg (5 mol %) of $RuCl_3 \cdot 3H_2O$ was obtained 1.02 g (85%) of **19**, which was identical to the acid using the two-phase permanganate method.

(3*S*,3′*S*)-1-[(4-Methoxybenzyl)oxy]-3-[[2,3,4-tris-*O*-(4-azidobutanoyl)-6-[3′-(2′,3′,4′-tris-*O*-(4-azidobutanoyl)-6′-*O*-(*tert*-butyldimethylsilyl)-*β*-D-glucopyranosyl]oxy]-1′-butanoyl-*β*-D-glucopyranosyl]oxy]butane (20). To a solution of 1.32 g (1.85 mmol) of **19**, 1.30 mg (1.85 mmol) of **17**, 113 mg (0.923 mmol, 0.5 equiv) of DMAP, and 30 mL of CH_2Cl_2 at 0 °C was slowly added (over 7 h) 380 mg (1.85 mmol) of DCC dissolved in 20 mL of CH_2Cl_2 and the resulting mixture stirred overnight at rt. The reaction mixture was diluted with EtOAc and filtered to remove DCU. Evaporation of solvent *in vacuo* left a waxy solid that was further purified by column chromatography (50% EtOAc/hexane) to give 1.94 g (75%) of **20** as a white solid: mp 55−56.5 °C; R_f = 0.59 (50% EtOAc/hexane); ^{1}H ($CDCl_3$) δ 0.04, 0.06 (2s, 6H), 0.9 (s, 9H), 1.23 (d, 3H, *J* = 6 Hz), 1.28 (d, 3H, *J* = 6 Hz), 1.65−1.70 (m, 2H), 1.8−1.85 (m, 12H), 2.3−2.4 (m, 13H), 2.5 (dd, 1H, *J* = 8, 16 Hz), 3.3−3.4 (m, 12H), 3.4−3.5 (m, 3H), 3.6−3.7 (m, 3H), 3.8 (s, 3H), 3.86−3.9 (m, 1H), 4.1−4.2 (m, 3H), 4.4 (d, 1H, *J* = 11.2 Hz), 4.4−4.5 (m, 2H), 4.6 (d, 1H, *J* = 8 Hz), 4.9−5.0 (m, 2H), 5.0−5.1 (m, 2H), 5.14−5.2 (m, 2H), 6.9 (d, 2H, *J* = 8.8 Hz), 7.24 (d, 2H, *J* = 8.8 Hz); ^{13}C ($CDCl_3$) δ 171.9, 171.8, 171.2, 171.1, 171.0, 170.9, 170.2, 159.2, 130.3, 129.2, 113.8, 100.8, 100.5, 74.9, 74.2, 73.5, 73.4, 73.0, 72.5, 71.6, 71.5, 71.4, 68.8,

68.5, 65.7, 62.0, 61.8, 55.2, 50.3, 50.27, 50.24, 50.2 (two overlapping carbons), 41.6, 37.0, 30.8, 30.74, 30.70, 30.66, 30.62 (one overlapping carbon), 25.7, 23.92, 23.88, 23.84, 23.82 (two overlapping carbons), 21.9, 21.7, 18.2, −5.4, −5.5. Anal. Calcd for $C_{58}H_{88}N_{18}O_{21}Si$ (1401.53): C, 49.70; H, 6.33; N, 17.99. Found: C, 49.99; H, 6.24; N, 17.93.

(3*S*,3′*S*)-3-[[2,3,4-Tris-*O*-(4-azidobutanoyl)-6-[3′-[[2′,3′,4′-tris-*O*-(4-azidobutanoyl)-6′-*O*-(*tert*-butyldimethylsilyl)-*β*-D-glucopyranosyl]oxy]]-1′-butanoyl-*β*-D-glucopyranosyl]oxy]-1-butanol (21). This compound was prepared according to the same procedure as **18**. From 1.46 g (1.04 mmol) of **20** and 261 mg (1.15 mmol, 1.1 equiv) of DDQ was obtained 1.14 g (85%) of **21** as a white solid: mp 73−75 °C; R_f = 0.24 (50% EtOAc/hexane); $[\alpha]^{24}_D$ +7.47° (*c* 3.86, THF); ^{1}H ($CDCl_3$) δ 0.04, 0.06 (2s, 6H), 0.9 (s, 9H), 1.28 (d, 3H, *J* = 6 Hz), 1.3 (d, 3H, *J* = 6.4 Hz), 1.7−1.74 (m, 2H), 1.8−1.9 (m, 12H), 2.3−2.4 (m, 13H), 2.5 (dd, 1H, *J* = 8, 16 Hz), 3.3−3.4 (m, 12H), 3.5−3.6 (m, 1H), 3.65−3.75 (m, 6H), 4.0 (m, 1H), 4.1−4.2 (m, 3H), 4.6 (d, 1H, *J* = 8.4 Hz), 4.64 (d, 1H, *J* = 7.6 Hz), 4.9 (t, 1H, *J* = 8.4 Hz), 4.96 (t, 1H, *J* = 8, 8.4 Hz), 5.0−5.1 (m, 2H), 5.15−5.2 (m, 2H); ^{13}C ($CDCl_3$) δ 172.0, 171.9, 171.23, 171.2, 171.1, 171.0, 170.2, 100.7, 100.6, 76.2, 74.3, 73.6, 73.4, 73.0, 71.67, 71.63, 71.6, 68.8, 68.5, 62.1, 61.9, 59.2, 50.35, 50.31, 50.3, 50.27, 50.25 (one overlapping carbon), 41.7, 39.1, 30.9, 30.8, 30.73, 30.7, 30.5 (one overlapping carbon), 25.7, 24.0, 23.9, 23.88, 23.85, 23.8 (one overlapping carbon), 21.8, 21.7, 18.2, −5.4, −5.5. Anal. Calcd for $C_{50}H_{80}N_{18}O_{20}Si$ (1281.38): C, 46.87; H, 6.29; N, 19.68. Found: C, 47.14, H, 6.23; N, 19.60.

(3*S*,3′*S*)-3-[[2,3,4-Tris-*O*-(4-azidobutanoyl)-6-[3′-[[2′,3′,4′-tris-*O*-(4-azidobutanoyl)-6′-*O*-(*tert*-butyldimethylsilyl)-*β*-D-glucopyranosyl]oxy]]-1′-butanoyl-*β*-D-glucopyranosyl]oxy]-1-butanoic Acid (22). This compound was prepared according to the same procedure as **19**. From 1.5 g (1.18 mmol) of **21**, 1.03 g (4.83 mmol, 4.1 equiv) of $NaIO_4$, 15.4 mg (0.05 equiv) of $RuCl_3 \cdot 3H_2O$, 35 mL of CCl_4, 20 mL of water, and 20 mL of acetonitrile was obtained 1.2 g (77%) of **22** as a white solid: mp 75−77 °C; R_f = 0.12 (50% EtOAc/hexane); ^{1}H ($CDCl_3$) δ 0.04, 0.06 (2s, 6H), 0.9 (s, 9H), 1.3 (d, 3H, *J* = 6 Hz), 1.32 (d, 3H, *J* = 6.6 Hz), 1.8−1.9 (m, 12H), 2.3−2.6 (m, 16H), 3.3−3.4 (m, 12H), 3.5−3.6 (m, 1H), 3.7−3.8 (m, 3H), 4.2 (m, 4H), 4.6 (d, 1H, *J* = 8.1 Hz), 4.7 (d, 1H, *J* = 7.8 Hz), 4.9−5.0 (m, 2H), 5.0−5.1 (m, 2H), 5.2−5.3 (m, 2H); ^{13}C ($CDCl_3$) δ 174.5, 172.0, 171.9, 171.3, 171.2, 171.1, 170.3, 101.0, 100.6, 74.3, 73.6, 73.5, 72.9, 71.7, 71.6, 71.4, 68.9, 68.5, 62.2, 61.9, 50.3, 41.7, 41.4, 30.9, 30.8 (overlapping carbons), 30.4, 29.6, 25.7, 23.9, 23.7, 21.7, 18.2, −5.4, −5.5. As this compound was hygroscopic no elemental analysis could be obtained.

(3*S*,3′*S*)-3-[[2,3,4-Tris-*O*-(4-azidobutanoyl)-6-[3′-[[2′,3′,4′-tris-*O*-(4-azidobutanoyl)-*β*-D-glucopyranosyl]oxy]]-1′-butanoyl-*β*-D-glucopyranosyl]oxy]-1-butanoic Acid (23). This compound was prepared according to the same procedure as **17**. From 383 mg (0.296 mmol) of **22** was obtained 300 mg (85%) of **23** as a viscous oil: R_f = 0.12 (50% EtOAc/hexane); ^{1}H ($CDCl_3$) δ 1.3 (d, 3H, *J* = 6.5 Hz), 1.32 (d, 3H, *J* = 6.0 Hz), 1.8−1.9 (m, ∼12H), 2.3−2.5 (m, ∼14H), 2.55−2.6 (m, 2H), 3.3−3.35 (m, ∼12H), 3.6 (m, 2H), 3.7 (m, 2H), 4.2−4.26 (m, 4H), 4.7 (2d, 2H, *J* = 8.0 and 8.0 Hz), 4.95 (m, 2H), 5.1 (m, 2H), 5.2 (m, 2H); ^{13}C ($CDCl_3$) δ 174.5, 171.9, 171.8, 171.7, 171.3, 171.1, 170.2, 100.8, 99.7, 74.2, 73.8, 73.1, 73.0, 72.8, 71.5, 71.47, 71.3, 68.8, 68.4, 61.9, 61.3, 50.27, 50.26, 50.24, 50.23, 41.6, 41.4, 30.78, 30.76, 30.74, 30.72, 30.6, 30.4, 23.86, 23.85, 23.83, 23.82, 23.7, 21.6, 21.5; FAB HRMS $C_{44}H_{64}O_{21}N_{18}$ calcd 1180.4493, found 1203.4412 (M^+ + Na), (−1.8 ppm deviation).

Protected Macrolactone 24. In a 100 mL round-bottomed flask was placed 100 mg (0.085 mmol) of **23** and 4 mL of THF. The solution was stirred under N_2, and then 0.013 mL (0.093 mmol, 1.1 equiv) of TEA was added *via* syringe. The solution was stirred for 5 min, and then 0.013 mL (0.085 mmol) of 2,4,6-trichlorobenzoyl chloride was added *via* syringe. The reaction mixture was stirred at rt for 2.5 h and then filtered using a Schlenk filtration apparatus. The solvent was removed *in vacuo*, and the mixed anhydride was diluted with 160 mL of toluene. The solution of the mixed anhydride was transferred *via* cannula to a 250 mL addition funnel atop a 1 L 2 N round-bottomed flask containing 250 mL of toluene and 62.1 mg (0.51 mmol, 6 equiv) of DMAP. The solution was slowly added (over 30 h) to the DMAP solution, which was heated to reflux. The reaction mixture was cooled, diluted with ether, and washed successively with 20 mL of 0.1 N HCl and 100 mL water. The organic layer was dried over $MgSO_4$. Filtration and evaporation of solvent *in vacuo* gave a viscous oil. Purification of the residue by column chromatography (50% EtOAc/hexane) gave 72 mg (73%) of **24** as a white solid: mp 150−151 °C; R_f = 0.48 (50% EtOAc/hexane); ^{1}H ($CDCl_3$) δ 1.24 (d, 6H, *J* = 6 Hz), 1.8−1.9 (m, 12H), 2.3−2.4 (m, 14H), 2.7 (dd, 2H, *J* = 3.7, 14.2 Hz), 3.3−3.4 (m, 12H), 3.8−3.9 (dt, 2H, *J* = 2.1, 9.3 Hz), 4.0−4.2 (m, 6H), 4.64 (d, 2H, *J* = 7.5 Hz), 4.8−4.95 (m, 4H), 5.3 (t, 2H, *J* = 9.3 Hz); ^{13}C($CDCl_3$) δ 171.9, 171.3, 170.9, 169.0, 98.2, 72.8, 71.6, 71.5, 71.3, 69.3, 63.6, 50.28, 50.26, 50.2, 41.4, 30.8, 30.7 (one overlapping carbon), 24.0, 23.8 (one overlapping carbon), 21.0; FAB HRMS $C_{44}H_{62}N_{18}O_{20}$ calcd 1163.4471, found 1163.4465 (10 ppm deviation).

Macrolactone 25. Into a 500 mL Parr flask was placed 99 mg (0.085 mmol) of **24**, 55 mg of palladium on carbon, 10 mL of THF, and 300 mL of distilled ethanol. The reaction mixture was hydrogenated with a Parr hydrogenator overnight at rt. The solution was filtered through a pad of Celite, washed with 200 mL of ethanol, and then heated to reflux for 4 h. Evaporation of the solvent *in vacuo* left a pale yellow oil that was further purified by column chromatography (30% MeOH/$CHCl_3$) to give 22 mg (52%) of **25** as a white foamy solid: mp 135 °C dec; R_f = 0.30 (30% MeOH/$CHCl_3$); ^{1}H (pyridine-d_5) δ 1.5 (d, 6H, *J* = 5.6 Hz), 2.5 (dd, 2H, *J* = 11.4, 13.4 Hz), 3.3 (dd, 2H, *J* = 3.8, 13.4 Hz), 3.8 (t, 2H, *J* = 9.2 Hz), 4.0 (m, 4H), 4.2 (t, 2H, *J* = 8.8 Hz), 4.6 (t, 2H, *J* = 10.8 Hz), 4.7 (m, 2H), 4.9 (dd, 2H, *J* = 1.4, 11.4), 4.95 (d, 2H, *J* = 8.0 Hz); ^{13}C (pyridine-d_5) δ 170.7, 102.3, 78.5, 74.9, 74.7, 72.5, 71.3, 66.1, 42.7, 22.0; FAB HRMS $C_{20}H_{33}O_{14}$ calcd 497.1869, found 497.1864 (MH^+) (1.2 ppm deviation).

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Supporting Information Available: Copies of the ^{1}H- and ^{13}C-NMR and HRMS spectra of compounds **23**−**25** (55 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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