Solid-Phase Synthesis of a Phytoalexin Elicitor Pentasaccharide Using a 4-Azido-3-chlorobenzyl Group as the Key for Temporary Protection and Catch-and-Release Purification

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A phytoalexin elicitor pentasaccharide of the rice blast disease fungus, *Pyricularia oryzae*, was synthesized by a new route involving a solid-phase method, in which a 4-azido-3-chlorobenzyl (ClAzb) group was used for temporary protection of the hydroxy functions and catch-and-release purification. Thioglycosides possessing the ClAzb group were used as glycosyl donors and a macroporous polystyrene as a solid support. The saccharide chain was elongated by repeating a set of reactions: removal of the ClAzb group, glycosylation and capping of the unglycosylated hydroxy groups. Cleavage from the solid support by treatment with sodium methoxide afforded a crude pentasaccharide possessing the ClAzb group as a tag. The pentasaccharide was then purified by a catch-and-release procedure based on the specific reaction between the azido group and a solid-supported phosphane. The final deprotection of all benzyl-type protective groups gave the desired phytoalexin elicitor pentasaccharide **1** in overall 15% yield (from a solid-supported monosaccharide **4**, average yield of 81% for each of a total of nine steps). The characteristic peaks of the azido group in the infrared spectrum were also useful for monitoring reactions in the solid phase.

Introduction

Solid-phase synthesis of oligosaccharides is an important topic in recent carbohydrate chemistry. Although various approaches to this methodology have already been reported,[1,2] there is a continuing demand for more efficient and general procedures aimed at the facile preparation of a variety of oligosaccharides for functional studies. We have reported practical, selective protection of hydroxy functions by the 4-azido-3-chlorobenzyl (ClAzb) group[3] and its application to solid-phase syntheses of oligosaccharides.[4] The ClAzb group is stable under various Lewis acidic conditions for glycosylation, but can readily be removed by conversion of the azido function to the corresponding iminophosphorane followed by oxidation using 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ). In the solid-phase synthesis, thioglycosides bearing the ClAzb group for temporary protection were used as glycosyl donors in combination with an ester-type linker,[2a,2c,2g−2j] and iterative glycosylation reactions and removal of the ClAzb group followed by alkaline cleavage of the linker afforded the desired oligosaccharides. A macroporous polystyrene, ArgoPore^{TM},[5] was employed as the solid support.

An obvious advantage of macroporous resins is that reactions can be effected successfully in any solvent without restriction. This is because these resins do not require swelling to permit reactions. In our previous work, α-selective glycosylation was achieved on ArgoPore^{TM} by virtue of the solvent effect of diethyl ether.[4,6] However, our experiments revealed that a significant amount of glycosyl acceptors on the resin remained intact after the glycosylation. This seems to be due to the presence of smaller pores, where the steric hindrance of the resin itself interferes significantly in the glycosylation. Such unchanged acceptors can be capped by acetylation and excluded from undesirable reactions in the subsequent steps. Nevertheless, after the final cleavage of the linker, the incomplete products contaminate the desired product and often cause difficulty in purification because their physicochemical properties are similar to those of the desired product. An efficient purification method with a simple procedure is required to reduce the problem of the incomplete products.

We have also previously demonstrated that the ClAzb group can be used as a new tag for catch-and-release purification.[7,8] A compound bearing the ClAzb group was selectively caught by a triphenylphosphane-polystyrene resin by the specific reaction between the azido group and the polymer-supported phosphane. Removal of the other compounds by simple rinsing of the resin followed by release from the resin by treatment with DDQ afforded the desired product with high purity. We expected that this catch-and-release purification method would be applicable to the final purification for solid-phase synthesis of oligosaccharides.[9]

In the present study, we combined the above two methodologies, i.e., selective protection and catch-and-release puri-

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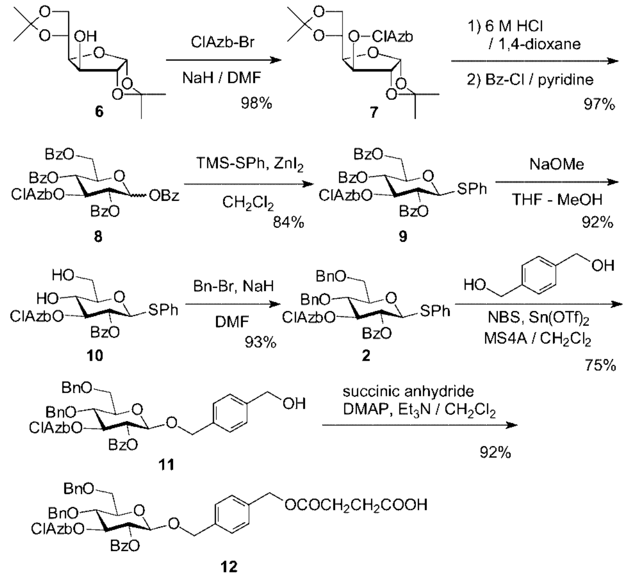
fication using the ClAzb group, for efficient multi-step, solid-phase synthesis of a complex oligosaccharide, a phytoalexin elicitor pentasaccharide **1**, from the rice blast disease fungus *Pyricularia oryzae*.[10−12]

Results and Discussion

The strategy employed for the present solid-phase synthesis of the phytoalexin elicitor pentasaccharide **1** is summarized in Scheme 1. The saccharide was bound to the solid support, a macroporous polystyrene, at the anomeric position via an ester-type linker cleavable by alkali treatment. The sugar chain was elongated from the reducing to the non-reducing end. Thioglycosides **2** and **3** bearing the ClAzb group were used as glycosyl donors. The ClAzb group of the glycosyl donor for the final glycosylation step, namely, thioglycoside **2**, was used as a tag for the catch-and-release purification. The pentasaccharide structure was constructed by repeating the sequence of glycosylation and selective cleavage of the ClAzb group on the solid support, and the ester-type linker was then cleaved to afford pentasaccharide **5**. The crude pentasaccharide **5**, which contained incomplete oligosaccharides, was subjected to the catch-and-release purification based on the specific reaction of the azido group and the triphenylphosphane resin. After the purification, the benzyl groups of the desired pentasaccharide were removed by catalytic hydrogenation to afford the phytoalexin elicitor pentasaccharide **1**.

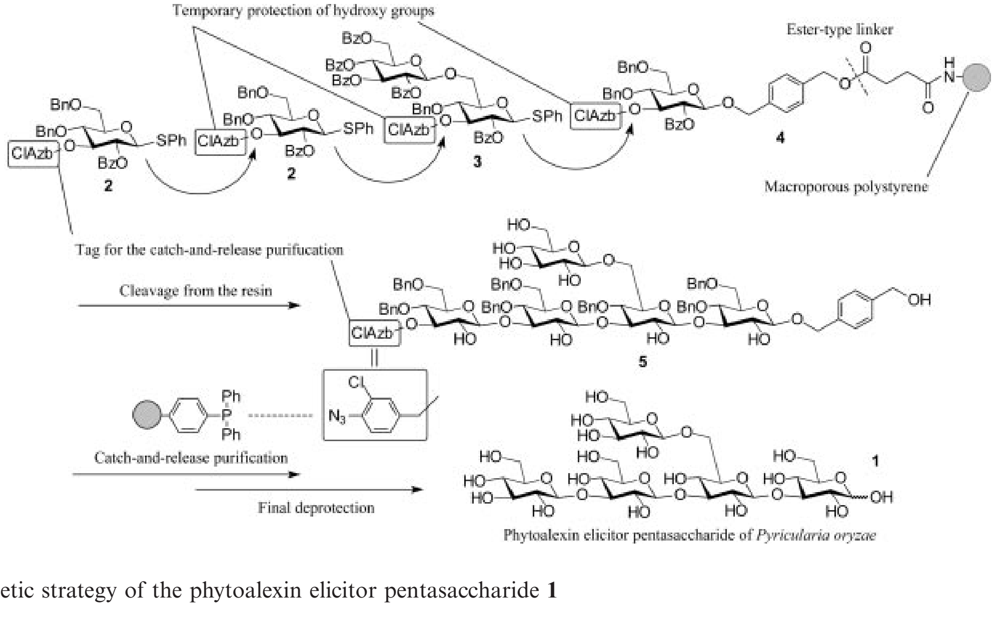
Synthesis of the Saccharide Components

Synthesis of thioglycoside **2** and the reducing end unit **12** having the ester-linker moiety is summarized in Scheme 2. 1,2:5,6-Diisopropylideneglucofuranose **6** was treated with 4-azido-3-chlorobenzyl bromide[3,13] and NaH to afford **7** in 98% yield. Furanose **7** was then hydrolyzed with hydrochloric acid, and subsequent benzoylation afforded pyranosyl benzoate **8** (α/β ≈ 1:1) in 97% yield. Reaction of **8** with phenylthiotrimethylsilane in the presence of zinc iodide afforded thioglycoside **9** in 84% yield.[14] The benzoyl groups at the 4- and 6-positions of **9** were selectively removed by treatment with sodium methoxide in MeOH/THF to give diol **10** in 92% yield and subsequent benzylation gave thioglycoside **2** in 93% yield. The ester-linker was attached to thioglycoside **2** by coupling with xylylene glycol using *N*-bromosuccinimide (NBS) and $Sn(OTf)_2$ as activating reagents to give glycoside **11** in 75% yield, and subsequent treatment with succinic anhydride afforded the reducing-end unit **12** in 92% yield.



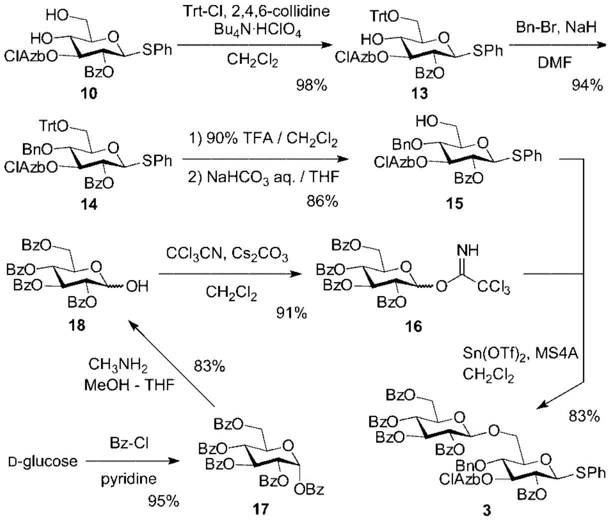
Scheme 2. Synthesis of the saccharide units **2** and **12**

Synthesis of thioglycoside **3** is illustrated in Scheme 3. The 6-position of diol **10** was protected with a trityl group using trityl chloride, 2,4,6-collidine and tetrabutylammonium perchlorate.[15] Then, 6-*O*-tritylthioglycoside **13**, obtained in 98% yield, was benzylated to afford thioglyco-



Scheme 1. Synthetic strategy of the phytoalexin elicitor pentasaccharide **1**

side **14** in 94% yield. The 6-*O*-trityl group was removed by successive treatments with trifluoroacetic acid and with an $NaHCO_3$ solution for hydrolysis of the trifluoroacetate partly formed to afford 6-*O*-free thioglycoside **15** in 86% yield. The resulting **15** was glycosylated with trichloroacetoimidate **16**,[16] which was prepared from D-glucose by benzoylation and selective cleavage of the 1-*O*-benzoyl group using methylamine followed by treatment with trichloroacetonitrile and Cs_2CO_3, in the presence of $Sn(OTf)_2$ as an activating reagent and 4-Å molecular sieves at ice/salt temperature to give thioglycoside **3** in 83% yield.

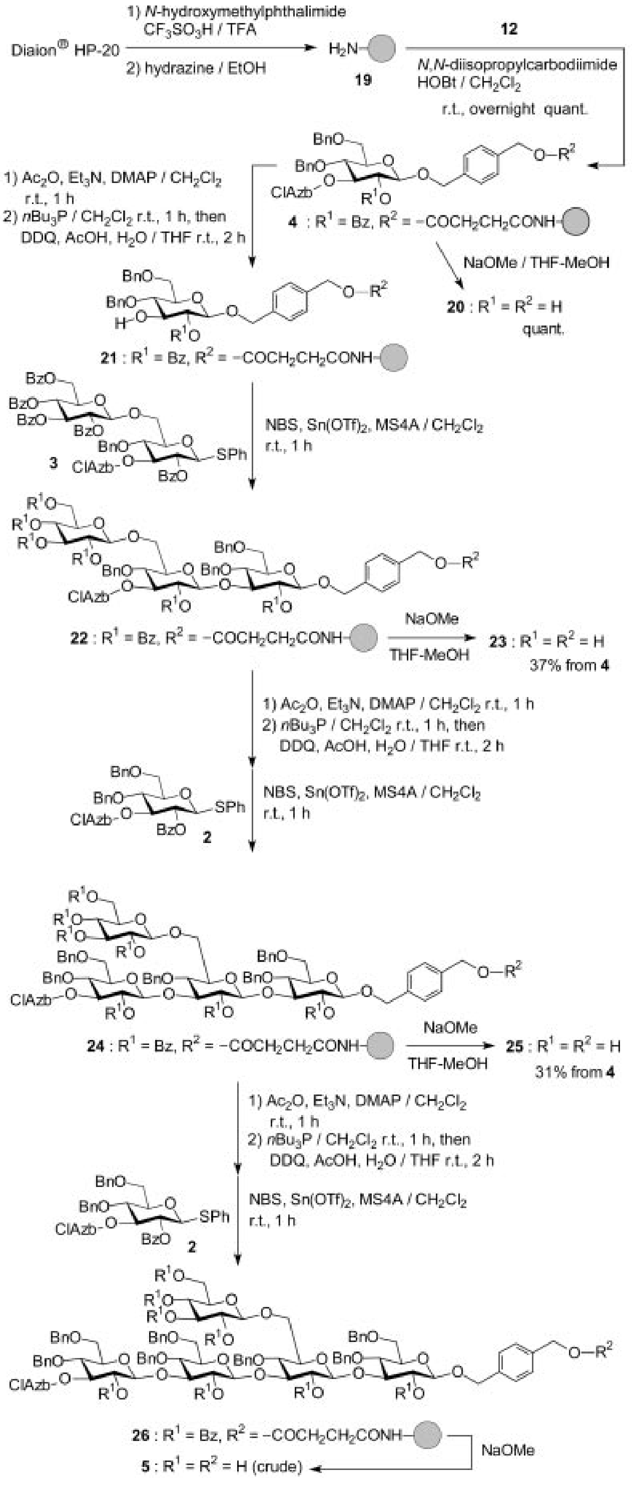


Scheme 3. Synthesis of saccharide unit **3**

Solid-Phase Synthesis of the Phytoalexin Elicitor Pentasaccharide

Among available macroporous polystyrene resins, Diaion® HP20 (average pore size: 260 Å)[17] was employed as a solid support in this work instead of ArgoPore™ used previously, because the average pore size of Diaion® HP20 is larger than that of ArgoPore™ (average pore size: 90 Å).[18]

As shown in Scheme 4, Diaion® HP20 was first aminomethylated by Merrifield's method[19] to afford resin **19** (loading of 0.19 mmol/g was determined by Ginsen's method[20]). Then, carboxylic acid **12** was introduced onto the aminomethylated resin **19** using *N*,*N*-diisopropylcarbodiimide and 1-hydroxybenzotriazole to give solid-supported monosaccharide **4** in quantitative yield. After capping of the possibly existing free amino groups on the resin with acetic anhydride, dimethylaminopyridine and triethylamine, the ClAzb group of solid-supported monosaccharide **4** was removed by treatment with tributylphosphane followed by DDQ oxidation for the subsequent glycosylation. The resulting **21** was glycosylated with thioglycoside **3** using NBS and $Sn(OTf)_2$ as activating reagents in the presence of 4-Å molecular sieves in CH_2Cl_2 to afford solid-supported trisaccharide **22** in 37% yield from **4**.



Scheme 4. Solid-phase synthesis of the pentasaccharide

These solid-phase reactions were monitored by infrared (IR) spectroscopy (KBr disks). As shown in Figure 1, introduction of carboxylic acid **12** onto the aminomethylated resin **19** (Spectrum a) was accompanied by the appearance of characteristic peaks of the azido group around 2120 cm^{-1} in the IR spectrum of **4** (Spectrum b). In the spectrum of

21 after the removal of the ClAzb group of **4**, the peaks attributable to the azido function completely disappeared (Spectrum c). After glycosylation with the ClAzb-glycosyl donor **3**, the peaks of the azido group again appeared in the IR spectrum of **22** (spectrum **d**).

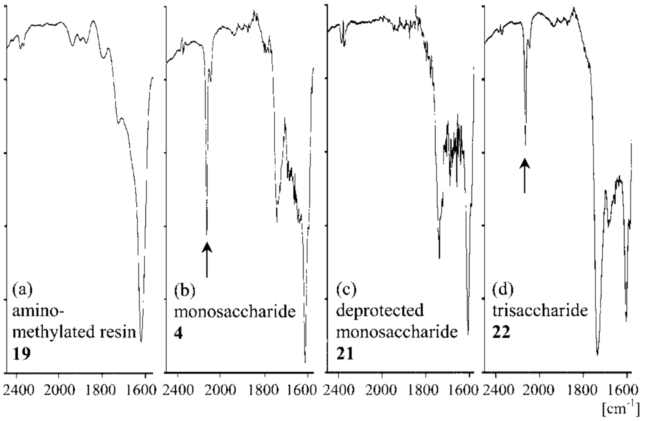
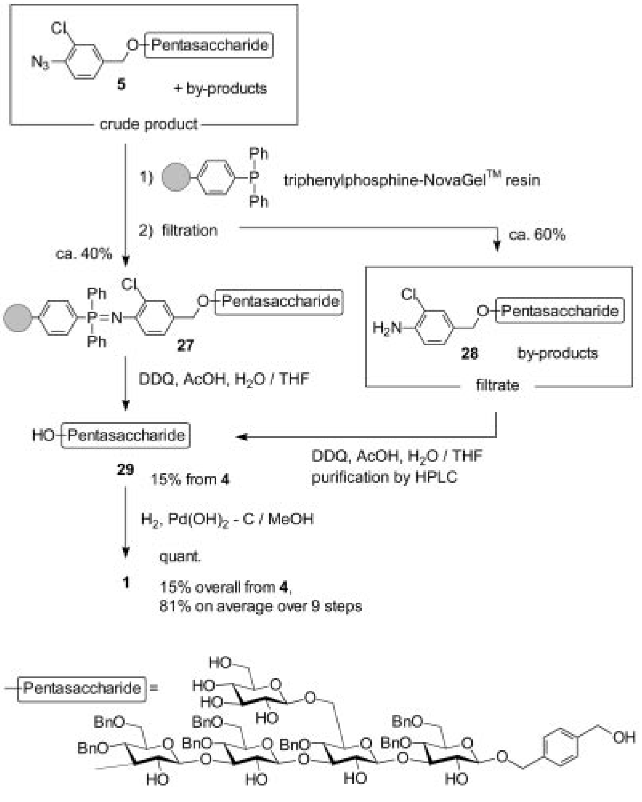


Figure 1. IR spectra of the solid-supported saccharides

The weight of resin **22** did not increase significantly after repeated glycosylation (no more than ca. 50% of the theoretical value), nor was the peak area of the azido group in the IR spectrum greatly enlarged: this suggests that some portion (ca. 50% of 0.19 mmol/g loading) of the acceptor hydroxy groups on the resin remained unchanged. As described above, this incomplete glycosylation is supposed to be due to heterogeneity in the pore size of the macroporous resin, i.e. introduction of the glycosyl donor was impeded by steric hindrance of the resin itself in smaller pores.[2m,4,6] Such unchanged hydroxy groups were capped by acetylation to avoid undesired glycosylation in the subsequent steps and the resulting incomplete products were to be removed in the final catch-and-release purification after cleavage from the resin.

The saccharide chain was further elongated by repeating the deprotection and glycosylation. The ClAzb group of solid-supported trisaccharide **22** was removed as described above. Subsequent glycosylation with thioglycoside **2** using NBS and $Sn(OTf)_2$ afforded solid-supported tetrasaccharide **24** in 31% yield (from **4**). Capping of the unchanged hydroxy groups, removal of the ClAzb group and glycosylation with thioglycoside **2** were repeated once again to afford solid-supported pentasaccharide **26**, which was then treated with 0.1 mol/L sodium methoxide in methanol/THF (1:1) to cleave the ester-linker and retrieve the saccharide moiety from the resin. This cleaving step was also monitored by IR spectra and complete cleavage was confirmed by the disappearance of the azido group peak in the IR spectrum of the resin (spectrum not shown). The crude product containing pentasaccharide **5** and by-products was then subjected to the catch-and-release purification using a triphenylphosphane resin.

Separation of pentasaccharide **29** is outlined in Scheme 5. The crude product was dissolved in CH_2Cl_2 and shaken with triphenylphosphane-NovaGel™, a triphenylphosphane-(polyethylene glycol-polystyrene-copolymer) resin,[21] to catch pentasaccharide **5** onto the resin. Iminophosphorane **27** bearing the pentasaccharide was then separated from the by-products remaining in the liquid phase by filtration. Iminophosphorane **27** was treated with DDQ to release the saccharide moiety from the resin. Excess DDQ was removed by Amberlyst® A-26 (OH^- form) after conversion into the corresponding dihydroquinone using L-ascorbic acid. 4-Amino-3-chlorobenzaldehyde derived from the ClAzb group was readily removed by Amberlyst® 15 (H^+ form) as described in a previous paper[7] to give pentasaccharide **29**, whose yield was, however, unexpectedly low (6% from **4**). Careful inspection led us to conclude that some portion of iminophosphorane **27** was hydrolyzed during the "catching" process to release the 4-amino-3-chlorobenzyl derivative **28** in the filtrate as detected by MS analysis. The filtrate containing 4-amino-3-chlorobenzyl derivative **28** was recovered and treated with DDQ to remove the 4-amino-3-chlorobenzyl group. Purification by reversed-phase HPLC using the pentasaccharide **29** obtained from the catch-and-release procedure as a reference substance afforded pentasaccharide **29** in 9% yield (from **4**) in a pure state. Partial hydrolysis of iminophosphorane **27** during the "catching" process suggests that more strictly anhydrous conditions are required to avoid leakage of the desired product into the filtrate, especially when hydrophilic polyhydroxy molecules like **5** are subjected to this purification method.



Scheme 5. Catch-and-release purification and the final deprotection

Finally, the benzyl groups of the combined pentasaccharide **29** were removed by catalytic hydrogenation using $Pd(OH)_2$ to give elicitor pentasaccharide **1** in quantitative yield (15% from **4**).

Conclusion

We have demonstrated the successful application of a novel methodology to a solid-phase synthesis of oligosaccharides, in which the ClAzb group was used both for temporary protection and for catch-and-release purification in combination with thioglycosides as glycosyl donors, a macroporous polystyrene as a solid support and the ester-type linker. The catch-and-release purification method based on the specific reaction between the azido group and solid-supported phosphane facilitated final purification of the product after it had been cleaved from the solid support. The ClAzb group was also useful as a tag for monitoring the reactions by IR spectroscopy. Even though improvements in the experimental conditions may increase the efficiency of the catch-and-release purification, the present methodology certainly provides a new and efficient synthesis of various oligosaccharides.

Experimental Section

General Remarks: All chemicals and solvents used were of reagent grade. CH_2Cl_2 used for glycosylations was distilled from calcium hydride under N_2. Analytical TLC was performed on Merck silica-gel 60 F_{254} plates (0.25 mm) and spots were visualized with ultraviolet light (254 nm) followed by spraying with a solution of anisaldehyde (0.5 mL) and concd. H_2SO_4 (1 mL) in acetic acid (50 mL) and heating. Preparative TLC was performed on Merck silica-gel 60 F_{254} plates (0.5 mm). Column chromatography was carried out on Wakogel® C-200. Preparative HPLC was carried out using a Waters 600 system with UV detector 2487. Melting points were determined with a Yamato MP-21 melting point apparatus and are uncorrected. Optical rotation was determined with a Horiba SEPA-300 polarimeter using a 1-dm cell at 25 °C. IR spectra were recorded with a Perkin−Elmer Paragon 1000 FT-IR spectrometer. NMR spectra were recorded with a Varian Mercury plus 300 (300 MHz) and Varian UNITY plus 600 (600 MHz) spectrometers, using tetramethylsilane (in $CDCl_3$) or H_2O (in D_2O) as internal standards. Assignments were made by COSY, TOCSY, ROESY, HMQC and HMBC experiments; the glucose residues of oligosaccharides are designated in alphabetical order from the reducing end. Mass spectra were recorded with a Perkin−Elmer Sciex API-300 mass spectrometer. Microanalyses were performed in the Microanalysis Laboratory of the Department of Chemistry, Graduate School of Science, Osaka University.

3-*O*-(4-Azido-3-chlorobenzyl)-1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (7): NaH (60% suspension in oil, 880 mg, 22.0 mmol) was added to a solution of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (**6**) (5.20 g, 20.0 mmol) in DMF (25 mL) at 0 °C. After stirring for 15 min, 4-azido-3-chlorobenzyl bromide (5.42 g, 22.0 mmol) was added and the mixture was stirred in situ for a further 3 h. The reaction was quenched by adding cold water (50 mL) and the product was extracted twice with ethyl acetate. The combined organic layers were washed with brine, dried with Na_2SO_4 and then concentrated in vacuo. The residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 3:1) to give **7** as an orange oil (8.35 g, 98%). TLC (hexane/ethyl acetate, 2:1): R_f = 0.68. $[\alpha]^{25}_{D}$ = −30.1 (*c* = 1.00, CH_2Cl_2). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.32 (s, 3 H, CH_3), 1.39 (s, 3 H, CH_3), 1.43 (s, 3 H, CH_3), 1.49 (s, 3 H, CH_3), 3.98 (d, *J* = 3.0 Hz, 1 H, 3-H), 3.99 (dd, *J* = 5.7, 8.7 Hz, 1 H, 6-H), 4.09 (dd, *J* = 3.0, 8.1 Hz, 1 H, 4-H), 4.12 (dd, *J* = 6.0, 8.7 Hz, 1 H, 6-H), 4.33 (ddd, *J* = 5.7, 6.0, 8.1 Hz, 1 H, 5-H), 4.56 (d, *J* = 12.3 Hz, 1 H, ArC*H*H), 4.58 (d, *J* = 3.6 Hz, 1 H, 2-H), 4.65 (d, *J* = 12.3 Hz, 1 H, ArC*H*H), 5.89 (d, *J* = 3.6 Hz, 1 H, 1-H), 7.12 (d, *J* = 8.1 Hz, 1 H, ClAzb), 7.24 (dd, *J* = 1.8, 8.1 Hz, 1 H, ClAzb), (d, *J* = 1.5 Hz, 1 H, ClAzb) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 25.3 (*C*H_3), 26.2 (*C*H_3), 26.7 (*C*H_3), 26.8 (*C*H_3), 67.4 (C-6), 70.7 (Ar*C*H_2), 72.0 (C-5), 81.1 (C-4), 81.4 (C-3), 82.3 (C-2), 105.0 (C-1), 108.9, 111.6, 119.2, 124.7, 126.6, 129.5, 135.2, 136.2 ppm. ESI-MS: *m*/*z* = 448.1 [M + Na^+]. $C_{19}H_{24}ClN_3O_6$ (425.86): calcd. C 53.59, H 5.68, N 9.87; found C 53.64, H 5.68, N 9.74.

3-*O*-(4-Azido-3-chlorobenzyl)-2,4,6-tri-*O*-benzoyl-α/β-D-glucopyranosyl Benzoate (8): A mixture of **7** (5.16 g, 12.1 mmol), hydrochloric acid (6 mol/L, 15 mL) and 1,4-dioxane (45 mL) was stirred at room temperature overnight. The mixture was cooled in an ice bath and neutralized with aqueous NaOH, then 1,4-dioxane was removed in vacuo. The product was extracted three times with ethyl acetate and the combined organic layers were washed with brine, dried with Na_2SO_4 and then concentrated in vacuo. The residue was dissolved in pyridine (30 mL) and the solution was cooled in an ice bath. Benzoyl chloride (6.97 mL, 60.5 mmol) was added to the solution dropwise and the mixture was stirred in situ for 3 h. The reaction was quenched by adding cold water (100 mL) and the product was extracted twice with ethyl acetate. The combined organic layers were washed with hydrochloric acid (1 mol/L) and brine, dried with Na_2SO_4 then concentrated in vacuo. The residue was crystallized from ethyl acetate and hexane to give the β-anomer of **8** as pale-yellow crystals (3.30 g, 36%). The mother liquor was concentrated in vacuo and the residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 3:1) to give a mixture of two anomers of **8** as an orange gum (5.65 g, 61%, α/β = 5.5:1).

8 (α-Anomer): TLC (hexane/ethyl acetate, 2:1): R_f = 0.59. ^1H NMR (300 MHz, $CDCl_3$): δ = 4.38 (dd, *J* = 4.8, 12.3 Hz, 1 H, 6-H), 4.39 (t, *J* = 9.9 Hz, 1 H, 3-H), 4.47 (ddd, *J* = 3.0, 4.8, 9.9 Hz, 1 H, 5-H), 4.55 (d, *J* = 12.0 Hz, 1 H, ArC*H*H), 4.58 (dd, *J* = 3.0, 12.3 Hz, 1 H, 6-H), 4.63 (d, *J* = 12.0 Hz, 1 H, ArC*H*H), 5.56 (dd, *J* = 3.9, 9.9 Hz, 1 H, 2-H), 5.68 (t, *J* = 9.9 Hz, 1 H, 4-H), 6.63 (d, *J* = 8.1 Hz, 1 H, ClAzb), 6.71 (d, *J* = 3.9 Hz, 1 H, 1-H), 6.94 (dd, *J* = 2.1, 8.1 Hz, 1 H, ClAzb), 7.07 (d, *J* = 2.1 Hz, 1 H, ClAzb), 7.34−7.69 (m, 12 H, ArH), 7.86−8.16 (m, 8 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 62.4 (C-6), 69.9 (C-4), 70.3 (C-5), 71.7 (C-2), 73.4 (Ar*C*H_2), 77.7 (C-3), 90.1 (C-1), 119.1, 124.1, 127.0, 127.9, 128.0, 128.10, 128.14, 128.38, 128.47, 128.52, 128.58, 128.76, 129.11, 129.20, 129.27, 129.34, 129.38, 129.42, 129.49, 129.7, 130.1, 132.7, 133.1, 133.2, 133.5, 135.0, 135.9, 163.8 (*C*=O), 164.3 (*C*=O), 164.6 (*C*=O), 165.6 (*C*=O) ppm. ESI-MS: *m*/*z* = 784.1 [M + Na^+].

8 (β-Anomer): M.p. 140−141 °C. TLC (hexane/ethyl acetate, 2:1): R_f = 0.59. $[\alpha]^{25}_{D}$ = −7.36 (*c* = 0.41, CH_2Cl_2). ^1H NMR (300 MHz, $CDCl_3$): δ = 4.14 (t, *J* = 8.7 Hz, 1 H, 3-H), 4.24 (ddd, *J* = 3.0, 4.8, 9.6 Hz, 1 H, 5-H), 4.41 (dd, *J* = 4.8, 12.0 Hz, 1 H, 6-H), 4.54 (s, 2 H, ArC*H*$_2$), 4.61 (dd, *J* = 3.0, 12.0 Hz, 1 H, 6-H), 5.68 (dd, *J* = 8.7, 9.6 Hz, 1 H, 4-H), 5.69 (dd, *J* = 7.8, 8.7 Hz, 1 H, 2-H), 6.16 (d, *J* = 7.8 Hz, 1 H, 1-H), 6.62 (d, *J* = 7.8 Hz, 1 H, ClAzb), 6.94 (dd, *J* = 2.1, 8.1 Hz, 1 H, ClAzb), 7.05 (d, *J* = 2.1 Hz, 1 H, ClAzb), 7.34−7.61 (m, 12 H, ArH), 7.92−8.01 (m, 8 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 62.6 (C-6), 70.0 (C-4), 71.8 (C-2), 72.8 (C-5), 73.0 (Ar*C*H$_2$), 80.3 (C-3), 92.3 (C-1), 119.1, 127.1, 127.9, 128.12, 128.15, 128.6, 129.1, 129.3, 129.36, 129.40, 129.6, 129.8, 132.6, 133.1, 133.2, 133.4, 134.8, 136.0, 164.2 (*C*=O), 164.31 (*C*=O), 164.35 (*C*=O), 165.6 (*C*=O) ppm. ESI-MS: *m*/*z* = 784.1 [M + Na$^+$]. $C_{41}H_{32}ClN_3O_{10}$ (762.17): calcd. C 64.61, H 4.23, N 5.51; found C 64.55, H 4.17, N 5.46.

Phenyl 3-*O*-(4-Azido-3-chlorobenzyl)-2,4,6-tri-*O*-benzoyl-1-thio-β-D-glucopyranoside (9): A mixture of **8** (5.50 g, 7.22 mmol, α/β = 5.5:1), phenylthiotrimethylsilane (2.05 mL, 10.8 mmol), ZnI_2 (1.15 g, 3.61 mmol) and CH_2Cl_2 (20 mL) was stirred at room temperature overnight. The mixture was filtered and the filtrate was washed with hydrochloric acid (1 mol/L) and brine, dried with Na_2SO_4 and then concentrated in vacuo. The residue was crystallized from hexane/ethyl acetate to give **9** as white crystals (4.55 g, 84%). M.p. 131−132 °C. TLC (toluene/ethyl acetate, 10:1): R_f = 0.62. $[\alpha]_D^{25}$ = +13.6 (*c* = 0.53, CH_2Cl_2). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 4.03 (t, *J* = 9.0 Hz, 1 H, 3-H), 4.05 (ddd, *J* = 3.0, 6.3, 9.9 Hz, 1 H, 5-H), 4.38 (dd, *J* = 6.3, 12.3 Hz, 1 H, 6-H), 4.45 (s, 2 H, ArC*H$_2$*), 4.64 (dd, *J* = 3.0, 12.3 Hz, 1 H, 6-H), 4.90 (d, *J* = 9.9 Hz, 1 H, 1-H), 5.34 (dd, *J* = 9.0, 9.9 Hz, 1 H, 2-H), 5.47 (dd, *J* = 9.0, 9.9 Hz, 1 H, 4-H), 6.58 (d, *J* = 8.1 Hz, 1 H, ClAzb), 6.87 (dd, *J* = 2.1, 8.1 Hz, 1 H, ClAzb), 6.97 (d, *J* = 2.1 Hz, 1 H, ClAzb), 7.05−7.10 (m, 2 H, ArH), 7.16−7.21 (m, 1 H, ArH), 7.39−7.64 (m, 11 H, ArH), 7.92−8.02 (m, 6 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 63.1 (C-6), 70.4 (C-4), 71.8 (C-2), 73.0 (Ar*C*H$_2$), 75.9 (C-5), 81.8 (C-3), 86.0 (C-1), 119.0, 124.0, 127.1, 127.7, 128.0, 128.12, 128.15, 128.4, 128.6, 129.0, 129.2, 129.3, 129.4, 129.6, 131.7, 132.4, 132.8, 133.1, 133.2, 134.8, 135.9, 164.3 (*C*=O), 164.4 (*C*=O), 165.6 (*C*=O) ppm. ESI-MS: *m*/*z* = 772.2 [M + Na$^+$]. $C_{40}H_{32}ClN_3O_8S$ (750.22): calcd. C 64.04, H 4.30, N 5.60; found C 64.04, H 4.26, N 5.46.

Phenyl 3-*O*-(4-Azido-3-chlorobenzyl)-2-*O*-benzoyl-1-thio-β-D-glucopyranoside (10): Sodium methoxide (243 mg, 4.50 mmol) was added to a solution of **9** (6.35 g, 8.46 mmol) in a mixture of methanol and THF (1:2, 75 mL) at room temperature. After stirring for 2 h, the mixture was neutralized with ion-exchange resin Amberlyst® 15 (H$^+$ form), then concentrated in vacuo. The residue was crystallized from hexane/ethyl acetate to give **10** as white crystals (4.22 g, 92%). M.p. 131−132 °C. TLC (hexane/ethyl acetate, 1:2): R_f = 0.49. $[\alpha]_D^{25}$ = +83.5 (*c* = 0.51, CH_2Cl_2). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 1.99 (t, *J* = 6.8 Hz, 1 H, 6-OH), 2.50 (d, *J* = 3.3 Hz, 1 H, 4-OH), 3.50 (ddd, *J* = 3.6, 5.1, 9.0 Hz, 1 H, 5-H), 3.68 (t, *J* = 9.0 Hz, 1 H, 3-H), 3.78 (dt, *J* = 3.3, 9.0 Hz, 1 H, 4-H), 3.85 (ddd, *J* = 5.1, 6.8, 12.0 Hz, 1 H, 6-H), 3.96 (ddd, *J* = 3.6, 6.8, 12.0 Hz, 1 H, 6-H), 4.58 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.66 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.82 (d, *J* = 10.1 Hz, 1 H, 1-H), 5.20 (dd, *J* = 9.0, 10.1 Hz, 1 H, 2-H), 6.85 (d, *J* = 8.1 Hz, 1 H, ClAzb), 7.05 (dd, *J* = 2.1, 8.1 Hz, 1 H, ClAzb), 7.16 (d, *J* = 2.1 Hz, 1 H, ClAzb), 7.24−7.29 (m, 3 H, ArH), 7.38−7.48 (m, 4 H, ArH), 7.57−7.63 (m, 1 H, ArH) 7.96−8.00 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 62.2 (C-6), 70.3 (C-4), 71.7 (C-2), 73.4 (Ar*C*H$_2$), 79.1 (C-5), 83.9 (C-3), 86.2 (C-1), 119.2, 124.3, 127.0, 127.7, 128.1, 128.6, 129.1, 129.4, 129.7, 132.0, 132.1, 133.0, 135.3, 136.0, 164.6 (*C*=O) ppm. ESI-MS: *m*/*z* = 564.0 [M + Na$^+$]. $C_{26}H_{24}ClN_3O_6S$ (542.00): calcd. C 57.62, H 4.46, N 7.75; found C 57.32, H 4.38, N 7.64.

Phenyl 3-*O*-(4-Azido-3-chlorobenzyl)-2-*O*-benzoyl-4,6-di-*O*-benzyl-1-thio-β-D-glucopyranoside (2): NaH (60% suspension in oil, 812 mg, 20.3 mmol) was added in portions to a solution of **10** (5.00 g, 9.23 mmol) and benzyl bromide (2.41 mL, 20.3 mmol) in DMF (20 mL) at 0 °C and the mixture was stirred for 2 h. The reaction was quenched by adding cold water (50 mL) and the product was extracted twice with ethyl acetate. The combined organic layers were washed with brine, dried with Na_2SO_4 and then concentrated in vacuo. The residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 5:1 → 2:1) to give **2** as white crystals (6.20 g, 93%). M.p. 118−119 °C. TLC (hexane/ethyl acetate, 2:1): R_f = 0.74. $[\alpha]_D^{25}$ = +66.9 (*c* = 0.51, CH_2Cl_2). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.59 (m, 1 H, 5-H), 3.70−3.78 (m, 3 H, 3-H, 4-H, 6-H), 3.82 (dd, *J* = 2.1, 10.8 Hz, 1 H, 6-H), 4.48 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.55 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.62 (d, *J* = 11.4 Hz, 2 H, ArC*H*H), 4.66 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.74 (d, *J* = 9.9 Hz, 1 H, 1-H), 4.75 (d, *J* = 11.1 Hz, 1 H, ArC*H*H), 5.19 (dd, *J* = 9.3, 9.9 Hz,1 H, 2-H), 6.71 (d, *J* = 8.1 Hz, 1 H, ClAzb), 6.97 (dd, *J* = 2.1, 8.1 Hz, 1 H, ClAzb), 7.07 (d, *J* = 1.8 Hz, 1 H, ClAzb), 7.16−7.35 (m, 13 H, ArH), 7.40−7.47 (m, 4 H, ArH), 7.55−7.62 (m, 1 H, ArH) 7.92−7.96 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 68.7 (C-6), 71.9 (C-2), 73.4 (Ar*C*H$_2$), 73.8 (Ar*C*H$_2$), 75.0 (Ar*C*H$_2$), 77.8 (C-4), 79.3 (C-5), 84.4 (C-3), 85.9 (C-1), 119.2, 124.3, 127.3, 127.4, 127.5, 127.6, 127.7, 128.2, 128.3, 128.6, 129.4, 129.5, 129.9, 132.4, 133.0, 135.6, 136.0, 137.5, 137.9, 164.7 (*C*=O) ppm. ESI-MS: *m*/*z* = 744.1 [M + Na$^+$]. $C_{40}H_{36}ClN_3O_6S$ (722.25): calcd. C 66.52, H 5.02, N 5.82; found C 66.47, H 4.95, N 5.76.

4-(Hydroxymethyl)benzyl 3-*O*-(4-Azido-3-chlorobenzyl)-2-*O*-benzoyl-4,6-di-*O*-benzyl-β-D-glucopyranoside (11): A mixture of **2** (1.50 g, 2.08 mmol), xylylene glycol (861 mg, 6.23 mmol), $Sn(OTf)_2$ (216 mg, 0.52 mmol), 4-Å molecular sieves (ca. 500 mg) and THF (25 mL) was stirred at room temperature for 15 min, then cooled to 0 °C. *N*-Bromosuccinimide (388 mg, 2.18 mmol) was added, the mixture was stirred for 30 min and then filtered. The filtrate was concentrated in vacuo and the residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 2:1) to give **11** as white crystals (1.17 g, 75%). M.p. 121−123 °C. TLC (hexane/ethyl acetate, 1:1): R_f = 0.45. $[\alpha]_D^{25}$ = +23.4 (*c* = 0.53, CH_2Cl_2). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.49 (ddd, *J* = 2.4, 4.2, 9.6 Hz, 1 H, 5-H), 3.67 (t, *J* = 9.2 Hz, 1 H, 3-H), 3.72−3.81 (m, 3 H, 4-H, 6-H, 6-H), 4.47 (d, *J* = 12.0 Hz, 1 H, ArC*H*H), 4.49 (d, *J* = 7.9 Hz, 1 H, 1-H), 4.55−4.68 (m, 7 H, ArC*H*H), 4.75 (d, *J* = 11.1 Hz, 1 H, ArC*H*H), 4.84 (d, *J* = 12.6 Hz, 1 H, ArC*H*H), 5.27 (dd, *J* = 7.9, 9.2 Hz, 1 H, 2-H), 6.70 (d, *J* = 7.8 Hz, 1 H, ClAzb), 6.98 (dd, *J* = 1.8, 8.1, ClAzb), 7.08 (d, *J* = 1.8 Hz, 1 H, ClAzb), 7.10−7.21 (m, 6 H, ArH), 7.25−7.44 (m, 10 H, ArH), 7.55−7.61 (m, 1 H, ArH), 7.84−7.88 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 64.9 (Ar*C*H$_2$O), 68.4 (C-6), 69.7 (Ar*C*H$_2$), 73.2 (C-2), 73.4 (2 C, Ar*C*H$_2$ × 2), 74.8 (Ar*C*H$_2$), 75.0 (C-5), 77.9 (C-4), 82.8 (C-3), 99.1 (C-1), 119.1, 124.0, 126.5, 127.2, 127.3, 127.4, 127.45, 127.52, 127.9, 128.0, 128.1, 129.3, 129.7, 132.7, 135.5, 135.8, 136.1, 137.4, 137.6, 139.8, 164.5 (*C*=O) ppm. ESI-MS: *m*/*z* = 772.3 [M + Na$^+$]. $C_{42}H_{40}ClN_3O_8$ (750.24): calcd. C 67.24, H 5.37, N 5.60; found C 67.23, H 5.28, N 5.49.

4-{[(3-Carboxypropanoyl)oxy]methyl}benzyl 3-*O*-(4-Azido-3-chlorobenzyl)-2-*O*-benzoyl-4,6-di-*O*-benzyl-β-D-glucopyranoside (12): Succinic anhydride (195 mg, 1.95 mmol) was added to a solution of **11** (977 mg, 1.30 mmol), dimethylaminopyridine (79 mg, 0.65 mmol) and triethylamine (0.18 mL, 1.30 mmol) in CH_2Cl_2 (5 mL) at room temperature and the mixture was stirred for 2 h, then washed with hydrochloric acid (0.1 mol/L) and brine, dried with Na_2SO_4 and concentrated in vacuo. Crystallization from hexane/ethyl acetate gave **12** as pale-yellow crystals (1.02 g, 92%). M.p. 125−128 °C. TLC (ethyl acetate): R_f = 0.64. $[\alpha]_D^{25}$ = +26.6 (*c* = 0.52, CH_2Cl_2).

^{1}H NMR (300 MHz, CDCl$_3$): δ = 2.65−2.68 (m, 4 H, COC*H*$_2$), 3.50 (ddd, *J* = 2.3, 3.8, 9.6 Hz, 1 H, 5-H), 3.68 (t, *J* = 9.2 Hz, 1 H, 3-H), 3.72−3.81 (m, 3 H, 4-H, 6-H, 6-H), 4.47 (d, *J* = 7.9 Hz, 1 H, 1-H), 4.47 (d, *J* = 12.1 Hz, 1 H, ArC*H*H), 4.57 (d, *J* = 12.2 Hz, 1 H, ArC*H*H), 4.60 (d, *J* = 10.8 Hz, 1 H, ArC*H*H), 4.61 (d, *J* = 12.6 Hz, 1 H, ArC*H*H), 4.65 (d, *J* = 12.1 Hz, 1 H, ArC*H*H), 4.66 (d, *J* = 12.2 Hz, 1 H, ArC*H*H), 4.75 (d, *J* = 10.8 Hz, 1 H, ArC*H*H), 4.84 (d, *J* = 12.6 Hz, 1 H, ArC*H*H), 5.05 (s, 2 H, ArC*H*$_2$), 5.27 (dd, *J* = 7.9, 9.2 Hz, 1 H, 2-H), 6.71 (d, *J* = 8.1 Hz, 1 H, ClAzb), 6.98 (dd, *J* = 1.8, 8.1, ClAzb), 7.08 (d, *J* = 1.8 Hz, 1 H, ClAzb), 7.09−7.45 (m, 16 H, ArH), 7.56−7.61 (m, 1 H, ArH), 7.85−7.88 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, CDCl$_3$): δ = 28.6 (CO*C*H$_2$), 28.9 (CO*C*H$_2$), 66.2 (Ar*C*H$_2$), 68.5 (C-6), 69.7 (Ar*C*H$_2$), 73.3 (C-2), 73.5 (2 C, Ar*C*H$_2$ × 2), 74.9 (Ar*C*H$_2$), 75.0 (C-5), 78.0 (C-4), 82.8 (C-3), 99.2 (C-1), 119.2, 124.2, 127.3, 127.5, 127.6, 127.61, 127.64, 127.7, 128.0, 128.1, 128.20, 128.25, 129.5, 129.8, 133.0, 134.8, 135.7, 136.0, 137.0, 137.5, 137.7, 164.7 (*C*=O), 171.6 (*C*=O) ppm. ESI-MS: *m*/*z* = 872.2 [M + Na$^+$], 848.2 [M − H]$^-$. $C_{46}H_{44}ClN_3O_{11}$ (850.32): calcd. C 64.98, H 5.22, N 4.94; found C 64.95, H 5.19, N 4.78.

Phenyl 3-*O*-(4-Azido-3-chlorobenzyl)-2-*O*-benzoyl-6-*O*-(triphenylmethyl)-1-thio-β-D-glucopyranoside (13): 2,4,6-Collidine (0.85 mL, 6.46 mmol) was added to a solution of **10** (2.50 g, 4.61 mmol), triphenylmethyl chloride (1.80 g, 6.46 mmol) and tetrabutylammonium perchlorate (394 mg, 1.15 mmol) in CH_2Cl_2 (20 mL) and the mixture was stirred at room temperature for 2 h. The mixture was washed with an aqueous solution of citric acid (10%) and brine, dried with Na_2SO_4, then concentrated in vacuo. The residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 4:1) to give **13** as a pale-yellow gum (3.55 g, 98%). TLC (hexane/ethyl acetate, 2:1): R_f = 0.63. $[\alpha]_D^{25}$ = +37.9 (*c* = 0.57, CH_2Cl_2). ^{1}H NMR (300 MHz, CDCl$_3$): δ = 2.43 (d, *J* = 3.0 Hz,1 H, 4-OH), 3.40−3.54 (m, 3 H, 5-H, 6-H, 6-H), 3.59 (t, *J* = 9.0 Hz, 1 H, 3-H), 3.80 (dt, *J* = 3.0, 9.0 Hz, 4-H), 4.53 (d, *J* = 12.0 Hz, 1 H, ArC*H*H), 4.67 (d, *J* = 12.0 Hz, 1 H, ArC*H*H), 4.75 (d, *J* = 9.9 Hz, 1 H, 1-H), 5.18 (dd, *J* = 9.0, 9.9 Hz, 1 H, 2-H), 6.79 (d, *J* = 8.1 Hz, 1 H, ClAzb), 7.00 (dd, *J* = 2.1, 8.1 Hz, 1 H, ClAzb), 7.14 (d, *J* = 2.1 Hz, 1 H, ClAzb), 7.18−7.33 (m, 12 H, ArH), 7.41−7.50 (m, 10 H, ArH), 7.57−7.62 (m, 1 H, ArH), 7.95−7.98 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, CDCl$_3$): δ = 63.4 (C-6), 71.5 (C-2), 71.7 (C-4), 73.2 (Ar*C*H$_2$), 78.1 (C-5), 83.6 (C-3), 85.8 (Ph$_3$*C*), 86.8 (C-1), 119.1, 124.1, 126.8, 127.1, 127.5, 127.6, 128.0, 128.2, 128.4, 129.2, 129.3, 129.7, 132.1, 132.3, 132.9, 135.5, 135.8, 143.1, 164.5 (*C*=O) ppm. ESI-MS: *m*/*z* = 806.1 [M + Na$^+$]. $C_{45}H_{38}ClN_3O_6S$ (784.32): calcd. C 68.91, H 4.88, N 5.36; found C 68.80, H 5.01, N 5.16.

Phenyl 3-*O*-(4-Azido-3-chlorobenzyl)-2-*O*-benzoyl-4-*O*-benzyl-6-*O*-(triphenylmethyl)-1-thio-β-D-glucopyranoside (14): NaH (60% suspension in oil, 190 mg, 4.74 mmol) was added in portions to a solution of **13** (2.86 g, 3.65 mmol) and benzyl bromide (0.56 mL, 4.74 mmol) in DMF (20 mL) at 0 °C and the mixture was stirred for 2 h. The reaction was quenched by adding cold water (50 mL) and the product was extracted twice with ethyl acetate. The combined organic layers were washed with brine, dried with Na_2SO_4 and concentrated in vacuo. The residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 5:1) to give **14** as white crystals (3.00 g, 94%). M.p. 162−164 °C. TLC (hexane/ethyl acetate, 3:1): R_f = 0.64. $[\alpha]_D^{25}$ = +46.5 (*c* = 0.50, CH_2Cl_2). ^{1}H NMR (300 MHz, CDCl$_3$): δ = 3.29 (dd, *J* = 4.1, 10.1 Hz, 1 H, 6-H), 3.54 (ddd, *J* = 1.5, 4.1, 9.0 Hz, 1 H, 5-H), 3.65 (dd, *J* = 1.5, 10.1 Hz, 1 H, 6-H), 3.69 (t, *J* = 9.0 Hz, 1 H, 3-H), 3.86 (t, *J* = 9.0 Hz, 1 H, 4-H), 4.31 (d, *J* = 10.4 Hz, 1 H, ArC*H*H), 4.45 (d, *J* = 11.8 Hz, 1 H, ArC*H*H), 4.56 (d, *J* = 10.4 Hz, 1 H, ArC*H*H), 4.65 (d, *J* = 11.8 Hz, 1 H, ArC*H*H), 4.80 (d, *J* = 10.1 Hz, 1 H, 1-H), 5.27 (dd, *J* = 9.0, 10.1 Hz, 1 H, 2-H), 6.70 (d, *J* = 8.1 Hz, 1 H, ClAzb), 6.85 (dd, *J* = 2.1, 8.1 Hz, 2 H, ArH), 6.96 (dd, *J* = 2.0, 8.1 Hz, 1 H, ClAzb), 7.06 (d, *J* = 2.0 Hz, 1 H, ClAzb), 7.16−7.30 (m, 14 H, ArH), 7.42−7.61 (m, 12 H, ArH), 7.94−7.97 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, CDCl$_3$): δ = 62.0 (C-6), 71.8 (C-2), 73.8 (Ar*C*H$_2$), 74.9 (Ar*C*H$_2$), 77.7 (C-4), 78.9 (C-5), 84.3 (C-3), 85.8 (Ph$_3$*C*), 86.3 (C-1), 119.1, 124.1, 126.6, 127.2, 127.5, 127.7, 127.9, 128.0, 128.4, 128.5, 129.30, 129.34, 129.8, 132.3, 132.4, 132.8, 135.4, 135.9, 137.0, 143.3, 164.5 (*C*=O) ppm. ESI-MS: *m*/*z* = 896.1[M + Na$^+$]. $C_{52}H_{44}ClN_3O_6S$ (874.45): calcd. C 71.42, H 5.07, N 4.81; found C 71.10, H 5.01, N 4.73.

Phenyl 3-*O*-(4-Azido-3-chlorobenzyl)-2-*O*-benzoyl-4-*O*-benzyl-1-thio-β-D-glucopyranoside (15): Trifluoroacetic acid (90%, 10 mL) was added to a solution of **14** (2.62 g, 3.00 mmol) in CH_2Cl_2 (10 mL) and the mixture was stirred at room temperature for 2 h. After concentration in vacuo, the residue was dissolved in ethyl acetate and washed with satd. aqueous $NaHCO_3$ and brine, then concentrated again. The residue was dissolved in THF (20 mL). Aqueous $NaHCO_3$ (84 mg, 2.0 mmol/2 mL) was added and the mixture was stirred at room temperature for 30 min, then concentrated in vacuo. The residue was dissolved in ethyl acetate, washed with brine, dried with Na_2SO_4 and then concentrated in vacuo. The residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 3:1) to give **15** as white crystals (1.63 g, 86%). M.p. 109−111 °C. TLC (toluene/ethyl acetate, 10:1): R_f = 0.28. $[\alpha]_D^{25}$ = +79.8 (*c* = 0.51, CH_2Cl_2). ^{1}H NMR (300 MHz, CDCl$_3$): δ = 1.88 (m, 1 H, 6-OH), 3.49 (ddd, *J* = 2.4, 4.2, 9.0 Hz, 1 H, 5-H), 3.70 (t, *J* = 9.0 Hz, 1 H, 4-H), 3.70−3.78 (m, 1 H, 6-H), 3.78 (t, *J* = 9.0 Hz, 1 H, 3-H), 3.90−3.97 (m, 1 H, 6-H), 4.51 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.69 (d, *J* = 11.7 Hz, 2 H, ArC*H*H × 2), 4.80 (d, *J* = 10.2 Hz, 1 H, 1-H), 4.81 (d, *J* = 11.4 Hz, 1 H, ArC*H*H), 5.19 (dd, *J* = 9.0, 10.2 Hz, 1 H, 2-H), 6.72 (d, *J* = 8.1 Hz, 1 H, ClAzb), 6.98 (dd, *J* = 2.1, 8.1 Hz, 1 H, ClAzb), 7.08 (d, *J* = 2.1 Hz, 1 H, ClAzb), 7.22−7.47 (m, 12 H, ArH), 7.57−7.66 (m, 1 H, ArH), 7.92−7.95 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, CDCl$_3$): δ = 61.7 (C-6), 71.9 (C-2), 73.7 (Ar*C*H$_2$), 75.0 (Ar*C*H$_2$), 77.4 (C-4), 79.4 (C-5), 84.0 (C-3), 85.8 (C-1), 119.1, 124.1, 127.2, 127.6, 127.7, 128.0, 128.2, 128.6, 129.1, 129.3, 129.7, 132.0, 132.2, 132.9, 135.3, 135.9, 137.2, 164.5 (*C*=O) ppm. ESI-MS: *m*/*z* = 654.0 [M + Na$^+$]. $C_{33}H_{30}ClN_3O_6S$ (632.13): calcd. C 62.70, H 4.78, N 6.65; found C 62.53, H 4.69, N 6.66.

2,3,4,6-Tetra-*O*-benzoyl-α-D-glucopyranosyl Benzoate (17): Benzoyl chloride (6.91 mL, 60.0 mmol) was added dropwise to a suspension of D-glucose (1.80 g, 10.0 mmol) in pyridine (50 mL) at 0 °C and the mixture was stirred for 2 h. The reaction was quenched by adding cold water (100 mL) and the product was extracted twice with ethyl acetate. The combined organic layers were washed with hydrochloric acid (1 mol/L) and brine, dried with Na_2SO_4 and then concentrated in vacuo. The residue was crystallized from hexane/ethyl acetate to give **17** as white crystals (6.66 g, 95%). M.p. 177−179 °C. TLC (hexane/ethyl acetate, 2:1): R_f = 0.49. $[\alpha]_D^{25}$ = +136.8 (*c* = 1.00, CH_2Cl_2). ^{1}H NMR (300 MHz, CDCl$_3$): δ = 4.48 (dd, *J* = 5.1, 12.6 Hz, 1 H, 6-H), 4.58−4.64 (m, 2 H, 5-H, 6-H), 5.67 (dd, *J* = 3.9, 9.9 Hz, 1 H, 2-H), 5.85 (t, *J* = 9.9 Hz, 1 H, 4-H), 6.31 (t, *J* = 9.9 Hz, 1 H, 3-H), 6.84 (d, *J* = 3.9 Hz, 1 H, 1-H), 7.24−7.56 (m, 14 H, ArH), 7.62−7.68 (m, 1 H, ArH), 7.86 (m, 4 H, ArH), 7.93 (m, 2 H, ArH), 8.01 (m, 2 H, ArH), 8.15 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, CDCl$_3$): δ = 62.3 (C-6), 68.6 (C-4), 70.3 (3 s, 3 C, C-2, C-3, C-5), 89.8 (C-1), 127.99, 128.02, 128.2, 128.3, 128.4, 128.6, 129.1, 129.35, 129.39, 129.45, 129.49, 129.6, 132.7, 132.9, 133.1, 133.5, 163.9 (*C*=O), 164.6 (*C*=O), 164.8 (*C*=O), 165.4 (*C*=O), 165.6 (*C*=O) ppm. ESI-MS: *m*/*z* = 723.2 [M + Na]$^+$. $C_{41}H_{32}O_{11}$ (700.69): calcd. C 70.28, H 4.60; found C 70.11, H 4.54.

2,3,4,6-Tetra-*O*-benzoyl-α/β-D-glucopyranose (18): A solution of methylamine in methanol (40%, 2 mL) was added to a solution of **17** (2.57 g, 3.66 mmol) in THF (20 mL) at room temperature and the mixture was stirred for 2 h. The mixture was concentrated in vacuo and the residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 3:1) to give **18** as a colorless solid (1.81 g, 83%, α/β = 4:1). TLC (hexane/ethyl acetate, 2:1): R_f = 0.36. ^{1}H NMR (300 MHz, $CDCl_3$): α-anomer: δ = 4.44 (dd, *J* = 4.5, 12.0 Hz, 1 H, 6-H), 4.65 (dd, *J* = 3.0, 12.0 Hz, 1 H, 6-H), 4.67 (ddd, *J* = 3.0, 4.5, 9.9 Hz, 1 H, 5-H), 5.32 (dd, *J* = 3.3, 9.9 Hz, 1 H, 2-H), 5.73 (t, *J* = 9.9 Hz, 1 H, 4-H), 5.75 (d, *J* = 3.3 Hz, 1 H, 1-H), 6.25 (t, *J* = 9.9 Hz, 1 H, 3-H), 7.24−7.61 (m, 12 H, ArH), 7.83−8.08 (m, 8 H, ArH); β-anomer: δ = 4.19 (ddd, *J* = 3.0, 5.1, 9.7 Hz, 1 H, 5-H), 4.49 (dd, *J* = 5.1, 12.3 Hz, 1 H, 6-H), 4.67 (dd, *J* = 3.0, 12.3 Hz, 1 H, 6-H), 5.06 (d, *J* = 8.1 Hz, 1 H, 1-H), 5.35 (dd, *J* = 8.1, 9.7 Hz, 1 H, 2-H), 5.70 (t, *J* = 9.7 Hz, 1 H, 4-H), 5.96 (t, *J* = 9.7 Hz, 1 H, 3-H), 7.24−7.61 (m, 12 H, ArH), 7.83−8.08 (m, 8 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): α-anomer: δ = 62.7 (C-6), 67.6 (C-5), 69.2 (C-4), 69.9 (C-3), 72.0 (C-2), 90.2 (C-1), 127.9, 128.00, 128.03, 128.07, 128.50, 128.54, 128.7, 129.2, 129.3, 129.4, 129.5, 132.7, 133.0, 133.1, 164.8 (*C*=O), 165.4 (2 C, *C*=O × 2), 165.8 (*C*=O) ppm. ESI-MS: *m*/*z* = 619.1 [M + Na$^+$]. $C_{34}H_{28}O_{10}$ (596.59): calcd. C 68.45, H 4.73; found C 68.06, H 4.73.

***O*-(2,3,4,6-Tetra-*O*-benzoyl-α/β-D-glucopyranosyl) Trichloroacetimidate (16):** Cs_2CO_3 (164 mg, 0.50 mmol) was added to a solution of **18** (1.50 g, 2.51 mmol) and trichloroacetonitrile (2.52 mL, 25.1 mmol) in CH_2Cl_2 (5 mL) at room temperature and the mixture was stirred for 2 h, then filtered. The filtrate was concentrated in vacuo and the residue was purified by silica-gel column chromatography (hexane/ethyl acetate, 3:1) to give **16** as a white solid (1.70 g, 91%, α/β = 5:1). TLC (hexane/ethyl acetate, 2:1): R_f = 0.56, 0.44 (α- and β-anomer, respectively). ^{1}H NMR (300 MHz, $CDCl_3$): α-anomer: δ = 4.48 (dd, *J* = 5.7, 12.9 Hz, 1 H, 6-H), 4.61−4.66 (m, 2 H, 5-H, 6-H), 5.61 (dd, *J* = 3.8, 10.0 Hz, 1 H, 2-H), 5.81 (t, *J* = 10.0 Hz, 1 H, 4-H), 6.27 (t, *J* = 10.0 Hz, 1 H, 3-H), 6.83 (d, *J* = 3.8 Hz, 1 H, 1-H), 7.24−7.58 (m, 12 H, ArH), 7.84−8.03 (m, 8 H, ArH), 8.62 (s, 1 H, NH); β-anomer: δ = 4.38 (ddd, *J* = 3.5, 4.8, 9.5 Hz, 1 H, 5-H), 4.54 (dd, *J* = 4.8, 11.9 Hz, 1 H, 6-H), 4.68 (dd, *J* = 3.5, 11.9 Hz, 1 H, 6-H), 5.82 (dd, *J* = 7.5, 9.0 Hz, 1 H, 2-H), 5.82 (dd, *J* = 9.0, 9.5 Hz, 1 H, 4-H), 5.97 (t, *J* = 9.0 Hz, 1 H, 3-H), 6.23 (d, *J* = 7.5 Hz, 1 H, 1-H), 7.24−7.56 (m, 12 H, ArH), 7.85−8.04 (m, 8 H, ArH), 8.70 (s, 1 H, NH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): α-anomer: δ = 62.3 (C-6), 68.5 (C-4), 70.0 (C-3), 70.5 (2 s, 2 C, C-2, C-5), 92.8 (C-1), 127.96, 127.99, 128.05, 128.17, 128.23, 128.5, 129.2, 129.3, 129.4, 129.5, 132.7, 132.9, 133.2, 160.0 (*C*=NH), 164.7 (*C*=O), 164.9 (*C*=O), 165.1 (*C*=O), 165.5 (*C*=O); β-anomer: δ = 62.6 (C-6), 68.9 (C-4), 70.5 (C-2), 72.4 (C-3), 72.8 (C-5), 95.6 (C-1), 127.96, 128.03, 128.05, 128.3, 128.6, 129.2, 129.37, 129.42, 129.44, 132.7, 133.0, 133.1, 160.5 (*C*=NH), 164.3 (*C*=O), 164.6 (*C*=O), 165.1 (*C*=O), 165.6 (*C*=O) ppm. ESI-MS: *m*/*z* = 762.1 [M + Na$^+$]. $C_{36}H_{28}Cl_3NO_{10}$ (740.97): calcd. C 58.35, H 3.81, N 1.89; found C 58.47, H 3.80, N 1.98.

Phenyl (2,3,4,6-Tetra-*O*-benzoyl-β-D-glucopyranosyl)-(1→6)-3-*O*-(4-azido-3-chlorobenzyl)-2-*O*-benzoyl-4-*O*-benzyl-1-thio-β-D-glucopyranoside (3): A mixture of imidate **16** (1.33 g, 1.80 mmol), thioglycoside **15** (948 mg, 1.50 mmol) and 4-Å molecular sieves (ca. 500 mg) in CH_2Cl_2 (10 mL) was stirred at room temperature for 15 min, then cooled to ice/salt temperature. $Sn(OTf)_2$ (75 mg, 0.18 mmol) was added and the mixture was stirred for 2 h, then filtered. The filtrate was concentrated in vacuo and the residue was purified by silica-gel column chromatography (toluene/ethyl acetate 10:1) to give **3** as white crystals (1.51 g, 83%). M.p. 164−167 °C. TLC (toluene/ethyl acetate, 10:1): R_f = 0.47. $[\alpha]_D^{25}$ = +38.6 (*c* = 0.51, CH_2Cl_2). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 3.45 (dd, *J* = 9.0, 9.3 Hz, 1 H, 4a-H), 3.59 (ddd, *J* = 1.8, 5.6, 9.3 Hz, 1 H, 5a-H), 3.65 (t, *J* = 9.0 Hz, 1 H, 3a-H), 3.83 (dd, *J* = 5.6, 11.8 Hz, 1 H, 6a-H), 4.06 (ddd, *J* = 3.1, 5.0, 9.6 Hz, 1 H, 5b-H), 4.15 (dd, *J* = 1.8, 11.8 Hz, 1 H, 6a-H), 4.38 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.46 (d, *J* = 10.9 Hz, 1 H, ArC*H*H), 4.49 (dd, *J* = 5.0, 12.0 Hz, 1 H, 6b-H), 4.53 (d, *J* = 10.9 Hz, 1 H, ArC*H*H), 4.55 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.63 (dd, *J* = 3.1, 12.0 Hz, 1 H, 6b-H), 4.66 (d, *J* = 10.0 Hz, 1 H, 1a-H), 4.92 (d, *J* = 7.8 Hz, 1 H, 1b-H), 5.11 (dd, *J* = 9.0, 10.0 Hz, 1 H, 2a-H), 5.56 (dd, *J* = 7.8, 9.6 Hz, 1 H, 2b-H), 5.66 (t, *J* = 9.6 Hz, 1 H, 4b-H), 5.85 (d, *J* = 9.6 Hz, 1 H, 3b-H), 6.70 (d, *J* = 8.1 Hz, 1 H, ClAzb), 6.91 (dd, *J* = 2.1, 8.1 Hz, 1 H, ClAzb), 7.07 (d, *J* = 2.1 Hz, 1 H, ClAzb), 7.09−7.13 (m, 2 H, ArH), 7.23−7.61 (m, 23 H, ArH), 7.80−7.94 (m, 8 H, ArH), 7.99−8.03 (m, 2 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 62.9 (C-6b), 67.7 (C-6a), 69.5 (C-4b), 71.6 (C-2b), 71.7 (C-2a), 72.1 (C-5b), 72.4 (C-3b), 73.5 (Ar*C*H2), 74.8 (Ar*C*H2), 77.6 (C-4a), 78.9 (C-5a), 84.1 (C-3a), 85.7 (C-1a), 100.7 (C-1b), 119.0, 124.0, 127.1, 127.3, 127.6, 127.8, 127.9, 127.98, 128.03, 128.1, 128.4, 128.6, 128.8, 129.17, 129.20, 129.3, 129.36, 129.39, 129.7, 132.0, 132.4, 132.7, 132.8, 133.0, 135.3, 135.8, 137.1, 164.4 (*C*=O), 164.5 (*C*=O), 164.7 (*C*=O), 165.3 (*C*=O), 165.6 (*C*=O) ppm. ESI-MS: *m*/*z* = 1232.3 [M + Na$^+$]. $C_{67}H_{56}ClN_3O_{15}S$ (1210.70): calcd. C 66.47, H 4.66, N 3.47; found C 66.20, H 4.58, N 3.51.

Aminomethylated Resin 19: A suspension of Diaion® HP20 (5.23 g), *N*-(hydroxymethyl)phthalimide (185 mg, 1.05 mmol), trifluoromethanesulfonic acid (0.47 mL, 5.23 mmol) in trifluoroacetic acid/CH_2Cl_2 (1:1, 50 mL) was shaken at room temperature for 5 h. The reaction was monitored by IR spectroscopy of washed resin samples (KBr pellets of 2−3 beads) and proceeded until no further change was observed around 1720 cm^{-1}. The mixture was filtered and the resin washed with methanol and CH_2Cl_2, then dried in vacuo. The resin was suspended in ethanol (45 mL), hydrazine hydrate (5 mL) was added and the mixture was refluxed for 16 h. The reaction was monitored by IR spectroscopy of washed resin samples (KBr pellets of 2−3 beads) and proceeded until the peak around 1720 cm^{-1} disappeared. The mixture was filtered while hot, and the resulting resin was washed with methanol and dried in vacuo to give **19** (5.59 g, 0.19 mmol/g loading) as faintly yellow beads.

Determination of the Loading Rate of Aminomethyl Group: The resin **19** (ca. 100 mg, exactly weighed) was washed with a solution of diisopropylethylamine in CH_2Cl_2 (5%, 5 mL × 2) and CH_2Cl_2 (5 mL × 2). Then, the resin was suspended in a solution of picric acid in CH_2Cl_2 (0.1 mol/L, 5 mL) and the suspension was shaken at room temperature for 1 h. The resin was filtered and washed with CH_2Cl_2 (5 mL × 5) and methanol (5 mL × 2). The picrate on the resin was eluted with a solution of diisopropylethylamine in CH_2Cl_2 (5%, 5 mL × 2) and CH_2Cl_2 (4 mL × 2). The filtrate containing the picrate was combined and diluted with CH_2Cl_2 to 20 mL. This solution was further diluted with ethanol (1:50) and subjected to UV measurements. The concentration was calculated using a standard straight line prepared with solutions of known amounts of picric acid.

Solid-Supported Monosaccharide 4: A mixture of carboxylic acid **12** (187 mg, 0.22 mmol), resin **19** (1.053 g, 0.2 mmol), *N*,*N*-diisopropylcarbodiimide (38 μL, 0.24 mmol), 1-hydroxybenzotriazole

(HOBt) (30 mg, 0.22 mmol) and CH_2Cl_2 (5.5 mL) was shaken at room temperature for 16 h. After filtration, the resin was washed with methanol and CH_2Cl_2, then dried in vacuo to give solid-supported monosaccharide **4** as a slightly yellowish powder (1.232 g, quant., calculated from weight gain of the resin).

4-(Hydroxymethyl)benzyl 3-*O*-(4-Azido-3-chlorobenzyl)-4,6-di-*O*-benzyl-β-D-glucopyranoside (20). General Procedure for Cleavage: Solid-supported monosaccharide **4** (245 mg, 0.04 mmol) was suspended in a mixture of methanol and THF (1:1, 5 mL). Sodium methoxide (27 mg, 0.5 mmol) was added and the mixture was shaken at room temperature for 4 h. The resin was filtered off and washed with methanol (5 mL × 2). Complete cleavage was confirmed by IR measurement (KBr disk) on a small portion of the resin (disappearance of the peak of the azido group around 2120 cm^{-1}). If necessary, the procedure was repeated to complete the cleavage. The filtrate and washings were combined and neutralized with Amberlyst® 15 (H^+ form), then concentrated in vacuo. The residue was purified by preparative TLC (hexane/ethyl acetate, 1:1) to give **20** as white crystals (25 mg, quant.). M.p. 145−146 °C. TLC (hexane/ethyl acetate, 1:1): $R_f = 0.42$. $[\alpha]_D^{25} = -36.2$ ($c = 0.52$, CH_2Cl_2). ^1H NMR (300 MHz, $CDCl_3$): δ = 1.61 (t, *J* = 5.7 Hz, 1 H, CH_2-O*H*), 2.31 (d, *J* = 2.1 Hz, 1 H, 2-OH), 3.46 (ddd, *J* = 2.4, 4.2, 8.4 Hz, 1 H, 5-H), 3.55 (t, *J* = 8.4 Hz, 1 H, 3-H), 3.60 (ddd, *J* = 2.1, 7.7, 8.4 Hz, 1 H, 2-H), 3.61 (t, *J* = 8.4 Hz, 1 H, 4-H), 3.71 (dd, *J* = 4.2, 10.8 Hz, 1 H, 6-H), 3.76 (dd, *J* = 2.4, 10.8 Hz, 1 H, 6′-H), 4.32 (d, *J* = 7.7 Hz, 1 H, 1-H), 4.54 (d, *J* = 12.3 Hz, 1 H, ArC*H*H), 4.54 (d, *J* = 11.4 Hz, 1 H, ArC*H*H), 4.61 (d, *J* = 11.4 Hz, 1 H, ArC*H*H), 4.63 (d, *J* = 12.3 Hz, 1 H, ArC*H*H), 4.69 (d, *J* = 5.7 Hz, 2 H, ArCH_2OH), 4.71 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.75 (d, *J* = 11.4 Hz, 1 H, ArC*H*H), 4.85 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.94 (d, *J* = 11.4 Hz, 1 H, ArC*H*H), 7.05 (d, *J* = 8.4 Hz, 1 H, ClAzb), 7.13−7.16 (m, 2 H, ArH), 7.20−7.35 (m, 14 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 64.8 (Ar*C*H_2OH), 68.5 (C-6), 70.6 (Ar*C*H_2), 73.3 (Ar*C*H_2), 73.4 (Ar*C*H_2), 74.6 (C-2), 74.8 (Ar*C*H_2), 75.0 (C-5), 77.2 (C-4), 84.1 (C-3), 101.3 (C-1), 119.1, 124.4, 126.7, 126.9, 127.3, 127.4, 128.00, 128.03, 128.1, 129.7, 135.9, 136.0, 136.3, 137.5, 137.6, 140.3 ppm. ESI-MS: *m*/*z* = 668.2 [M + Na^+]. $C_{35}H_{36}ClN_3O_7$ (646.13): calcd. C 65.06, H 5.62, N 6.50; found C 64.81, H 5.55, N 6.46.

Solid-Supported Trisaccharide 22

1. General Procedure for Capping of Free Hydroxy Groups: Resin **4** (1.232 g, 0.2 mmol) was suspended in CH_2Cl_2 (5 mL). Triethylamine (28 μL, 0.2 mmol), acetic anhydride (19 μL, 0.2 mmol) and dimethylaminopyridine (6 mg, 0.05 mmol) were added and the mixture was shaken at room temperature for 1 h. The resin was then filtered off, washed with methanol (10 mL × 2) and CH_2Cl_2 (10 mL × 2), then subjected to the subsequent deprotection step.

2. General Procedure for Removal of the ClAzb Groups: Resin **4** (0.2 mmol) was suspended in CH_2Cl_2 (5 mL). Tributylphosphane (148 μL, 0.6 mmol) was added and the mixture was shaken at room temperature for 1 h. The resin was then filtered off, washed with CH_2Cl_2, then suspended in THF (5 mL) again. DDQ (68 mg, 0.3 mmol), acetic acid (50 μL) and H_2O (50 μL) were added and the mixture was shaken at room temperature for 2 h, then filtered off. The resin was washed with DMF (10 mL), a solution of triethylamine in DMF (5%, 10 mL × 2), methanol (10 mL × 2) and CH_2Cl_2 (10 mL × 2), and dried in vacuo to give resin **21** as a slightly yellowish powder (1.201 g).

3. General Procedure for the Solid-Phase Glycosylation: Resin **21** (1.201 g, 0.2 mmol) was suspended in CH_2Cl_2 (5 mL). Glycosyl donor **3** (701 mg, 0.6 mmol), $Sn(OTf)_2$ (63 mg, 0.15 mmol) and 4-Å molecular sieves (bead type, ca. 0.5 g) were added and the mixture was shaken at room temperature for 15 min. The reaction was started by addition of NBS (112 mg, 0.63 mmol) and the mixture was shaken at room temperature for 1 h, then filtered. The resin was suspended in CH_2Cl_2 (5 mL) and allowed to settle to remove molecular sieves. The resin was further washed with methanol (10 mL × 2) and CH_2Cl_2 (10 mL × 2), and dried in vacuo to give solid-supported trisaccharide **22** as a slightly yellowish powder (1.325 g). IR measurement (KBr disk) was carried out on the resin to confirm the introduction of ClAzb-donor onto the resin (peak of the azido group at 2126 cm^{-1}). If necessary, the procedure was repeated to complete the glycosylation.

4-(Hydroxymethyl)benzyl β-D-Glucopyranosyl-(1→6)-3-*O*-(4-azido-3-chlorobenzyl)-4,6-di-*O*-benzyl-β-D-glucopyransyl-(1→3)-4,6-di-*O*-benzyl-β-D-glucopyranoside (23): Solid-supported trisaccharide **22** (331 mg) was treated according to the General Procedure for cleavage and the product was purified by silica-gel column chromatography (CH_2Cl_2/methanol, 98:2) to give trisaccharide **23** as a colorless solid (20 mg, 37% from **4**). TLC (CH_2Cl_2/methanol, 9:1): $R_f = 0.35$. ^1H NMR (300 MHz, $CDCl_3$ + 5% CD_3OD): δ = 2.94 (m, 1 H, 5c-H), 3.11 (dd, *J* = 7.5, 8.7 Hz, 1 H, 2c-H), 3.28 (t, *J* = 8.7 Hz, 1 H, 3c-H), 3.33 (t, *J* = 8.7 Hz, 1 H, 4c-H), 3.40−3.67 (m, 10 H), 3.68 (dd, *J* = 4.2, 10.9 Hz, 1 H, 6a-H), 3.75 (dd, *J* = 2.1, 10.9 Hz, 1 H, 6a-H), 3.89 (overlapped, 1 H, 6b-H), 3.91 (t, *J* = 9.5 Hz, 1 H, 3a-H), 4.14 (d, *J* = 7.5 Hz, 1 H, 1c-H), 4.33 (d, *J* = 7.8 Hz, 1 H, 1b-H), 4.50 (d, *J* = 10.2 Hz, 1 H, ArC*H*H), 4.54 (d, *J* = 12.3 Hz, 1 H, ArC*H*H), 4.58 (d, *J* = 11.1 Hz, 2 H, ArC*H*H), 4.61 (s, 2 H, ArCH_2O), 4.61 (d, *J* = 12.3 Hz, 1 H, ArC*H*H), 4.65 (d, *J* = 9.3 Hz, 1 H, 1a-H), 4.68 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.77 (d, *J* = 11.1 Hz, 1 H, ArC*H*H), 4.86 (d, *J* = 11.7 Hz, 1 H, ArC*H*H), 4.89 (d, *J* = 10.2 Hz, 1 H, ArC*H*H), 4.90 (d, *J* = 11.1 Hz, 1 H, ArC*H*H), 7.04 (d, *J* = 8.1 Hz, 1 H, ClAzb), 7.19−7.37 (m, 21 H, ArH) ppm. ^{13}C NMR (75 MHz, $CDCl_3$ + 5% CD_3OD): δ = 61.4 (6c-C), 64.5 (Ar*C*H_2OH), 68.0 (C-6b), 68.5 (C-6a), 69.4 (4c-C), 70.4 (Ar*C*H_2), 72.9, 73.1 (2c-C), 73.4 (Ar*C*H_2), 73.6 (Ar*C*H_2), 74.6 (4 C), 74.8 (Ar*C*H_2), 75.1 (5c-C), 75.9 (3c-C), 76.0, 77.5, 82.6 (C-3a), 84.3 (C-3b), 100.7 (C-1b), 102.0 (C-1a), 102.7 (1c-C), 119.2, 124.4, 126.9, 127.0, 127.46, 127.50, 127.57, 127.60, 128.0, 128.1, 128.2, 128.3, 129.7, 135.8, 136.0, 136.2, 137.3, 137.4, 137.5, 140.5 ppm. ESI-MS: *m*/*z* = 1082.4 [M + Na^+]. $C_{54}H_{62}ClN_3O_{17}$ (1060.5).

Solid-Supported Tetrasaccharide 24: Solid-supported trisaccharide **22** (994 mg) was treated according to the General Procedures for capping of free hydroxy groups and removal of the ClAzb groups, then dried in vacuo. The resin (979 mg) was treated with thioglycoside **2** according to the General Procedure for the solid-phase glycosylation to give solid-supported tetrasaccharide **24** as a slightly yellowish powder (1.025 g).

4-(Hydroxymethyl)benzyl 3-*O*-(4-Azido-3-chlorobenzyl)-4,6-di-*O*-benzyl-β-D-glucopyranosyl-(1→3)-[β-D-glucopyranosyl-(1→6)]-4,6-di-*O*-benzyl-β-D-glucopyranosyl-(1→3)-4,6-di-*O*-benzyl-β-D-glucopyranoside (25): Solid-supported tetrasaccharide **24** (342 mg) was cleaved according to the General Procedure for cleavage and the product was purified by silica-gel column chromatography (CH_2Cl_2/methanol, 98:2) to give tetrasaccharide **25** as a colorless solid (22 mg, 31% from **4**). For NMR measurement, tetrasaccharide **25** was purified by reversed-phase HPLC (column: Waters Prep Nova-Pak® HR C18, 6 μm, 25 × 100 mm, mobile phase: acetonitrile/water, 7:3, flow rate: 7.0 mL/min, detection: UV 210 nm, retention time = 17.9 min). TLC (CH_2Cl_2/methanol, 9:1): $R_f = 0.32$. ^1H NMR (600 MHz, $CDCl_3$ + 5% CD_3OD): δ = 2.92 (ddd, *J* = 3.0, 4.8, 9.0 Hz, 1 H, 5c′-H), 3.14 (dd, *J* = 7.8, 9.0 Hz, 1 H, 2c′-H), 3.29 (t, *J* = 9.0 Hz, 1 H, 3c′-H), 3.34 (t, *J* = 9.0 Hz, 1 H, 4c′-

H), 3.38 (ddd, J = 2.1, 3.3, 9.0 Hz, 1 H, 5c-H), 3.42 (dd, J = 2.1, 10.8 Hz, 1 H, 6c-H), 3.45−3.48 (m, 2 H, 5b-H, 5a-H), 3.50−3.69 (m, 11 H), 3.70 (dd, J = 3.0, 11.4 Hz, 1 H, 6c′-H), 3.75 (dd, J = 2.2, 10.8 Hz, 1 H, 6a-H), 3.82 (t, J = 9.0 Hz, 1 H, 3b-H), 3.86 (dd, J = 2.1, 9.6 Hz, 1 H, 6b-H), 3.90 (t, J = 9.0 Hz, 1 H, 3a-H), 4.13 (d, J = 7.8 Hz, 1 H, 1c′-H), 4.31 (d, J = 12.0 Hz, 1 H, ArC*H*H), 4.36 (d, J = 7.8 Hz, 1 H, 1a-H), 4.44 (d, J = 12.0 Hz, 1 H, ArC*H*H), 4.48 (d, J = 10.2 Hz, 1 H, ArC*H*H), 4.52 (d, J = 11.4 Hz, 1 H, ArC*H*H), 4.50 (d, J = 12.0 Hz, 1 H, ArC*H*H), 4.59 (d, J = 11.4 Hz, 1 H, ArC*H*H), 4.61 (d, J = 12.0 Hz, 1 H, ArC*H*H), 4.62 (d, J = 7.8 Hz, 1 H, 1c-H), 4.63 (s, 2 H, ArCH_2OH), 4.64 (d, J = 11.4 Hz, 1 H, ArC*H*H), 4.70 (d, J = 7.6 Hz, 1 H, 1b-H), 4.71 (d, J = 11.4 Hz, 1 H, ArC*H*H), 4.73 (d, J = 12.0 Hz, 1 H, ArC*H*H), 4.88 (d, J = 12.0 Hz, 1 H, ArC*H*H), 4.92 (d, J = 11.4 Hz, 1 H, ArC*H*H), 4.97 (d, J = 10.2 Hz, 1 H, ArC*H*H), 5.15 (d, J = 11.4 Hz, 1 H, ArC*H*H), 7.07−7.15 (m, 3 H, ArH), 7.21−7.43 (m, 29 H, ArH) ppm. ^{13}C NMR (151 MHz, $CDCl_3$+ 10% CD_3OD): δ = 61.4 (C-6c′), 64.1 (ArCH$_2$OH), 68.0 (6c-C), 68.1 (C-6b), 68.6 (C-6a), 69.7 (C-4c′), 70.5 (ArCH$_2$), 73.2 (ArCH$_2$), 73.3 (4 C, C-2a, C-2c′, ArCH$_2$ × 2), 73.4 (ArCH$_2$), 74.2 (ArCH$_2$), 74.5 (2 C, C-5a, C-5b), 74.6 (2c-C), 74.7 (C-2b), 74.7 (ArCH$_2$), 75.0 (5c-C), 75.2 (C-5c′), 75.4 (C-3c′), 75.9 (C-4a), 76.2 (C-4b), 76.4 (4c-C), 84.3 (C-3a), 84.5 (3c-C), 86.6 (C-3b), 101.0 (C-1a), 103.1 (2 C, C-1b, C-1c′), 105.5 (1c-C), 119.3, 126.8, 127.2, 127.3, 127.4, 127.5, 127.6, 127.7, 127.9, 128.1, 128.2, 129.8, 135.9, 136.0, 136.6, 137.6, 137.8, 137.9, 138.3, 140.6 ppm. ESI-MS: m/z = 1424.6 [M + Na$^+$]. $C_{74}H_{84}ClN_3O_{22}$ (1402.9).

Pentasaccharide 5: Solid-supported tetrasaccharide **24** (683 mg) was treated according to the General Procedures for capping of free hydroxy groups and removal of the ClAzb groups, then dried in vacuo. The resin (675 mg) was treated with thioglycoside **2** according to the General Procedure for the solid-phase glycosylation to give solid-supported pentasaccharide **26** as a slightly yellowish powder (701 mg). The resin was then treated according to the General Procedure for cleavage to give a mixture containing pentasaccharide **5**. The product was subjected to the catch-and-release purification. ESI-MS: m/z = 1766.8 [M + Na$^+$]. $C_{54}H_{62}ClN_3O_{17}$ (1745.3).

Catch-and-Release Purification of Pentasaccharide 5: The crude product containing pentasaccharide **5** was dispersed in CH_2Cl_2 (5 mL) and the insoluble substance was filtered off. The filtrate was concentrated and dried in vacuo. The residue was dissolved in CH_2Cl_2 (2 mL). To this solution was added triphenylphosphane−NovaGel^{TM} resin (Novabiochem, 0.48 mmol/g, 417 mg, 0.2 mmol, pre-washed with CH_2Cl_2) and the mixture was shaken at room temperature for 2 h. The resin was then filtered and washed with methanol (5 mL × 2) and CH_2Cl_2 (5 mL × 2). The filtrate and the washings (containing pentasaccharide **28**) were combined and subjected to the recovery procedure (vide infra). The resin was suspended in THF (2 mL), then DDQ (45 mg, 0.2 mmol), acetic acid (50 μL) and H_2O (50 μL) were added. The mixture was shaken at room temperature for 2 h, then filtered and the resin was washed with methanol (5 mL × 2) and CH_2Cl_2 (5 mL × 2). The filtrate and washings were combined and added to a methanolic solution of L-ascorbic acid (35 mg, 0.2 mmol in 5 mL). After stirring for 5 min, the solution was passed through two columns of ion-exchange resins Amberlyst® A-26 (OH$^-$ form, 2 × 5 cm) and Amberlyst® 15 (H$^+$ form, 1.2 × 4 cm) in this order. The solvent was removed in vacuo to give pentasaccharide **29** as a colorless solid (9 mg, 6% from **4**).

Recovery of Pentasaccharide from the Filtrate of the Catch-and-Release Purification: The filtrate of the "catching" process containing pentasaccharide **28** was concentrated in vacuo and the residue was dissolved in THF (5 mL). DDQ (23 mg, 0.1 mmol), acetic acid (50 μL) and H_2O (50 μL) were added and the mixture was stirred at room temperature for 2 h, then quenched by addition of a methanolic solution of L-ascorbic acid (18 mg, 0.1 mmol in 5 mL). The mixture was passed through two columns of ion-exchange resins Amberlyst® A-26 (OH$^-$ form, 2 × 5 cm) and Amberlyst® 15 (H$^+$ form, 1 × 5 cm) in this order, then concentrated in vacuo. The residue was purified by reversed-phase HPLC (column: Waters Prep Nova-Pak® HR C18, 6 μm, 25 × 100 mm, mobile phase: acetonitrile/water, 7:3, flow rate: 8.0 mL/min, detection: UV 210 nm, retention time: 16.5 min) using pentasaccharide **29** obtained by the catch-and-release procedure as a reference substance to give **29** as a colorless solid (14 mg, 9% from **4**).

Pentasaccharide 28: Detected by MS analysis of the filtrate. ESI-MS: m/z = 1740.9 [M + Na$^+$]. $C_{94}H_{108}ClNO_{27}$ (1719.3).

4-(Hydroxymethyl)benzyl 4,6-Di-*O*-benzyl-β-D-glucopyranosyl-(1→3)-4,6-di-*O*-benzyl-β-D-glucopyranosyl-(1→3)-[β-D-glucopyranosyl-(1→6)]-4,6-di-*O*-benzyl-β-D-glucopyranosyl-(1→3)-4,6-di-*O*-benzyl-β-D-glucopyranoside (29): ^{1}H NMR (600 MHz, $CDCl_3$ + 10% CD_3OD): δ = 2.79 (ddd, J = 3.0, 4.8, 9.0 Hz, 1 H, 5c′-H), 3.06 (dd, J = 7.7, 9.0 Hz, 1 H, 2c′-H), 3.20 (t, J = 9.0 Hz, 1 H, 3c′-H), 3.23 (t, J = 9.0 Hz, 1 H, 4c′-H), 3.28−3.31 (m, 2 H, 5c-H, 5d-H), 3.34 (dd, J = 7.8, 9.0 Hz, 1 H, 2d-H), 3.35 (dd, J = 1.7, 11.1 Hz, 1 H, 6c-H), 3.36−3.42 (m, 3 H, 6d-H, 5a-H, 5b-H), 3.43−3.54 (m, 11 H), 3.56 (t, J = 9.0 Hz, 1 H, 4c-H), 3.58 (dd, J = 4.4, 10.8 Hz, 1 H, 6a-H), 3.60 (dd, J = 3.0, 12.0 Hz, 1 H, 6c′-H), 3.65 (dd, J = 1.8, 10.8 Hz, 1 H, 6a-H), 3.70 (t, J = 9.1 Hz, 1 H, 3c-H), 3.73 (t, J = 8.8 Hz, 1 H, 3b-H), 3.82 (dd, J = 1.7, 11.0 Hz, 1 H, 6b-H), 3.84 (t, J = 9.0 Hz, 1 H, 3a-H), 4.07 (d, J = 7.7 Hz, 1 H, 1c′-H), 4.20 (d, J = 12.1 Hz, 1 H, ArC*H*H), 4.23 (d, J = 12.1 Hz, 1 H, ArC*H*H), 4.29 (d, J = 8.0 Hz, 1 H, 1a-H), 4.32 (d, J = 12.0 Hz, 1 H, ArC*H*H), 4.35 (d, J = 12.1 Hz, 1 H, ArC*H*H), 4.37 (d, J = 10.7 Hz, 1 H, ArC*H*H), 4.38 (d, J = 11.0 Hz, 1 H, ArC*H*H), 4.45 (d, J = 12.4 Hz, 1 H, ArC*H*H), 4.45 (d, J = 10.7 Hz, 1 H, ArC*H*H), 4.51 (d, J = 12.0 Hz, 2 H, ArC*H*H × 2), 4.53 (s, 2 H, ArCH_2O), 4.54 (d, J = 7.8 Hz, 1 H, 1d-H), 4.57 (d, J = 11.8 Hz, 1 H, ArC*H*H), 4.60 (d, J = 8.0 Hz, 1 H, 1c-H), 4.64 (d, J = 8.0 Hz, 1 H, 1b-H), 4.77 (d, J = 10.7 Hz, 1 H, ArC*H*H), 4.82 (d, J = 12.1 Hz, 1 H, ArC*H*H), 4.90 (d, J = 10.7 Hz, 1 H, ArC*H*H), 5.03 (d, J = 11.0 Hz, 1 H, ArC*H*H), 5.07 (d, J = 11.3 Hz, 1 H, ArC*H*H), 7.10−7.30 (m, 39 H, ArH) ppm. ^{13}C NMR (151 MHz, $CDCl_3$+ 10% CD_3OD): δ = 61.2 (C-6c′), 63.7 (ArCH$_2$OH), 68.0 (C-6b), 68.1 (6c-C), 68.2 (6d-C), 68.5 (C-6a), 69.6 (C-4c′), 70.3 (ArCH$_2$), 72.9 (ArCH$_2$), 73.0 (ArCH$_2$), 73.1 (ArCH$_2$), 73.2 (C-2c′), 73.4 (C-2a), 74.0 (ArCH$_2$), 74.1 (ArCH$_2$), 74.2 (ArCH$_2$), 74.35 (ArCH$_2$), 74.42 (C-5b), 74.5 (C-5a), 74.6 (C-2b), 74.7 (2 C, 5c-C, 5d-C), 74.77 (2c-C), 74.84 (2d-C), 75.1 (C-5c′), 75.6 (4c-C), 75.8 (C-3c′), 76.06 (C-4a), 76.09 (C-4b), 76.6 (3d-C), 77.1 (4d-C), 84.3 (C-3a), 86.6 (3c-C), 86.8 (C-3b), 100.9 (C-1a), 102.9 (C-1b), 103.1 (C-1c′), 104.5 (1c-C), 104.9 (1d-C), 126.5, 127.0, 127.2, 127.25, 127.28, 127.41, 127.44, 127.6, 127.7, 127.77, 127.84, 127.9, 135.9, 137.48, 137.52, 137.8, 137.9, 138.20, 138.24, 140.4 ppm. ESI-MS: m/z = 1601.7 [M + Na$^+$]. $C_{87}H_{102}O_{27}$ (1579.8).

β-D-Glucopyranosyl-(1→3)-β-D-glucopyranosyl-(1→3)-[β-D-glucopyranosyl-(1→6)]-β-D-glucopyranosyl-(1→3)-α/β-D-glucopyranose (1): Pd(OH)$_2$/C (20%, 20 mg) was added to a solution of pentasaccharide **29** (9.2 mg, 5.8 μmol) in methanol (3 mL) and the mixture was stirred under 5 atm of hydrogen at room temperature overnight. The Pd catalyst was removed by filtration and the filtrate was concentrated in vacuo to give pentasaccharide **1** as a colorless solid (5.2 mg, quant., α/β = 1:2). ^{1}H NMR (600 MHz, D_2O): α-anomer (selected data): δ = 5.05 (d, *J* = 4.2 Hz, 1 H, 1a-H); β-anomer: δ = 3.11 (dd, *J* = 7.8, 9.6 Hz, 1 H, 2c′-H), 3.17 (dd, *J* = 8.4, 9.6 Hz, 1 H, 2d-H), 3.20 (t, *J* = 9.0 Hz, 1 H, 4c′-H), 3.21 (t, *J* = 9.6 Hz, 1 H, 4d-H), 3.24 (dd, *J* = 7.8, 9.0 Hz, 1 H, 2a-H), 3.26 (ddd, *J* = 2.1, 4.2, 8.4 Hz, 1 H, 5c′-H), 3.27−3.35 (m, 7 H, 5a-H, 5c-H, 5d-H, 3c′-H, 3d-H, 4a-H, 4c-H), 3.36 (dd, *J* = 8.4, 9.6 Hz, 1 H, 2c-H), 3.39 (t, *J* = 8.4 Hz, 1 H, 2b-H), 3.42 (t, *J* = 8.4 Hz, 1 H, 4b-H), 3.49−3.57 (m, 6 H, 5b-H, 6d-H, 6c′-H, 6c-H, 6a-H, 3a-H), 3.59 (t, *J* = 9.6 Hz, 1 H, 3c-H), 3.62 (t, *J* = 8.4 Hz, 1 H, 3b-H), 3.69−3.75 (m, 5 H, 6a-H, 6b-H, 6c-H, 6c′-H, 6d-H), 4.03 (m, 1 H, 6b-H), 4.33 (d, *J* = 7.8 Hz, 1 H, 1c′-H), 4.49 (d, *J* = 7.8 Hz, 1 H, 1a-H), 4.55 (d, *J* = 8.4 Hz, 1 H, 1b-H), 4.70 (d, *J* = 8.4 Hz, 1 H, 1d-H), 4.75 (d, *J* = 8.4 Hz, 1 H, 1c-H) ppm. ^{13}C NMR (151 MHz, D_2O): α-anomer (selected data): δ = 91.8 (C-1a); β-anomer: δ = 60.5 (4 C, C-6a, 6c-C, C-6c′, 6d-C), 67.8−68.0 (3 C, C-4a, C-4b, 4c-C), 68.5 (C-6b), 69.4 (2 C, C-4c′, 4d-C), 72.9−73.3 (4 C, C-2b, 2c-C, C-2c′, 2d-C), 74.1 (C-5b), 75.4−75.8 (7 C, C-2a, C-3c′, 3d-C, C-5a, 5c-C, C-5c′, 5d-C), 83.6 (C-3b), 84.0 (2 C, C-3a, 3c-C), 95.5 (C-1a), 102.3 (1c-C), 102.6 (3 C, C-1b, C-1c′, 1d-C) ppm. ESI-MS: *m/z* = 851.4 [M + Na^+]. $C_{30}H_{52}O_{26}$ (828.72).

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