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Convergent Synthesis of 4-*O*-Phosphorylated L-*glycero*-D-*manno*-Heptosyl Lipopolysaccharide Core Oligosaccharides Based on Regioselective Cleavage of a 6,7-*O*-Tetraisopropyldisiloxane-1,3-diyl Protecting Group

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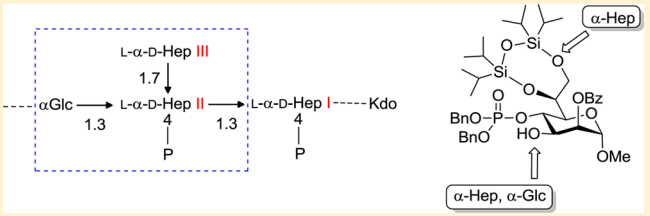
Supporting Information

ABSTRACT: The structurally conserved lipopolysaccharide core region of many Gram-negative bacteria is composed of trisaccharides containing 4-*O*-phosphorylated L-*glycero*-D-*manno*-heptose (L,D-Hep) units, which act as ligands for antibodies and lectins. The disaccharides Glc-(1→3)-Hep4P Hep-(1→3)-Hep4P and Hep-(1→7)-Hep4P and the branched trisaccharide Glc-(1→3)-[Hep-(1→7)]-Hep4P, respectively, have been synthesized from a methyl heptopyranoside acceptor in less than 10 steps. The synthetic strategy was based on the early introduction of a phosphotriester at position 4 of heptose followed by a regioselective opening of a 6,7-*O*-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl) group allowing for a straightforward access to glycosylation at position 7. Perbenzylated *N*-phenyl trifluoroacetimidate glucosyl and heptosyl derivatives served as α-selective glycosyl donors.



INTRODUCTION

Lipopolysaccharide (LPS) is a biomedically highly relevant glycolipid located in the outer leaflet of the cell membrane of Gram-negative bacteria.[1,2] LPS is essential for many functions of the bacterial membrane, providing stability, a protective shield, and permeation control, and is thus indispensable for the viability of bacteria.[3] LPS is also a major virulence factor which is involved in a multitude of interactions with the adaptive and innate immune system of respective host organisms.[4,5] In structural terms, LPS of Enterobacteriaceae comprises a highly variable O-antigenic polysaccharide chain followed by a core region which provides the link to the endotoxic lipid A domain.[6−8] Within the core region, the inner part of enterobacterial LPS is composed of the higher carbon sugars 3-deoxy-D-*manno*-oct-2-ulosonic acid (Kdo) and L-*glycero*-D-*manno*-heptose (L,D-Hep) residues.[9] Specifically, phosphorylated heptosyl units are important antigens suitable for the development of vaccines against pathogenic bacteria such as *Haemophilus influenzae* and *Neisseria meningitidis*.[10,11] A prototype phosphorylated heptose core structure as found in *Escherichia coli* and *Salmonella enterica* LPS is shown in Figure 1.

The branched 4-*O*-phosphorylated heptosyl trisaccharide core domain has recently been reported as essential part mediating the binding to the cross-reactive antibacterial monoclonal antibody WN1 222-5.[12−15] Of note, the paratope of this antibody mimics the receptor binding site of Toll-like receptor 4 (TLR-4), wherein the 4-*O*-phosphoryl heptosyl domains are involved in multiple ionic and hydrogen-bonded interactions.[16] In addition, L,D-heptosyl residues have recently been reported to interact with C-type lectins such as lung surfactant protein D (SP-D), concanavalin A, as well as bacterial lectins from *Burkholderia cenocepacia*.[17−20]

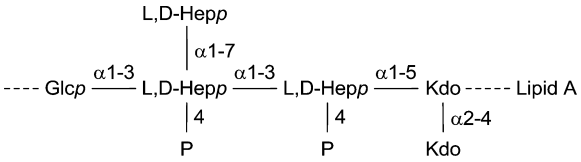


Figure 1. Common inner core oligosaccharide domains in enterobacterial LPS.

Thus, the chemical synthesis of defined heptosyl oligosaccharides is a challenging task in order to further elucidate the molecular basis of these biomedically relevant protein−LPS interactions and to provide ligands for immunochemical applications to be translated into future vaccine development.[21] The chemical synthesis of suitably protected heptosyl building blocks has been accomplished by de novo approaches as well as by exquisite orthogonal protecting group manipulations followed by selective glycosylation strategies to produce spacer-equipped oligosaccharides corresponding to LPS-inner core part structures related to *Yersinia pestis*, *Pseudomonas aeruginosa*, *N. meningitidis*, and *H. influenzae* antigens.[22−26] The latter target structures comprised 4-*O*-β-D-glucopyranosylheptosyl units with 6-*O*-phosphorylethanolamine substitution introduced at the neighboring L,D-Hep residue.[27,28]

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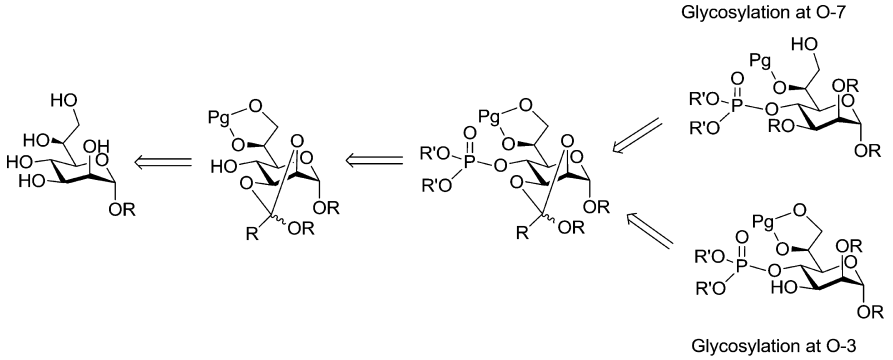
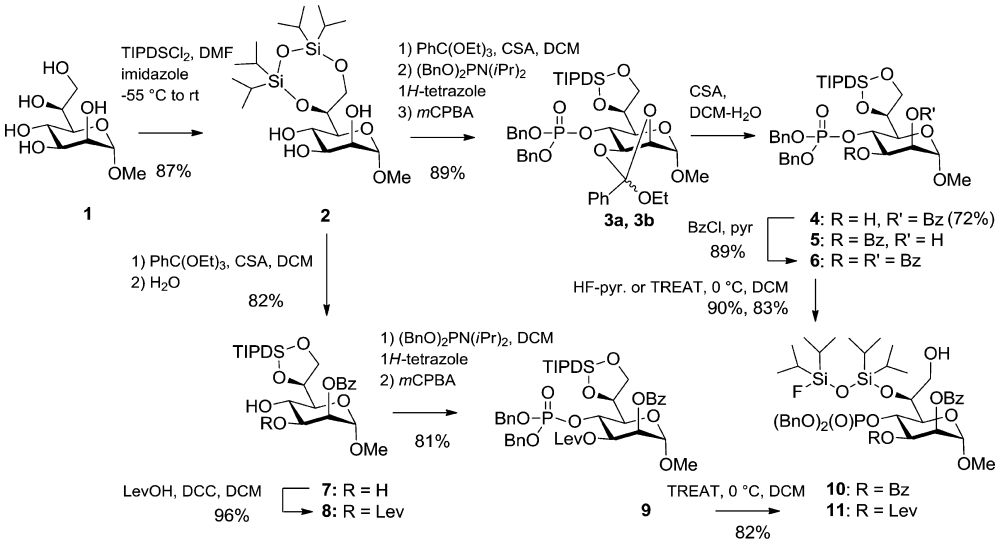


Figure 2. Retrosynthetic analysis for the synthesis of 4-*O*-phosphorylated heptosyl glycosides.

Scheme 1. Synthesis of Fully Differentiated 4-*O*-Phosphorylated Heptoside Acceptor Derivatives



The disaccharide fragment Hep4P-(1→3)-Hep4P has previously been synthesized from an orthogonally protected disaccharide precursor which was phosphorylated following cleavage of the respective protective group at either of the 4-positions.[29] Herein we disclose a highly convergent approach allowing access to α-glucosylated 4-*O*-phosphorylated heptosides based on an early introduction of a 4-*O*-phosphotriester moiety, thereby minimizing the number of protection and deblocking steps. In addition, in combination with a regioselective opening of a 1,1,3,3-tetraisopropyldisiloxane-1,3-diyl (TIPDS) protecting group to give O-7 acceptor heptoside derivatives, a straightforward assembly of several (1→7)- and (1→3)-linked 4-*O*-phosphorylated heptosides, has been elaborated.

RESULTS AND DISCUSSION

The common enterobacterial heptose region as shown in Figure 1 reveals a repetitive substitution pattern comprising two heptosyl units harboring a 4-*O*-phosphoryl substituent which are extended at position 3 by another glycose residue (note: a reversed pattern is seen in *N. meningitidis* and *H. influenzae* LPS, wherein a β-D-glucopyranosyl residue is present at O-4). The 3-*O*-α-D-glucosyl substituted heptose residue is additionally substituted at O-7 by a second heptose unit. Thus, retrosynthetic analysis would suggest assembling these ligands from a side-chain protected heptoside precursor to be converted into the corresponding 4-*O*-phosphotriester intermediate (Figure 2).

Regioselective 2,3-*O*-orthoester opening should then allow for extension at O-3, while regioselective opening of the protecting group at the side chain would generate a 7-OH glycosyl acceptor. Thus, several phosphorylated heptosyl LPS ligands would be accessible from a common 4-*O*-phosphorylated building block, thereby minimizing the number of protecting group manipulations—a highly important issue in current oligosaccharide synthesis.[30] The presence of a protected phosphate moiety to be kept throughout the synthesis, however, clearly implicates additional synthetic challenges to be met during the assembly of the oligosaccharide.

Methyl L-*glycero*-D-*manno*-heptopyranoside **1**, obtained previously by the Brimacombe approach,[31] was used for the regioselective protection of the side-chain diol at C6 and C7. Reaction of crystalline **1** with $TIPDSCl_2$ in the presence of imidazole gave directly the 6,7-*O*-TIPDS-protected derivative **2** in 87% yield (Scheme 1).

Starting from the TIPDS-protected heptoside **2**, two approaches for the differentiation of the remaining hydroxyl groups were developed via initial selective *syn*-2,3-*O*-orthoester formation. The first approach utilized the 2,3-*O*-orthobenzoate as a temporary protecting group that is sufficiently stable to allow phosphorylation using phosphoramidite-based coupling methodology. Indeed, reaction of the intermediate orthoester with dibenzyl *N*,*N*-diisopropylaminophosphoramidite/1*H*-tet-

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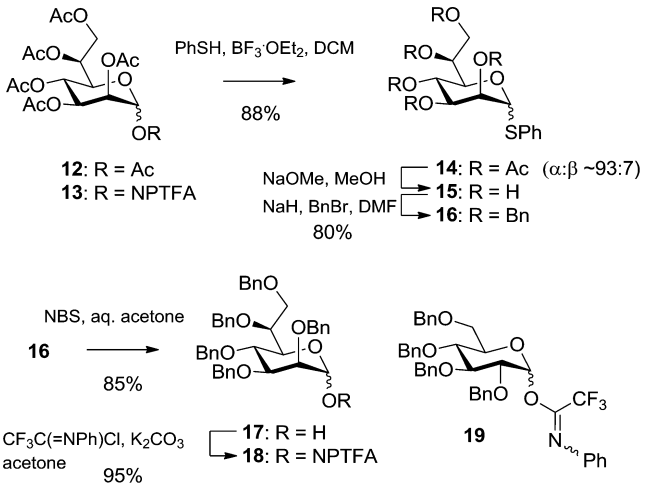
razole[32] followed by oxidation with *m*-CPBA gave a separable mixture of the two diastereomers **3a**/**3b** (~3:1) in 89% yield. The phosphoester substitution at position 4 was confirmed by the respective heteronuclear $^{1}H/^{31}P$ and $^{13}C/^{31}P$ spin-coupling interactions. Selective acid-induced orthoester opening then furnished 2-*O*-benzoate **4** in 72% yield together with minor amounts of the corresponding 3-*O*-benzoate **5**. The orthoester mixture was also directly converted into 2,3-di-*O*-benzoate **6** in a two-step yield of 89%. Alternatively, the intermediate orthobenzoate was directly opened by the action of camphorsulfonic acid to give 2-*O*-benzoate **7** (82%) which was further transformed into the 3-*O*-Lev-protected compound **8** via a Steglich-type protocol in 96% yield. Almost complete regioselectivity in the latter step was achieved by gradually treating the reaction mixture with a solution of DCC (note: the 3,4-di-*O*-levulinated byproduct, however, was readily formed when the reaction was performed under conventional reaction conditions). Formation of the corresponding 4-*O*-Lev-protected isomer was not observed. Subsequent phosphotriester formation at position 4 of the 3-*O*-Lev derivative **8** was uneventful and delivered the orthogonally protected compound **9** in 81% yield.

Next, the 7-OH acceptor derivatives **10** and **11** were approached by a selective partial cleavage of the 6,7-*O*-TIPDS group of fully protected intermediates **6** and **9**, respectively. This methodology was originally developed by the group of Ziegler[33,34] for hexopyranosides and has so far been exclusively used in this context. Initially, this protodesilylation was attempted with HF-pyridine as reagent, according to the published protocol, but turned out to be difficult to elaborate into a reliable procedure for the regioselective opening of the exocyclic TIPDS group in heptoside derivatives **6** and **9**, respectively. Even when the reagent was added in moderate excess and at low temperatures, the undesirable cleavage of both silyl ether groups could not be completely suppressed. Still, by close monitoring of the reaction and careful handling during the workup, a good selectivity and high isolated yield could be achieved for compound **10**. Eventually, exchange of the reagent to triethylamine trihydrofluoride (TREAT) allowed for a better control of the reaction progress and resulted in a reliable and scalable preparation of **10** and **11**, respectively, since complete desilylation by TREAT would require substantially more reagent amounts, higher temperatures, and extended reaction times.[35] The 6-*O*-FTIPDS-protected acceptor **10** was stable upon storage for several months in a refrigerator. Also, a trial experiment of acceptor **11** under glycosylation conditions (at −40 °C in the presence of boron trifluoride etherate) indicated that the 6-*O*-FTIPDS group was not affected.

The 4-*O*-phosphorylated heptoside acceptor derivatives **4**, **10**, and **11** then served as versatile precursors for ready attachment of sugars at O-3 (**4**) as well as O-7 (**10**, **11**), allowing also for subsequent coupling steps to give O-7/O-3 disubstituted products.

For the synthesis of heptosyl oligosaccharides, trihaloacetimidate leaving groups developed by Schmidt have mainly been used.[36,37] Initially, the readily available per-*O*-acetylated *N*-phenyltrifluoroacetimidate donor **13** was tested, since it usually provides a good stereocontrol in the glycosylation step via 2-*O*-acyl group participation leading to 1,2-*trans* glycosides. Several glycosylation attempts utilizing **13** and the glycosyl acceptor molecules **4** or **10**, however, produced mainly orthoester species accompanied by other byproducts which were not further analyzed. As the imidate **13** has recently been reported to be a suitable donor for the glycosylation of a 2,3,4,6-tetra-*O*-acetylheptoside acceptor,[38] the poor outcome of the glycosylation reactions at the primary alcohol position of **10** may thus have been due to the steric bulk imposed by the adjacent FTIPDS group. Hence, an "armed" per-*O*-benzylated heptosyl donor was envisaged to be more effective and was prepared in a straightforward sequence from the known[31] hexa-*O*-acetyl heptose derivative **12** (Scheme 2). First, treatment of **12** with

Scheme 2. Synthesis of Heptosyl and Glucosyl Donors



thiophenol in the presence of excess boron trifluoride etherate gave a separable mixture of the anomeric phenyl 1-thioglycoside in 88% yield. The anomeric mixture as well as the isolated α-glycoside **14** was then processed into the phenyl penta-*O*-benzyl-1-thioglycoside **16** in a combined yield of 80% via sodium methoxide catalyzed transesterification to give **15** followed by benzylation. Subsequent hydrolysis of the thioglycoside with NBS gave the lactol **17** in 85% yield, which was eventually converted into the *N*-phenyltrifluoroacetimidate (NPTFA) derivative **18**. The corresponding tetra-*O*-benzyl D-glucopyranosyl NPTFA donor **19** was prepared according to published procedures.[39] Depending on the mode of activation of the leaving group of donor **19** and the solvent used, highly selective glucosylation reactions have been reported leading to either β- or α-selective glycoside formation.[39,40]

Glycosylation of alcohol **10** using a slight excess of heptosyl donor **18** was performed in dichloromethane in the presence of 0.05 equiv of TMSOTf. The coupling step proceeded smoothly and gave a separable 4.9:1 anomeric mixture of disaccharides **20a** and **20b** in 83% yield (Scheme 3). No relevant side reaction was observed when working at a temperature of −78 °C. TLC indicated that the glycosylation reaction was already complete within 20 min. The α-anomeric configuration of the distal heptose unit in **20a** was inferred from the value of the heteronuclear $J_{C\text{-}1,H\text{-}1}$ coupling constant (172 Hz)—being in the expected range for an α-D-*manno*-configuration—in contrast to **20b**, which had a $J_{C\text{-}1,H\text{-}1}$ coupling constant of 153.5 Hz. In addition, the assigned substitution at position 7 was supported by HMBC correlation signals from H-1 of the distal heptose (δ 5.02) to C-7 (δ 66.9) of the methyl heptoside unit in **20a** as well as, conversely, from H-7b (δ 3.74) to the anomeric carbon of the distal heptose unit in **20b**, respectively. Similarly, the glycosylation reaction of the 3-*O*-levulinoyl derivative **11** was

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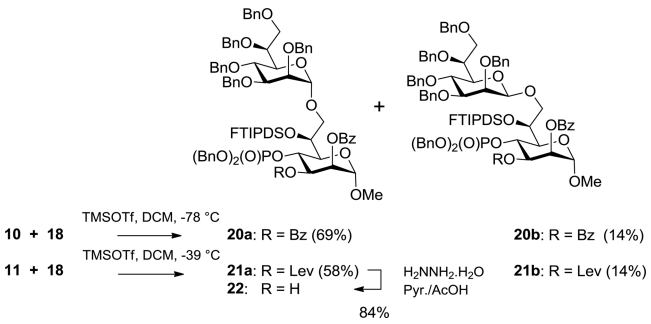
Scheme 3. Synthesis of the (1→7) Linked 4-*O*-Phosphorylated Heptobioside



performed at −39 °C and provided a 4.1:1 anomeric mixture (ratio based on the integration values of the downfield-shifted H-2 signals) of **21a** and **21b** in 72% yield. Disaccharide **21a** was isolated by HPLC and was then subjected to treatment with hydrazine acetate to furnish the glycosyl acceptor derivative **22** in 84% yield.

In contrast to the smooth glycosylation of the primary alcohol **10**, glycosylation at position 3 of acceptor **4** using heptosyl imidate **18** met with difficulties (Scheme 4). Specifically, the reaction required a higher temperature, and the donor **18** was consumed by debenzylation at O-6/intramolecular cyclization with formation of the known[24] 1,6-anhydro sugar **25**. In order to suppress this side reaction, heptosyl donor **18** (2 equiv) was slowly added to a mixture of acceptor and promotor, but the isolated yield of pure α-anomer **24** did not exceed 36% under various reaction conditions tested. In contrast, the synthesis of the related 3-*O*-glucosyl derivative **23** using donor **19** was robust (∼75% glycosylation yield) and gave good isolated yields of the pure α-anomer (>60%) with a temperature-dependent α to β ratio between 3:1 to 5:1 (with slightly increased α-selectivity observed for glycosylations at higher temperatures). The α-anomeric configuration of the D-glucosyl residue in compound **23** was inferred from the $J_{H\text{-}1,H\text{-}2}$ coupling constant (3.4 Hz).

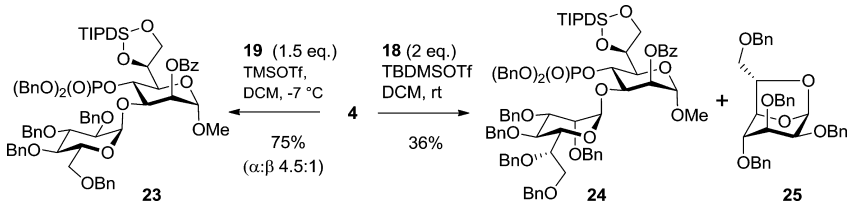
Based on the results obtained for the synthesis of the disaccharides, trisaccharide **27** was targeted via a short route by converting α-glucosyl-(1→3)-heptoside **23** into the corresponding 7-*O*-acceptor **26** (Scheme 5). Again, regioselective TIPDS cleavage of **23** by the action of TREAT was accomplished in high yield thereby providing evidence that this methodology is also applicable at the disaccharide stage. Gratifyingly, the 6-O-FTIPDS group was compatible with the ensuing coupling step using 1.5 equiv of donor **18** and 0.05 equiv of TMSO-triflate as promotor. Additional promotor, however, had to be added, and the temperature was gradually raised from −40 to 0 °C in order to drive the reaction to completion. Thus, a 3.3:1 α/β anomeric mixture of trisaccharides was formed in 69% yield, from which the α-glycoside **27** was eventually isolated in 51% yield by HPLC separation. As minor byproducts, the 1,6-anhydroheptose derivative **25** and a 7-*O*-trimethylsilyl acceptor derivative were also isolated.

Alternatively, the glycosylation sequence was reversed and the (1→7)-linked heptobioside **22** was subjected to glycosylation with the trifluoroacetimidate glucosyl donor **19**. The coupling reaction of **19** with **22** produced a separable mixture of the anomeric trisaccharides in 82% yield and in high α-selectivity (α/β = 9:1). The trisaccharide **27** was eventually obtained after HPLC purification in 74% isolated yield. Both pathways delivered the protected trisaccharide **27** in comparable overall yield (17% versus 19%) but in a different number of steps (five versus seven steps when starting from **2**).

In summary, the side-chain TIPDS protecting group pattern turned out as a versatile means for chain elongation at the primary alcohol group of L,D-heptose. No evidence for 6-*O*-glycosylated products was found throughout these glycosylation steps.

Global deprotection of **6**, **20a**, **23**, **24**, and **27** was performed by initial desilylation, followed by hydrogenation and final alkaline saponification of the benzoate ester groups, and was optimized using monosaccharide **6** (Scheme 6). The choice to first cleave the silyl-protecting group allowed for an additional chromatographic purification step prior to final deprotection. However, careful optimization of the desilylation conditions and close monitoring was necessary to prevent partial debenzylation of the phosphate moiety[41,42] forming water-soluble compounds, in particular, when the more reactive HF−pyridine reagent was used. Treatment with TREAT, however, provided a safe alternative. Hydrogenolysis of **28** followed by alkaline transesterification/ester hydrolysis of the dibenzoate **29** yielded the known 4-*O*-phosphoryl heptoside **30**.[43,44] The di- and trisaccharide derivatives were treated similarly to the deprotection of the monosaccharide **6**. The desilylation of **23** and **24** was accomplished under mild TREAT conditions affording **34** and **37** without significant phosphate−debenzylation. By contrast, the 7-*O*-heptosides **20a** and **27**, respectively, required the more reactive HF−pyridine reagent under carefully monitored reaction conditions to afford **31** and **40** in good isolated yields and without hydrolysis of the benzyl phosphate group. Hydrogenolysis and alkaline ester cleavage was uneventful in all cases, complicated only by the fact that benzoylated heptosides **32**, **38**, and **41** were insoluble in MeOH at basic pH and needed addition of water to achieve quantitative cleavage. The formed methylbenzoate and benzoic acid were subsequently extracted with Et_2O or $CHCl_3$, respectively. The NMR data of **30** and **39** were in good agreement with published values.[29,44] The structures of **33**, **39**, and **42** were fully assigned on the basis of one- and two-dimensional NMR measurements, and this data will be used in ongoing STD-NMR experiments with heptose-binding lectins.

Scheme 4. Synthesis of (1→3) Linked 4-*O*-Phosphorylated Heptoside Derivative



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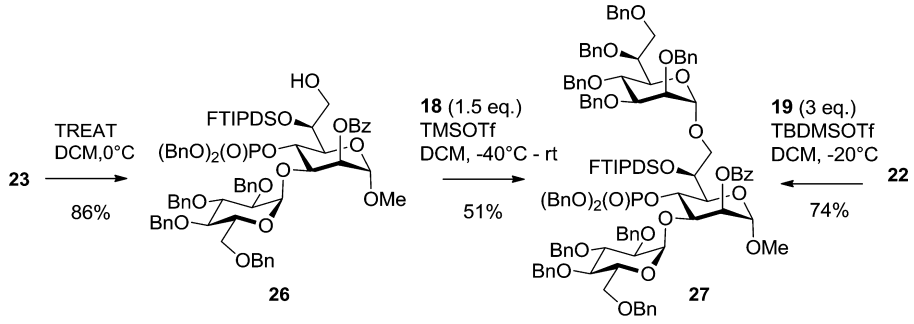
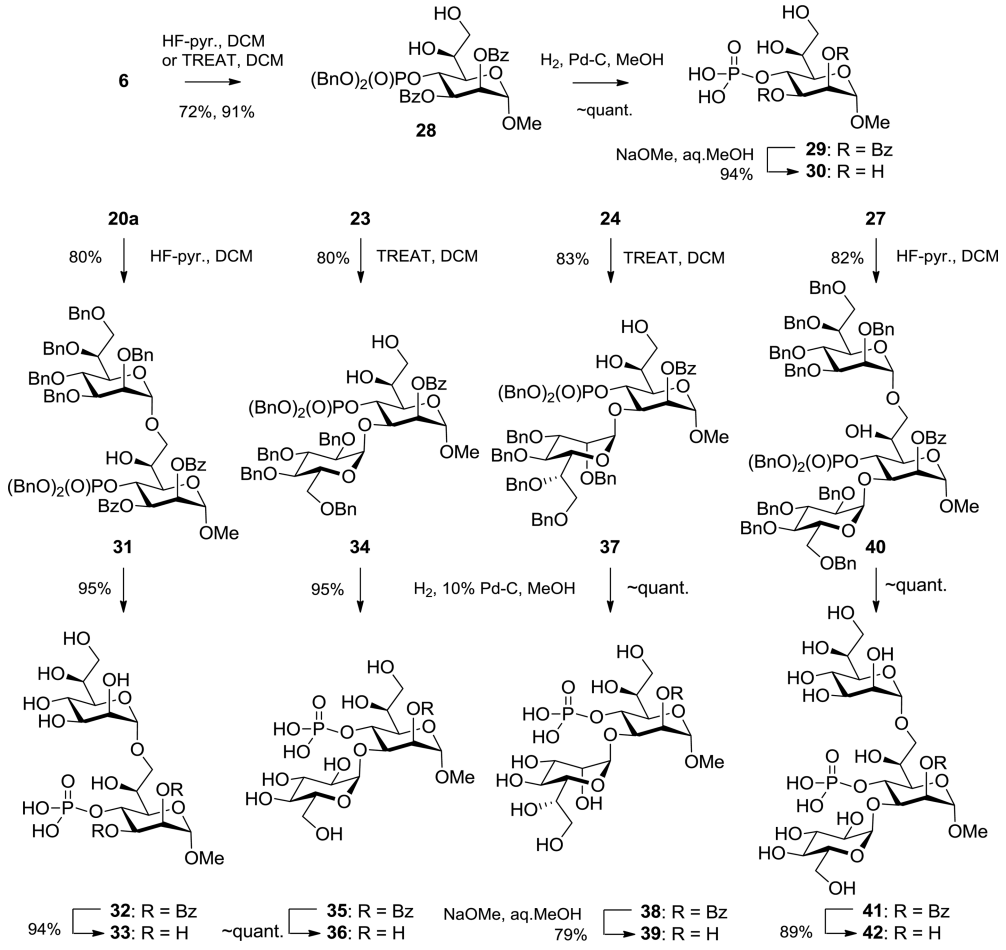
Scheme 5. Two Synthetic Pathways toward Phosphorylated Trisaccharide 27



Scheme 6. Global Deprotection of Oligosaccharides



CONCLUSIONS AND OUTLOOK

A straightforward synthetic route toward LPS-oligosaccharide fragments containing a central 4-*O*-phosphorylated heptosyl residue has been established. This strategy capitalizes on the introduction of the required phosphorylation pattern already at the early stage of monosaccharide building blocks followed by a regioselective partial cleavage of a side-chain TIPDS protecting group as a robust and high-yielding method to generate fully protected 7-*O*-heptosyl acceptor derivatives. In addition, the presence of the resulting 6-*O*-fluorosilyl protecting group after regioselective TIPDS cleavage may also be exploited for subsequent selective substitution at position 6 of heptoses. The selective ring-opening of a side-chain locked TIPDS group should also work for the synthesis of other higher-carbon sugars such as Kdo and provide rapid access to 8-O-substituted Kdo derivatives.

In conclusion, starting from a methyl heptoside, less than 10 steps were needed to complete the synthesis of a series of α-(1→3)- and α-(1→7)-connected LPS heptose fragments (Figure 3).

EXPERIMENTAL SECTION

General Methods. All starting materials and reagents were purchased from commercial sources and used without further purification. DCM was distilled from CaH_2 and stored over molecular sieves 4 Å. Residual moisture was confirmed by Karl Fischer tritration to be at least below 5 ppm. Reactions were monitored by TLC on silica gel 60 F254 plates; spots were detected by UV light examination or visualized by spraying with anisaldehyde−sulfuric acid and heating.

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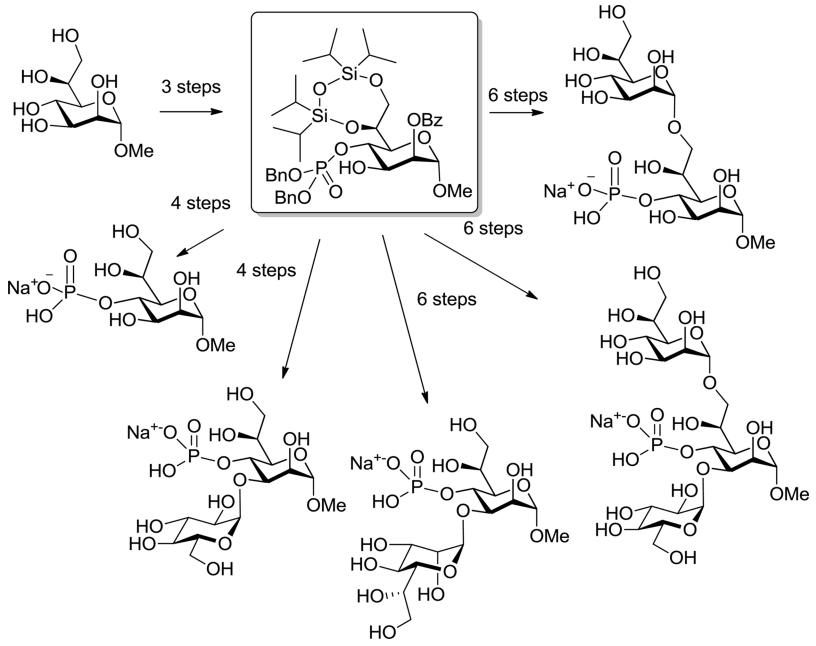

Figure 3. Summary of di- and trisaccharide ligands derived from the TIPDS-protected 4-*O*-phosphotriester precursor.

Normal-phase column chromatography was performed on silica gel 60 (230−400 mesh) or on prepacked SPE columns (2 g/6 mL). Preparative normal-phase HPLC was performed on column A (250 × 20 mm, S-5 μm, 6 nm) or column B (250 × 10 mm, S-5 μm, 6 nm). NMR spectra were recorded at 297 K in the solvent indicated, with 300 and 600 MHz instruments, respectively, employing standard software provided by the manufacturer. ^{1}H NMR spectra were referenced to tetramethylsilane (TMS, δ = 0) or by calibration with the residual solvent peaks for solutions in organic solvents and to DSS for solutions in D_2O. ^{13}C NMR spectra were referenced to TMS (δ = 0), residual solvent peaks ($CDCl_3$, δ = 77.0, CD_3OD, δ = 49.0) in organic solvents and to 1,4-dioxane (δ = 67.4) for solutions in D_2O. ^{31}P NMR spectra in D_2O were referenced to external H_3PO_4 (δ = 0). Assignments were based on COSY, HSQC, and HMBC experiments. HPLC−MS monitoring was done by injection of 0.01−0.1% solutions (5−20 μL) on a system with two gradient pumps, degasser, and a LCMS-2200 EV detector with mobile phase A = H_2O (0.1% HCOOH) and mobile phase B = CH_3CN (0.1% HCOOH) on a column (3.5 μm, 100 Å, 4.6 × 150 mm). Method A: flow rate: 0.75 mL/min (0−22 min); gradient: 0−2 min: 85% B, 2−17 min: 85−40% B, 17−22 min: 40% B. Method B: flow rate: 0.75 mL/min (0−22 min); gradient: 0−2 min: 95% B, 2−17 min: 95−40% B, 17−22 min: 40% B. Accurate mass analysis (2 ppm mass accuracy) was carried out from 10−100 mg/L solutions via LC−TOFMS measurements using an autosampler, an HPLC system with binary pumps, degasser, and column thermostat and ESI-TOF mass spectrometer.

General Procedure 1 for Cleavage of the 6-O-FTIPDS Group with TREAT. The fully protected heptoside was coevaporated with toluene, dissolved in dry DCM (1−6 mL), and transferred into a Teflon flask. TREAT (0.3 mL, ∼150 equiv of F^-) was added dropwise to the vigorously stirred solution, which was kept at rt for 15−21 h. The solution was poured into a stirred mixture of cold 50% aq $NaHCO_3$ and EtOAc. Phases were separated, and the aqueous layer was extracted twice with EtOAc. The combined organic layers were washed with satd aq $NaHCO_3$ and brine, dried (Na_2SO_4), concentrated, and coevaporated with toluene. The crude material was then purified by silica gel chromagraphy.

General Procedure 2 for Hydrogenolysis of Benzyl Derivatives. A solution of the heptoside in dry MeOH (5−8 mL) was purged with argon, and 10% Pd/C was added. The atmosphere was exchanged for H_2, and the suspension was stirred at rt for the time indicated. The atmosphere was exchanged to argon, and the suspension was filtered through Celite and washed repeatedly with MeOH. The filtrate was concentrated to yield the acidic form or was treated with Et_3N and concentrated to afford the target compound as Et_3N species.

*Methyl 6,7-O-(1,1,3,3-Tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-heptopyranoside (**2**).* Compound **1** (300 mg, 1.338 mmol, crystallized from hot 2-propanol) was coevaporated with toluene (3×) and then dissolved in dry DMF (4.7 mL). 1*H*-Imidazole (228 mg, 3.35 mmol, 2.5 equiv) was added, and the solution was cooled to −55 °C. $TIPDSCl_2$ (0.444 mL, 1.40 mmol, 1.05 equiv) was added via a syringe during 10 min, and the solution was slowly warmed to room temperature during 2.5 h. The reaction mixture was diluted with EtOAc (40 mL) and washed with satd aq $NaHCO_3$. The aqueous layer was reextracted with EtOAc and washed with brine. The combined organic phase was dried (Na_2SO_4) and concentrated. The crude material was purified by flash column chromatography on a silica gel cartridge (100 g, toluene/EtOAc 2:3→1:4) to give compound **2** (546.5 mg, 87%) as a syrup: R_f 0.29 (toluene/EtOAc 1:1); $[\alpha]_D^{20}$ +48.4 (*c* 1.3, MeOH); ^{1}H NMR (600 MHz, $CDCl_3$) δ 4.71 (d, *J* = 1.3 Hz, 1H, H-1), 4.30 (dt, *J* = 3.0, 5.0 Hz, 1H, H-6), 4.03 (d, *J* = 5.0 Hz, 2H, H-7a, H-7b), 3.85 (dd, *J* = 1.8, 3.5 Hz, 1H, H-2), 3.84 (t, *J* = 9.5 Hz, 1H, H-4), 3.75 (dd, *J* = 3.4, 9.2 Hz, 1H, H-3), 3.58 (dd, *J* = 2.9, 9.6 Hz, 1H, H-5), 3.35 (s, 3H, OCH_3), 1.12−0.94 (m, 28H, TIPDS-CH_3, TIPDS-CH); ^{13}C NMR (151 MHz, $CDCl_3$) δ 100.8 (C-1), 75.3 (C-6), 72.1 (C-3), 70.95 (C-5), 70.2 (C-2), 68.2 (C-4), 67.3 (C-7), 55.0 (OCH_3), 17.4, 17.4, 17.29, 17.27, 17.24, 17.21 (8 × TIPDS-CH_3), 12.9, 12.7, 12.4, 12.3 (TIPDS-CH); HRMS ($^{+}$ESI-TOF) *m*/*z* [M + Na]$^{+}$ calcd for $C_{20}H_{42}NaO_8Si_2$ 489.2310, found 489.2312.

*Methyl 4-O-Dibenzyloxyphosphoryl-2,3-O-ethoxybenzylidene-6,7-O-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-heptopyranoside (**3a/3b**).* Triethyl orthobenzoate (0.59 mL, 2.61 mmol) and camphorsulfonic acid (25 mg, 0.11 mmol) were added to a solution of triol **2** (1.00 g, 2.14 mmol) in dry DCM (18 mL). The reaction mixture was stirred at rt for 30 min, when TLC (toluene/EtOAc 5:1 + Et_3N) indicated almost complete conversion to the intermediate orthoester diastereoisomers (∼2:1 ratio). Et_3N (0.3 mL, 2.14 mmol) was added, and the solution was concentrated and coevaporated with dry toluene. The residue was dissolved in dry DCM (18 mL). Dibenzyl *N*,*N*-diisopropylphosphoramidite (1.08 mL, 3.21 mmol) was added followed by dropwise addition of a 0.45 M solution of 1*H*-tetrazole in acetonitrile (6.2 mL, 2.785 mmol). The solution was stirred for 45 min at rt and then cooled to −78 °C. A solution of *m*-CPBA (0.96 g; approximately 77%, 4.29 mmol) in DCM (6 mL) was added, and the reaction mixture was stirred for 75 min at this

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temperature. Triethylamine (0.75 mL, 5.36 mmol) was added, and the solution was warmed to rt. The reaction mixture was then added to a stirred mixture of satd aq $NaHCO_3$ (40 mL) and EtOAc (40 mL). Phases were separated, and the aqueous layer was extracted with EtOAc (30 mL). The combined organic layers were washed with satd aq $NaHCO_3$ (30 mL) and brine (30 mL), dried (Na_2SO_4), and concentrated. The crude was purified by chromatography (SiO_2: 150 g, toluene/EtOAc 15:1→12:1; the column was preconditioned with toluene/EtOAc 15:1 containing 0.3% Et_3N) to give **3a** (0.532 g, 29%) and **3b** (1.103 g, 60%) as a syrup. Data for isomer **3a**: R_f 0.73 (toluene/EtOAc 3:1); $[\alpha]_D^{20}$ +25 (*c* 0.6, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47−7.44 (m, 2H, 2 × PhH), 7.35−7.28 (m, 13H, 13 × PhH), 5.14 (dd, J = 11.9, $J_{H,P}$ = 8.2 Hz, 1H, $POCH_2$), 5.10 (dd, J = 11.6, $J_{H,P}$ = 6.9 Hz, 1H, $POCH_2$), 5.08−5.03 (m, 2H, $POCH_2$), 5.01 (app dt, J = 9.6, $J_{H,P}$ = 6.8 Hz, 1H, H-4), 4.95 (bs, 1H, H-1), 4.60 (app t, J = 6.9 Hz, H-3), 4.35 (app d, J = 9.1 Hz, 1H, H-6), 4.12 (dd, J = 12.2, 8.8 Hz, 1H, H-7a), 3.94 (dd, J = 6.9, 1.1 Hz, 1H, H-2), 3.88 (m, 3H, OCH_2, H-7b), 3.68 (dd, J = 10.0 Hz, 1.4 Hz, 1H, H-5), 3.34 (s, 3H, OCH_3), 1.19 (t, J = 7.1 Hz, 2H, OCH_2CH_3), 1.12−1.03 (m, 26H, TIPDS), 1.00−0.92 (m, 2H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 139.07, 136.11, 136.0, 128.9, 128.5, 128.4, 128.3, 128.1, 127.82, 127.79, 126.0, 121.7 (Cq, orthoester), 98.4 (C-1), 76.3 (C-3), 75.2 (C-2), 74.8 (d, $J_{C,P}$ = 6.5 Hz, C-4), 73.55 (C-6), 69.45 (d, $J_{C,P}$ = 5.5 Hz, $POCH_2$), 69.3 (d, $J_{C,P}$ = 5.5 Hz, $POCH_2$), 69.0 (d, $J_{C,P}$ = 9.5 Hz, C-5), 68.3 (C-7), 59.0 (OCH_2CH_3), 55.4 (OCH_3), 17.7, 17.6, 17.43, 17.36, 17.35, 17.3, 17.2 (TIPDS-CH_3), 15.0 (OCH_2CH_3), 13.23, 13.20, 12.7, 12.6 (4 × TIPDS-CH). HRMS ($^+$ESI-TOF) m/z [M + Na]$^+$ calcd for $C_{43}H_{63}NaO_{12}PSi_2$ 881.3488, found 881.3491.

Data for **3b**: R_f 0.66 (toluene/EtOAc 3:1); $[\alpha]_D^{20}$ +9 (*c* 0.5, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.71−7.65 (m, 2H, PhH), 7.37−7.23 (m, 13H, PhH), 5.07−4.89 (m, 4H, 1.5 × $POCH_2$, H-1), 4.90 (dd, J = 11.8, $J_{H,P}$ = 8.5 Hz, 1H, $POCH_2$), 4.86 (app t, J = 6.7 Hz, 1H, H-3), 4.55 (app dt, J = 10.4, $J_{H,P}$ = 6.9 Hz, 1H, H-4), 4.51 (dd, J = 6.5, 1.0 Hz, 1H, H-2), 4.27 (app d, J = 8.8 Hz, 1H, H-6), 4.06 (dd, J = 12.1, 8.8 Hz, 1H, H-7a), 3.79 (dd, J = 12.2, J = 1.5 Hz, 1H, H-7b), 3.67 (dd, J = 9.9, 1.6 Hz, 1H, H-5), 3.35 (q, J = 7.1 Hz, 2H, OCH_2CH_3), 3.36 (s, 3H, OCH_3), 1.13 (t, J = 7.1 Hz, 3H, OCH_2CH_3), 1.07−0.85 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 137.0, 136.0, 135.9, 129.0, 128.5, 128.5, 128.4, 128.31, 128.27, 128.21, 128.18, 127.9, 127.83, 127.77, 126.5 (PhC), 120.9 (Cq, orthoester), 98.0 (C-1), 77.4 (C-3), 75.75 (C-2), 75.05 (d, $J_{C,P}$ = 6.5 Hz, C-4), 73.3 (C6), 69.33 (d, $J_{C,P}$ = 5.5 Hz, $POCH_2$), 69.28 (d, $J_{C,P}$ = 5.5 Hz, $POCH_2$), 68.6 (d, $J_{C,P}$ = 8.9 Hz, C-5), 68.0 (C-7), 59.3 (OCH_2CH_3), 55.4 (OCH_3), 17.6, 17.5, 17.4, 17.3, 17.25, 17.22, 17.21, 17.1 (8 × TIPDS-CH_3), 15.1 (OCH_2CH_3), 13.2, 13.1, 12.7, 12.6 (4 × TIPDS-CH). HRMS ($^+$ESI-TOF) m/z [M + Na]$^+$ calcd for $C_{43}H_{63}NaO_{12}PSi_2$ 881.3488, found 881.3494.

*Methyl 2-O-Benzoyl-4-O-dibenzyloxyphosphoryl-6,7-O-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-hepto-pyranoside (**4**).* Orthoester **3a**/**3b** (1.61 g, 1.877 mmol) was dissolved in DCM (32 mL), and CSA (44 mg, 0.188 mmol) was added at rt followed by dropwise addition of H_2O (∼0.1 mL). The reaction mixture was stirred at rt for 1 h. The organic layer was washed with satd aq $NaHCO_3$ (30 mL), and the aqueous layer was reextracted with DCM (30 mL). The combined organic layers were washed with satd aq $NaHCO_3$ (30 mL) and brine (15 mL), dried (Na_2SO_4), and concentrated. The crude (1.593 g) was purified by column chromatography (SiO_2: 150 g, toluene/EtOAc 10:1→ 7:1→ 5:1) to yield pure target compound **4** (1.129 g, 72%) as a syrup and a second fraction containing a mixture of 2-*O*- and 3-*O*-monobenzoate **4** and **5** (280 mg, 18%). Data for **4**: R_f 0.30 (toluene/EtOAc 3:1); $[\alpha]_D^{20}$ +26 (*c* 0.3, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.06−8.04 (m, 2H, BzH2/H6), 7.59−7.55 (m, 1H, BzH4), 7.43−7.39 (m, 2H, BzH3/H5), 7.38−7.33 (m, 3H, PhH), 7.23−7.32 (m, 7H, PhH), 5.40 (dd, J = 3.6, 1.7 Hz, 1H, H-2), 5.08−5.00 (m, 4H, 2 × $POCH_2$), 4.80 (td, J = 9.4, $J_{H,P}$ = 7.8 Hz, 1H, H-4), 4.79 (d, J = 1.4 Hz, 1H, H-1), 4.76 (d, J = 4.6 Hz, 1H, 3-OH), 4.35 (dt, J = 9.9, 4.6 Hz, 1H, H-3), 4.32 (d, J = 9.3 Hz, 1H, H-6), 4.08 (dd, J = 12.4, 8.7 Hz, 1H, H-7a), 3.79 (dd, J = 12.3, 1.2 Hz, 1H, H-7b), 3.60 (dd, J = 9.5, 1.0 Hz, 1H, H-5), 3.34 (s, 3H, OCH_3), 1.10−0.83 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.8 (PhC═O), 135.5 (d, $J_{C,P}$ = 6.8 Hz, $POCH_2PhC1$), 135.4 (d, $J_{C,P}$ = 6.9 Hz, $POCH_2PhC1'$), 133.15, 130.0, 129.7, 128.60, 128.58, 128.5, 128.3, 128.2, 127.9 (PhC), 98.439 (C-1), 76.8 (C-4), 73.4 (C-6), 72.2 (C-2), 71.0 (d, $J_{C,P}$ = 1.6 Hz, C-5), 70.2 (d, $J_{C,P}$ = 5.5 Hz, $POCH_2$), 69.8 (d, $J_{C,P}$ = 5.4 Hz, $POCH_2$), 68.5 (C-3), 68.15 (C-7), 55.2 (OCH_3), 17.62, 17.56, 17.4, 17.3, 17.25, 17.2, 17.1 (8 × TIPDS-CH_3), 13.3, 13.2, 12.6 (4 × TIPDS-CH); HRMS ($^+$ESI-TOF) m/z [M + H]$^+$ calcd for $C_{41}H_{60}O_{12}$ PSi_2 831.3355, found 831.3355.

Data for **5**: R_f 0.29 (hexane/EtOAc 3:1); $[\alpha]_D^{20}$ +21.4 (*c* 0.9, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.16−8.13 (m, 2H, BzH2/H6), 7.53−7.50 (m, 1H, BzH4), 7.40−7.36 (m, 2H, BzH3/H5), 7.28−7.25 (m, 3H, PhH), 7.22−7.18 (m, 1H, PhH), 7.18−7.14 (m, 4H, PhH), 6.93 −6.90 (m, 2H, PhH), 5.52 (dd, J = 9.7, 3.2 Hz, 1H, H-3), 5.17 (app q, J = 9.3 Hz, 1H, H-4), 4.91 (dd, J = 11.8, $J_{H,P}$ = 7.0 Hz, 1H, $POCH_2$), 4.84 (dd, J = 11.8, $J_{H,P}$ = 8.5 Hz, 1H, $POCH_2$), 4.73 (d, J = 2.1 Hz, 1H, H-1), 4.71 (dd, J = 11.7, $J_{H,P}$ = 6.8 Hz, 1H, $POCH_2$), 4.54 (dd, J = 11.8, $J_{H,P}$ = 8.0 Hz, 1H, $POCH_2$), 4.38 (app dt, J = 8.7, 1.3 Hz, 1H, H-6), 4.19−4.14 (m, 2H, H-2, H-7a), 3.85 (dd, J = 12.4, 1.4 Hz, 1H, H-7b), 3.75 (dd, J = 9.5, 1.2 Hz, 1H, H-5), 3.40 (s, 3H, OCH_3), 2.10 (d d, J = 6.8 Hz, 1H, 2-OH), 1.12−0.87 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.7 (PhC═O), 135.6 and 135.4 (d, $J_{C,P}$= 7.7 Hz, $POCH_2PhC1$), 133.2, 130.2, 129.5, 128.4, 128.35, 128.3, 128.27, 128.1, 127.7, 127.4 (PhC), 100.5 (C-1), 73.7 (C-6), 73.3 (C-3), 72.0 (d, $J_{C,P}$ = 8.8 Hz, C-5), 71.8 (d, $J_{C,P}$ = 6.1 Hz, C-4), 69.1 (C-2), 69.06 (d, $J_{C,P}$ = 5.5 Hz, $POCH_2$), 68.95 (d, $J_{C,P}$ = 5.5 Hz, $POCH_2$), 67.9 (C-7), 55.3 (OCH_3), 17.6, 17.4, 17.4, 17.3, 17.2 (8 × TIPDS-CH_3), 13.55, 13.4, 12.72, 12.69 (4 × TIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −2.77; HRMS ($^+$ESI-TOF) m/z [M + H]$^+$ calcd for $C_{41}H_{60}O_{12}PSi_2$: m/z = 831.3355, found 831.3363.

*Methyl 2,3-di-O-benzoyl-4-O-dibenzyloxyphosphoryl-6,7-O-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-heptopyranoside (**6**).* A solution of orthoester **3a**/**3b** (1.09 g, 1.268 mmol) in DCM (22 mL) was treated with CSA (29 mg, 0.127 mmol) and water (75 μL) as described for the preparation of **4**. The crude material (1.163 g) was dissolved in pyridine (5.3 mL) and BzCl (0.3 mL, 2.5 mmol) was added dropwise at rt and the reaction mixture was stirred overnight. The reaction was quenched by addition of MeOH (0.1 mL, 2.5 mmol) and stirring was continued for 30 min. The solution was diluted with EtOAc (50 mL), washed with cold 1 M HCl (with re-extraction of the aqueous phase). The combined organic layers were washed with water, satd aq $NaHCO_3$, brine, dried (Na_2SO_4) and concentrated. The crude material (1.291 g) was purified by column chromatography (SiO_2: 20 g, DCM → DCM/EtOAc 30:1) to give compound **6** (1.051 g, 88.6% for 2 steps) as a colorless oil that crystallized upon storage, m.p.: 97−100 °C (EtOAc); R_f 0.33 (toluene/EtOAc 9:1); $[\alpha]_D^{20}$ −35 (*c* 0.5, $CHCl_3$); ^{1}H NMR (600 MHz) δ 8.03−8.01 (m, 2H, BzH2/H6), 7.98−7.97 (m, 2H, BzH2/H6), 7.60−7.57 (m, 1H, BzH4), 7.45−7.40 (m, 3H, BzH3/H5, BzH4), 7.28−7.23 (m, 6H, BzH3/H5, 4 × PhH), 7.20−7.12 (m, 4H, PhH), 6.91−6.88 (m, 2H, PhH), 5.76 (dd, J = 9.8, 3.5 Hz, 1H, H-3), 5.58 (dd, J = 3.5, 1.7 Hz, 1H, H-2), 5.32 (app q, J = 9.4 Hz, 1H, H-4), 4.91 (dd, J = 11.8, $J_{H,P}$ = 7.1 Hz, 1H, $POCH_2$), 4.89 (d, J = 1.4 Hz, 1H, H-1), 4.81 (dd, J = 11.8, $J_{H,P}$ = 9.0 Hz, 1H, $POCH_2$), 4.68 (dd, J = 11.8, $J_{H,P}$ = 6.7 Hz, 1H, $POCH_2$), 4.50 (dd, J = 11.8, $J_{H,P}$ = 7.9 Hz, 1H, $POCH_2$), 4.45 (app d, J = 8.6 Hz, 1H, H-6), 4.17 (dd, J = 12.4, 8.7 Hz, 1H, H-7a), 3.87 (dd, J = 12.4, 1.1 Hz, 1H, H-7b), 3.86 (app d, J = 9.5 Hz, 1H, H-5), 3.43 (s, 3H, OCH_3), 1.13−0.94 (m, 28 H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.5 (PhC═O), 165.4 (PhC═O), 135.6 (d, $J_{C,P}$ = 7.3 Hz, $POCH_2PhC1$), 135.4 (d, $J_{C,P}$ = 7.7 Hz, $POCH_2PhC1$), 133.3, 133.0, 130.0, 129.9, 129.4, 129.35, 128.41, 128.36, 128.3, 128.25, 128.2, 128.1, 127.7, 127.3 (PhC), 98.35 (C-1), 73.5 (C-6), 71.9 (d, $J_{C,P}$ = 6.5 Hz, C-5), 71.85 (d, J = 4.4 Hz, C-4), 70.9 (C-3), 70.4 (C-2), 69.1 (d, $J_{C,P}$ = 6.2 Hz, $POCH_2$), 68.9 (d, $J_{C,P}$ = 5.2 Hz, $POCH_2$), 68.1 (C-7), 55.3 (OCH_3), 17.7, 17.6, 17.39, 17.36, 17.3, 17.25, 17.21, 17.17 (8 × TIPDS-CH_3), 13.6, 13.5, 12.7, 12.7 (4 × TIPDS-CH); HRMS ($^+$ESI-TOF) m/z [M + H]$^+$ calcd for $C_{48}H_{64}O_{13}PSi_2$ 935.3618, found 935.3625.

*Methyl 2-O-benzoyl-6,7-O-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-heptopyranoside (**7**).* A solution of triol **2** (2.00 g, 4.28 mmol) in dry DCM (40 mL) and triethyl

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orthobenzoate (1.17 mL, 5.16 mmol) was treated with CSA (49 mg, 0.22 mmol) at rt. TLC monitoring (hexane/EtOAc 2:1) revealed almost complete conversion into the intermediate orthoester after 10 min. After 30 min, H_2O (160 μL, ∼8.5 mmol) was added, and stirring was continued for 1 h at rt. The solution was diluted with DCM (60 mL) and washed with satd aq $NaHCO_3$ (90 mL). The aqueous layer was reextracted with DCM (70 mL), and the combined organic layers were washed with brine (60 mL), dried (Na_2SO_4), and concentrated. The crude material (∼2.5 g) was purified by vacuum flash chromatography (SiO_2: 50 g, toluene/EtOAc 5:1) to give **7** (2.00 g, 81.7%) as a white solid foam: $[\alpha]_D^{20}$ +12.8 (*c* 2.1, $CDCl_3$); ^1H NMR (600 MHz, $CDCl_3$) δ 8.06−8.03 (m, 2H, BzH2/H6), 7.60−7.56 (m, 1H, BzH4), 7.45−7.41 (m, 2H, BzH3/H5), 5.32 (dd, *J* = 1.7, 2.9 Hz, 1H, H-2), 4.81 (d, *J* = 1.6 Hz, 1H, H-1), 4.38 (ddd, *J* = 1.4, 2.3, 8.5 Hz, 1H, H-6), 4.13−4.06 (m, 3H, H-4, H-7a, H-3), 4.00 (dd, *J* = 1.4, 12.2 Hz, 1H, H-7b), 3.66 (dd, *J* = 2.4, 9.2 Hz, 1H, H-5), 3.37 (s, 3H, OCH_3), 2.77 (d, *J* = 1.8 Hz, 1H, 4-OH), 2.29 (d, *J* = 5.3 Hz, 1H, 3-OH), 1.13−0.94 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 166.2 (PhC═O), 133.4, 129.9, 129.5, 128.4 (PhC), 98.8 (C-1), 74.4 (C-6), 72.1 (C-2), 71.9 (C-5), 70.8 (C-3), 68.15 (C-4), 67.8 (C-7), 55.1 (OCH_3), 17.5, 17.42, 17.39, 17.30, 17.26, 17.2 (TIPDS-CH_3), 13.0, 12.7, 12.6, 12.4 (TIPDS-CH); HRMS ($^+$ESI-TOF) *m*/*z* [M + Na]$^+$ calcd for $C_{27}H_{46}NaO_9Si_2$ 593.2573, found 593.2575.

*Methyl 2-O-Benzoyl-3-O-(4-oxopentanoyl)-6,7-O-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-heptopyranoside (**8**).* A solution of DCC (304 mg, 1.472 mmol) in dry DCM (2.4 mL) was slowly added in several portions for a period of 45 min to a solution of diol **7** (700 mg, 1.23 mmol), levulinic acid (157 mg, 1.249 mmol), and DMAP (7.5 mg, 0.061 mmol) in dry DCM (14 mL) at rt. The reaction mixture was then diluted with DCM (40 mL) and filtered over a plug of cotton. The organic layer was washed with satd aq $NaHCO_3$ (30 mL), and the aqueous layer was re-extracted with DCM (40 mL). The combined organic phases were washed with brine (30 mL), dried (Na_2SO_4), and concentrated. The residue was dissolved in a small volume of DCM, filtered, and concentrated. The crude material (870 mg) was purified by MPLC-column chromatography (SiO_2: 60 g, flow-rate: 40 mL/min toluene/EtOAc 7:1) to afford compound **8** (785 mg, 96%) as a glasslike solid: $[\alpha]_D^{20}$ +8.4 (*c* 1.1, $CHCl_3$); ^1H NMR (600 MHz, $CDCl_3$) δ 8.07−8.05 (m, 2H, BzH2/H6), 7.61−7.58 (m, 1H, BzH4), 7.47−7.42 (m, 2H, BzH3/H5), 5.42 (dd, *J* = 1.8, 3.5 Hz, 1H, H-2), 5.31 (dd, *J* = 3.4, 9.8 Hz, 1H, H-3), 4.78 (d, *J* = 1.7 Hz, 1H, H-1), 4.45−4.42 (m, 1H, H-6), 4.26 (dt, *J* = 3.4, 9.7 Hz, 1H, H-4), 4.11 (dd, *J* = 8.6, 12.1 Hz, 1H, H-7a), 3.98 (dd, *J* = 1.3, 12.1 Hz, 1H, H-7b), 3.73 (dd, *J* = 2.2, 9.6 Hz, 1H, H-5), 3.38 (s, 3H, OCH_3), 2.83 (d, *J* = 3.4 Hz, 1H, 4-OH), 2.77 (ddd, *J* = 6.1, 7.7, 18.4 Hz, 1H, Lev-H3a), 2.66 (dt, *J* = 6.2, 18.4 Hz, 1H, Lev-H3b), 2.57 (ddd, *J* = 5.7, 7.8, 17.0 Hz, 1H, Lev-H2a), 2.48 (dt, *J* = 6.4, 17.0 Hz, 1H, Lev-H2b), 2.08 (s, 3H, Lev-CH_3), 1.15−0.94 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 207.15 (Lev-C4), 172.3 (Lev-C1), 165.4 (PhC═O), 133.4, 129.8, 129.5, 128.4 (PhC), 98.7 (C-1), 73.8 (C-6), 72.8 (C-3), 72.5 (C-5), 70.0 (C-2), 68.1 (C-7), 65.5 (C-4), 55.0 (OCH_3), 38.1 (Lev-C3), 29.6 (Lev-C5), 28.1 (Lev-C2), 17.44, 17.42, 17.41, 17.36, 17.3, 17.2 (8 × TIPDS-CH_3) 13.0, 12.6, 12.35 (4 × TIPDS-CH); HRMS ($^+$ESI-TOF) *m*/*z* [M + Na]$^+$ calcd for $C_{32}H_{52}NaO_{11}Si_2$ 691.2940, found 691.2940.

*Methyl 2-O-Benzoyl-4-O-dibenzyloxyphosphoryl-3-O-(4-oxopentanoyl)-6,7-O-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-heptopyranoside (**9**).* A solution of 1*H*-tetrazole in CH_3CN (∼0.45 M, dried over molecular sieves) was added dropwise at rt to a solution of alcohol **8** (86 mg, 0.129 mmol) and dibenzyl *N*,*N*-diisopropylphosphoramidite (60 μL, 0.18 mmol) in dry DCM (1.7 mL). TLC (toluene/EtOAc 5:1) indicated complete conversion to the intermediate phosphite species after 10 min. The reaction mixture was cooled to −72 °C, and *m*-CPBA (71 mg, 0.315 mmol) was added in one portion. After the mixture was stirred for 40 min, Et_3N (54 μL, 0.386 mmol) was added. The solution was warmed to rt and was separated between EtOAc and satd aq $NaHCO_3$. The aqueous layer was again extracted with EtOAc, and the combined organic layers were washed with satd aq $NaHCO_3$ and brine, dried (Na_2SO_4), and concentrated. The crude material was purified by repeated chromatography on silica gel (SiO_2: 2 g cartridge, toluene→toluene/EtOAc 3:1), then by preparative HPLC (column A, toluene/EtOAc 10:1 to 5:1), to give **9** (97 mg, 81%): $[\alpha]_D^{20}$ −4.5 (*c* 0.9, $CHCl_3$); ^1H NMR (600 MHz, $CDCl_3$) δ 8.07−8.04 (m, 2H, BzH2/H6), 7.62−7.58 (m, 1H, BzH4), 7.45−7.41 (m, 2H, BzH3/H5), 7.29−7.23 (m, 10H, PhH), 5.54 (dd, *J* = 3.5, 9.8 Hz, 1H, H-3), 5.46 (dd, *J* = 1.8, 3.6 Hz, 1H, H-2), 5.03 (app q, *J* = 9.4 Hz, 1H, H-4), 5.01−4.91 (m, 4H, 2 × POCH_2), 4.79 (d, *J* = 1.6 Hz, 1H, H-1), 4.45−4.42 (m, 1H, H-6), 4.13 (dd, *J* = 8.7, 12.4 Hz, 1H, H-7a), 3.84 (dd, *J* = 1.2, 12.3 Hz, 1H, H-7b), 3.82−3.79 (m, 1H, H-5), 3.38 (s, 3H, OCH_3), 2.56−2.47 (m, 2H, Lev-H3a/H3b), 2.46−2.32 (m, 2H, Lev-H2a/H2b), 1.97 (s, 3H, Lev-CH_3), 1.12−0.91 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.1 (Lev-C4), 171.8 (Lev-C1), 165.5 (PhC═O), 135.7 (d, $J_{C,P}$ = 7.1 Hz, $POCH_2PhC$), 135.6 (d, $J_{C,P}$ = 6.6 Hz, $POCH_2PhC$), 133.4, 130.0, 129.3, 128.49, 128.47, 128.44, 128.38, 127.95, 127.8 (PhC), 98.4 (C-1), 73.4 (C-6), 72.0 (d, $J_{C,P}$ = 7.1 Hz, C-4), 71.65 (d, $J_{C,P}$ = 8.4 Hz, C-5), 70.3 (C-3), 70.0 (C-2), 69.3 (d, $J_{C,P}$ = 5.3 Hz, POCH_2), 69.2 (d, $J_{C,P}$ = 5.6 Hz, POCH_2), 68.1 (C7), 55.2 (OCH_3), 37.7 (Lev-C3), 29.55 (Lev-CH_3), 27.9 (Lev-C2), 17.6, 17.5, 17.4, 17.3, 17.2, 17.1 (8 × TIPDS-CH_3), 13.36, 13.34, 12.64, 12.62 (4 × TIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −3.47; HRMS ($^+$ESI-TOF) *m*/*z* [M + H]$^+$ calcd for $C_{46}H_{66}O_{14}PSi_2$ 929.3723, found 929.3731.

*Methyl 2,3-Di-O-benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraisopropyl-1,3-disiloxane-1-yl)-L-glycero-α-D-manno-heptopyranoside (**10**). Method A.* Compound **6** (290 mg, 0.310 mmol) was dissolved in dry DCM (15 mL), transferred into a Teflon flask, and cooled in an ice bath. HF−pyridine reagent (88 μL, ∼10 equiv of F^-) was added in four portions every 2 min to prevent local overheating. The solution was stirred for 35 min at 0 °C. The reaction was quenched by dropping the solution into stirred ice-cold satd aq $NaHCO_3$ (60 mL). The aqueous layer was extracted with DCM (3 × 30 mL), and the combined organic layers were washed with satd aq $NaHCO_3$, and brine, dried (Na_2SO_4), and concentrated. The crude material (19.8 mg) was purified by column chromatography (SiO_2: 17 g, toluene/EtOAc 2:3) to furnish **10** (245 mg, 83%).

Method B. A solution of compound **6** (20 mg, 21.4 μmol) in dry DCM (1.0 mL) was treated with TREAT (174 μL, ∼150 equiv of F) at 0 °C for 1 h according to general procedure 1. The residue (19.8 mg) was purified by column chromatography (SiO_2: 2 g cartridge, hexane/EtOAc 3:1) to give **10** (18.3 mg, 90%) which solidified upon storage in a refrigerator. Analytical data for **10**: R_f 0.20 (toluene/EtOAc 5:1); $[\alpha]_D^{20}$ −51.8 (*c* 0.5, $CHCl_3$); ^1H NMR (600 MHz, $CDCl_3$) δ 8.04−8.01 (m, 2H, BzH2/H6), 7.95−7.93 (m, 2H, BzH2/H6), 7.60−7.57 (m, 1H, BzH4), 7.45−7.41 (m, 3H, BzH3/H5, BzH4), 7.27−7.22 (m, 5H, BzH3/H5, 3 × PhH), 7.19−7.17 (m, 1H, PhH), 7.14−7.10 (m, 4H, PhH), 6.91−6.89 (m, 2H, PhH), 5.80 (dd, *J* = 3.5, 9.7 Hz, 1H, H-3), 5.59 (dd, *J* = 1.7, 3.5 Hz, 1H, H-2), 5.33 (app q, *J* = 9.7 Hz, 1H, H-4), 4.90 (d, *J* = 1.9 Hz, 1H, H-1), 4.88 (dd, *J* = 7.1, 11.6 Hz, 1H, POCH_2), 4.78 (dd, *J* = 8.8, 11.8 Hz, 1H, POCH_2), 4.70 (dd, *J* = 6.9, 11.8 Hz, 1H, POCH_2), 4.55 (dd, *J* = 8.5, 11.8 Hz, 1H, POCH_2), 4.37−4.34 (m, H-6), 4.10 (dd, *J* = 1.9, 9.8 Hz, 1H, H-5), 3.93 (dd, *J* = 4.7, 11.1 Hz, 1H, H-7a), 3.86 (dd, *J* = 6.1, 11.1 Hz, 1H, H-7b), 3.47 (s, 3H, OCH_3), 1.16−0.95 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.6 (PhC═O), 165.4 (PhC═O), 135.6 (d, $J_{C,P}$ = 7.0 Hz, $POCH_2PhC$), 135.4 (d, $J_{C,P}$ = 7.5 Hz, $POCH_2PhC$), 133.4, 133.0, 123.0, 129.9, 129.42, 129.38, 128.41, 128.39, 128.31, 128.26, 128.24, 128.1, 127.8, 127.5 (PhC), 98.35 (C-1), 72.4 (d, $J_{C,P}$ = 6.3 Hz, C-4), 71.4 (C-6), 71.0 (C-3), 70.6 (C-2), 70.4 (d, $J_{C,P}$ = 7.6 Hz, C-5), 69.2 (d, $J_{C,P}$ = 5.9 Hz, $POCH_2$), 69.1 (d, $J_{C,P}$ = 5.4 Hz, $POCH_2$), 63.6 (C-7), 55.4 (OCH_3), 17.5, 17.4, 17.3, 17.2, 16.7, 16.6 (8 × FTIPDS-CH_3), 13.6, 13.1 (2 × FTIPDS-CH), 12.61 and 12.59 (2 d, *J* = 16.5 Hz, FTIPDS-CH); HRMS ($^+$ESI-TOF) *m*/*z* [M + H]$^+$ calcd for $C_{48}H_{65}FO_{13P}Si_2$ 955.3680, found 955.3693.

*Methyl 2-O-Benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraisopropyl-1,3-disiloxane-1-yl)-3-O-(4-oxopentanoyl)-L-glycero-α-D-manno-heptopyranoside (**11**).* A solution of compound **9** (45 mg, 48.4 μmol) in dry DCM (1.2 mL) was treated with TREAT (158 μL, ∼60 equiv of F) at 0 °C for 3.5 h according to general procedure 1. The residue was purified by column chromatography (SiO_2: 2 g cartridge, toluene/EtOAc 10:1→5:1→2:1) to give **11** as

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colorless solid (37.8 mg, 82%). Alternatively, compound **11** was prepared in a two-step sequence from **8**: Alcohol **8** (350 mg, 0.522 mmol) was treated as described for **11** with phosphoramidite (245 μL, 0.731 mmol) and a solution of 1*H*-tetrazole in CH_3CN (~0.45 M, 0.68 mmol, dried over molecular sieves) followed by oxidation with *m*-CPBA (287 mg, 1.28 mmol). The crude material was directly submitted to selective TIPDS cleavage as described above with TREAT (1.7 mL, ~60 equiv of F^-) and purified by column chromatography (SiO_2: 50 g, toluene/EtOAc 5:1) to afford **11** (397 mg, 80% for two steps) as a colorless foam: $[\alpha]_D^{20}$ −20 (*c* 1.1, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.07−8.04 (m, 2H, BzH2/H6), 7.61−7.58 (m, 1H, BzH4), 7.45- 7.42 (m, 2H, BzH3/H5), 7.30−7.20 (m, 10H, PhH), 5.55 (dd, *J* = 3.5, 9.8 Hz, 1H, H-3), 5.46 (dd, *J* = 1.7, 3.6 Hz, 1H, H-2), 5.08 (app q, *J* = 9.8 Hz, 1H, H-4), 5.01−4.94 (m, 3H, POCH_2), 4.92 (dd, *J* = 6.8, 11.7 Hz, 1H, POCH_2), 4.81 (d, *J* = 1.6 Hz, 1H, H-1), 4.34−4.32 (m, 1H, H-6), 4.04 (dd, *J* = 2.0, 9.8 Hz, 1H, H-5), 3.90 (dd, *J* = 4.8, 11.1 Hz, 1H, H-7a), 3.83 (dd, *J* = 6.2, 11.1 Hz, 1H, H-7b), 3.42 (s, 3H, OCH_3), 2.49 (t, *J* = 7.1 Hz, 2H, Lev-H3a, H3b), 2.41−2.28 (m, 2H, Lev-H2a, H2b), 1.97 (s, 3H, Lev-CH_3), 1.07−0.94 (m, 28H, FTIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.1 (Lev-C4), 171.8 (Lev-C1), 165.5 (PhC=O), 135.7 (d, $J_{C,P}$ = 7.5 Hz, 2 × POCH$_2$PhC1), 133.4, 129.9, 129.35, 128.50, 128.47, 128.46, 128.42, 128.39, 128.0, 127.8 (PhC), 98.4 (C-1), 72.4 (d, $J_{C,P}$ = 6.7 Hz, C-4), 71.2 (C-6), 70.5 (C-3), 70.3 (d, $J_{C,P}$ = 7.8 Hz, C-5), 70.25 (C-2), 69.44 (d, $J_{C,P}$ = 5.5 Hz, POCH_2), 69.36 (d, $J_{C,P}$ = 5.5 Hz, POCH_2), 63.6 (C-7), 55.3 (OCH_3), 37.65 (Lev-C3), 29.6 (Lev-CH_3), 27.9 (Lev-C2), 17.5, 17.4, 17.3, 17.2 (4 × FTIPDS-CH_3) 16.7 (2 × FTIPDS-CH_3), 16.6 (2 × FTIPDS-CH_3), 13.6, 13.1 (2 × FTIPDS-CH), 12.57 and 12.56 (2 d, *J* = 16.4 Hz, FTIPDS-CH); HRMS ($^+$ESI-TOF) *m*/*z* [M + H]$^+$ calcd for $C_{46}H_{67}FO_{14}PSi_2$ 949.3786, found 949.3792.

*Phenyl 2,3,4,6,7-Penta-O-acetyl-1-thio-L-glycero-α-D-manno-heptopyranoside (**14**).* Peracetate **12**[31] (1.00 g, 2.16 mmol) was dissolved in dry DCM (10 mL), and the solution was stripped with argon for several minutes. Thiophenol (0.44 mL, 4.3 mmol) and then $BF_3{\cdot}OEt_2$ (1.33 mL, 10.8 mmol) were added dropwise, each within ~15 min, and the solution was stirred at rt for 23 h. The reaction mixture was poured into 1:1 DCM/satd aq $NaHCO_3$ (100 mL). The phases were separated, and the aqueous layer was extracted with DCM (3×). The combined organic layer was washed twice with satd aq $NaHCO_3$, 0.5% aq I_2-solution, 5% aq $Na_2S_2O_3$, and brine. The organic phase was dried (Na_2SO_4) and concentrated. The crude material was purified by vacuum flash chromatography (SiO_2: 22 g, hexane/EtOAc 2:1) to give **14** as an anomeric mixture (980 mg, 88.4%, α/β ~ 93:7) that was used for the further steps. To obtain pure α-anomer, the material was crystallized from hot dry EtOH (10 mL) to give **14** as colorless crystals (657 mg, 59%), mp 109−111 °C (EtOH). The anomers can alternatively be separated by chromatography using Et_2O/hexane 3:2 as eluent. Analytical data for α-anomer **14**: R_f 0.21 (hexane/Et_2O 2:3); $[\alpha]_D^{20}$ +93.9 (*c* 1.9, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.43−7.40 (m, 2H, PhH), 7.34−7.26 (m, 3H, PhH), 5.62 (d, *J* = 1.6 Hz, 1H, H-1), 5.52 (dd, *J* = 1.5, 3.4 Hz, 1H, H-2), 5.37 (app t, *J* = 10.1, 1H, H-4), 5.31 (dd, *J* = 3.4, 10.1 Hz, 1H, H-3), 5.29 (ddd, *J* = 2.0, 5.6, 7.5 Hz, 1H, H-6), 4.55 (dd, *J* = 2.1, 10.0 Hz, 1H, H-5), 4.03 (dd, *J* = 5.8, 11.4 Hz, 1H, H-7a), 3.99 (dd, *J* = 7.5, 11.4 Hz, 1H, H-7b), 2.18, 2.12, 2.04, 2.01, and 1.90 (5s, 5 × 3H, CH_3C=O); ^{13}C NMR (151 MHz, $CDCl_3$) δ 170.3, 170.2, 169.9, 169.8, 169.55 (5 × C=O), 132.5, 130.9, 129.4, 127.9 (PhC), 85.6 (C-1), 70.9 (C-2), 69.7 (C-5), 69.6 (C-3), 67.0 (C-6), 64.8 (C-4), 61.8 (C-7), 20.9, 20.64, 20.59, 20.58, 20.5 (5 × CH_3C=O); HRMS ($^+$ESI-TOF) *m*/*z* [M + NH_4]$^+$ calcd for $C_{23}H_{32}NO_{11}S$ 530.1691, found 530.1680.

*Phenyl 1-Thio-L-glycero-α-D-manno-heptopyranoside (**15**).* Peracetate **14** (48 mg, 1.26 mmol) was dissolved in dry MeOH (15 mL), 1 M NaOMe (0.38 mL, ~0.25 equiv) was added, and the reaction mixture was stirred at rt for 4 h. The pH was adjusted ~7.0 by addition of DOWEX 50 cation-exchange resin (H^+-form). The resin was removed by filtration and washed with MeOH, and the filtrate was concentrated to give **15** (373 mg, 98%) as a colorless syrup: R_f 0.24 (EtOAc/MeOH 4:1); $[\alpha]_D^{20}$ +251.8 (*c* 1.2, MeOH); ^{1}H NMR (600 MHz, MeOD) δ 7.52−7.48 (m, 2H, PhH), 7.35−7.31 (m, 2H, PhH), 7.30−7.26 (m, 1H, PhH), 5.48 (d, *J* = 1.6 Hz, 1H, H-1), 4.07 (dd, *J* = 1.5, 3.3 Hz, 1H, H-2), 3.99−3.96 (m, 2H, H-5, H-6), 3.93 (app t, *J* = 9.6 Hz, 1H, H-4), 3.70 (dd, *J* = 3.3, 9.3 Hz, 1H, H-3), 3.48 (dd, *J* = 7.4, 11.0 Hz, 1H, H-7a), 3.39 (dd, *J* = 5.2, 11.0 Hz, 1H, H-7b); ^{13}C NMR (151 MHz, MeOD) δ 135.5, 133.0, 130.1, 128.6 (PhC), 90.3 (C-1), 74.25 (C-5), 73.6 (C-2), 73.4 (C-3), 71.0 (C-6), 68.0 (C-4), 65.0 (C-7); HRMS ($^-$ESI-TOF) *m*/*z* [M + HCOO]$^-$ calcd for $C_{14}H_{19}O_8S$ 347.0806, found 347.0803.

*Phenyl 2,3,4,6,7-Penta-O-benzyl-1-thio-L-glycero-α-D-manno-heptopyranoside (**16**).* Thioglycoside **15** (310 mg, 1.025 mmol) was coevaporated with toluene and dissolved in dry DMF (20 mL). The solution was cooled to 0 °C, and NaH (60%, 226 mg, 5.65 mmol, 5.5 equiv) was added in portions. The resulting slurry was stirred for ~0.5 h, and benzyl bromide (0.74 mL, 6.15 mmol, 6.0 equiv) was added dropwise. The reaction mixture was warmed to rt and was stirred for 18 h. Since mainly two polar spots were visible on TLC (toluene/EtOAc 20:1, EtOAc/MeOH = 4:1), additional NaH (75 mg, 1.87 mmol, ~1.8 equiv) was added at 0 °C. The ice bath was removed, and stirring was continued for 20 min. BnBr (0.06 mL, 0.25 mmol, 0.24 equiv) was added, and the mixture was stirred for an additional 45 min without significant additional formation of product. MeOH (0.84 mL, ~20 equiv) was added leading to formation of H_2 (caution!). After 30 min, the reaction mixture was separated between Et_2O (50 mL) and satd aq $NaHCO_3$ (100 mL). The aqueous layer was extracted with Et_2O (50 mL), and the combined organic layers were washed with satd aq $NaHCO_3$ (50 mL), water (50 mL), and brine (50 mL). The organic layer was dried (Na_2SO_4), filtered, and concentrated, and the residue was coevaporated with toluene. The crude material was submitted to vacuum flash chromatography (SiO_2: 30 g toluene → toluene/EtOAc 120:1→80:1) to give **16** (625.5 mg, 81%) as a colorless oil: $[\alpha]_D^{20}$ +73.6 (*c* 0.8, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39−7.36 (m, 4H, PhH), 7.34−7.19 (m, 26H, PhH), 5.75 (d, *J* = 1.7 Hz, 1H, H-1), 4.88 and 4.34 (2 d, *J* = 11.0 Hz, 2H, CH_2Ph), 4.84 and 4.52 (2 d, *J* = 11.8 Hz, 2H, CH_2Ph), 4.76 and 4.63 (2 d, *J* = 12.2 Hz, 2H, CH_2Ph), 4.57 (bs, 2H, CH_2Ph), 4.38 and 4.35 (2 d, *J* = 11.9 Hz, 2H, CH_2Ph), 4.25 (app t, *J* = 9.5 Hz, 1H, H-4), 4.15−4.11 (m, 2H, H-5, H-6), 3.98 (dd, *J* = 2.0, 2.9 Hz, 1H, H-2), 3.88 (dd, *J* = 3.0, 9.1 Hz, 1H, H-3), 3.69 (dd, *J* = 6.7, 10.0 Hz, 1H, H-7a), 3.46 (dd, *J* = 5.1, 10.0 Hz, 1H, H-7b); ^{13}C NMR (151 MHz, $CDCl_3$) δ 138.7, 138.7, 138.2, 138.1, 137.95 (PhC), 134.4 (SPhC-1), 130.7, 128.9, 128.4, 128.33, 128.29, 128.2, 127.9, 127.73, 127.71, 127.68, 127.6, 127.50, 127.47, 127.35, and 127.0 (PhC), 85.2 (C-1), 80.6 (C-3), 76.0 (C-2), 75.3 (C-6), 74.7 (CH_2Ph), 74.35 (C-4), 73.3 (CH_2Ph), 73.1 (C-5), 72.8 (CH_2Ph), 72.1 (CH_2Ph), 72.0 (CH_2Ph), 71.0 (C-7); HRMS ($^+$ESI-TOF) *m*/*z* [M + NH_4]$^+$ calcd for $C_{48}H_{52}NO_6S$ 770.3510, found 770.3544.

*2,3,4,6,7-Penta-O-benzyl-L-glycero-D-manno-heptopyranose (**17**).* Thioglycoside **16** (833 mg, 1.106 mmol) was dissolved in 24:1 acetone/water (28 mL) and stirred with external cooling using an EtOH−ice bath. A solution of NBS (591 mg, 3.32 mmol) in 24:1 acetone/water (6 mL) was added dropwise within ~5 min keeping the temperature below −5 °C. After 15 min, the reaction was quenched by pouring the reaction mixture into an ice-cold stirred mixture of satd aq $NaHCO_3$ (25 mL), 5% aq $Na_2S_2O_3$ (25 mL), and EtOAc (50 mL). The aqueous layer was extracted with EtOAc (20 mL) and the combined organic layers were washed with satd aq $NaHCO_3$ (30 mL), water (30 mL), brine (30 mL), dried (Na_2SO_4) and concentrated. The crude material (785 mg) was submitted to preparative MPLC (SiO_2: 60 g; flow rate: 35 mL/min; hexane/EtOAc 3:1) to give **17** (621 mg, 85%) as a colorless oil: 0.32 (hexane/EtOAc 2:1); ^{1}H NMR (600 MHz, $CDCl_3$, α/β ratio appr. 2:1, * denotes signals assigned to the β-anomer) δ 7.38−7.17 (m, 25H, PhH), 5.25 (d, *J* = 1.9 Hz, 1H, H-1), 5.12 (d, *J* = 11.6 Hz, 1H, PhCH_2*), 4.88 (d, *J* = 11.4 Hz, 1H, PhCH_2), 4.86 (d, *J* = 8.2 Hz, 1H, PhCH_2*), 4.84 (d, *J* = 9.0 Hz, 1H, PhCH_2*), 4.81 (d, *J* = 11.6 Hz, 1H, PhCH_2), 4.73 (d, *J* = 11.6 Hz, 1H, PhCH_2*), 4.72 (bs, 2H, PhCH_2), 4.70 (d, *J* = 11.7 Hz, 1H, PhCH_2*), 4.66 (d, *J* = 11.6 Hz, 1H, PhCH_2*), 4.59−4.58 (m, 3H, H-1*, 2 × PhCH_2), 4.57 (d, *J* = 11.9 Hz, 1H, PhCH_2), 4.54 (d, *J* = 11.9 Hz, 1H, PhCH_2*), 4.54 (d, *J* = 12.1 Hz, 1H, PhCH_2*), 4.53 (d, *J* = 11.4 Hz, 1H, PhCH_2), 4.51 (d, *J* = 11.5 Hz, 1H, PhCH_2), 4.46 (d, *J* = 11.9 Hz, 1H, PhCH_2), 4.37−4.34 (m, 2H, PhCH_2, PhCH_2*), 4.19 (t, *J* = 9.5 Hz, 1H, H-4), 4.16 (t,

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J = 9.5 Hz, 1H, H-4*), 4.12−4.08 (m, 2H, H-6, H-6*), 3.96 (dd, J = 3.0, 9.2 Hz, 1H, H-3), 3.92 (dd, J = 1.7, 9.7 Hz, 1H, H-5), 3.86−3.83 (m, 2H, H-2*, H-7*a), 3.80−3.75 (m, 3H, H-2, H-7a, H-7*b), 3.72 (dd, J = 6.2, 9.8 Hz, 1H, H-7b), 3.63 (dd, J = 2.7, 9.4 Hz, 1H, H-3*), 3.42 (dd, J = 1.9, 9.6 Hz, 1H, H-5*); ^{13}C NMR (151 MHz, $CDCl_3$) δ 138.9, 138.8, 138.7, 138.6, 138.45, 138.4, 138.33, 138.30, 138.2, 137.9, 128.5, 128.5, 128.4, 128.36, 128.34, 128.28, 128.25, 128.2, 128.05, 127.9, 127.86, 127.85, 127.80, 127.77, 127.74, 127.72, 127.69, 127.6, 127.54, 127.50, 127.46, 127.38 (PhC), 94.0 (C-1*), 92.8 (C-1), 83.9 (C-3*), 80.1 (C-3), 76.3 (C-2*), 75.3 (C-5*), 75.0 (C-6, C-6*), 74.71 (CH_2Ph*), 74.68 (C-2), 74.6 (CH_2Ph*), 74.5 (CH_2Ph), 74.4 (C-4), 74.0 (C-4*), 73.4 (CH_2Ph*), 73.25 (CH_2Ph), 72.75 (CH_2Ph*) 72.7 (CH_2Ph), 72.55 (CH_2Ph), 72.4 (CH_2Ph*), 72.1 (CH_2Ph), 71.7 (C-5), 70.5 (C-7*), 70.0 (C-7); HRMS ($^+$ESI-TOF) m/z [M + NH_4]$^+$ calcd for $C_{42}H_{48}O_7N$ 678.3435, found 678.3431.

*2,3,4,6,7-Penta-O-benzyl-L-glycero-D-manno-heptopyranosyl N-Phenyltrifluoroacetimidate (**18**).* Reducing sugar **17** (100 mg, 0.151 mmol) was dissolved in acetone (2.0 mL). K_2CO_3 (42 mg, 0.303 mmol) and *N*-phenyltrifluoroacetimidoyl chloride (63 mg, 0.30 mmol) were added rapidly, and the reaction mixture was stirred at rt for 4.5 h. The suspension was filtered through a plug of Celite and washed thoroughly with acetone. After addition of one drop of triethylamine, the solution was concentrated and the crude material was purified by column chromatography (SiO_2: 15 g, toluene/EtOAc 20:1 + 0.2% Et_3N) to give **18** (119 mg, 94.5%) as a colorless oil: ^{1}H NMR of main isomer (600 MHz, $CDCl_3$) δ 7.37−7.18 (m, 28H, Ph*H*), 6.73 −6.68 (m, 2H, Ph*H*), 6.30 (bs, 1H, H-1), 4.87−4.83 (m, 2H, CH_2Ph), 4.76−4.60 (bs, 1H, CH_2Ph), 4.63 (d, J = 11.7 Hz, 1H, CH_2Ph), 4.58−4.49 (m, 4H, 2 × CH_2Ph), 4.38−4.34 (m, 1H, CH_2Ph), 4.29−4.23 (m, 1H), 4.14−4.10 (m, 1H, H-6), 3.94−3.88 (m, 2H), 3.85 (dd, J = 6.8, 10.0 Hz, 1H, H-7a), 3.83−3.78 (bs, 1H), 3.70 (dd, J = 5.2, 10.0 Hz, 1H, H-7b); ^{13}C NMR (151 MHz, $CDCl_3$) δ 143.5, 142.8, 142.55, 138.6, 138.4, 138.2, 138.0, 137.7, 128.8, 128.43, 128.37, 128.36, 128.32, 128.27, 128.05, 128.0, 127.82, 127.77, 127.72, 127.69, 127.6, 127.4, 119.4 (PhC), 79.3, 75.0 (C-6), 74.75 (CH_2Ph), 74.5, 73.7, 73.5 (CH_2Ph), 73.2, 72.7, 72.53, 72.48 (3 × CH_2Ph), 70.66 (C-7).

*Methyl (2,3,4,6,7-Penta-O-benzyl-L-glycero-α-D-manno-heptopyranosyl)-(1→7)-2,3-di-O-benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraisopropyl-1,3-disiloxane-1-yl)-L-glycero-α-D-manno-heptopyranoside (**20a**) and Methyl (2,3,4,6,7-Penta-O-benzyl-L-glycero-β-D-manno-heptopyranosyl)-(1→7)-2,3-di-O-benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraisopropyl-1,3-disiloxane-1-yl)-L-glycero-α-D-manno-heptopyranoside (**20b**).* Dry DCM (5 mL) and ground molecular sieves (4 Å, 300 mg) were placed in a flame-dried, two-necked 10 mL flask. Acceptor **10** (207 mg, 0.217 mmol) and donor **18** (216 mg, 260 mmol, 1.2 equiv) were combined and coevaporated with dry toluene, transferred into the suspension, stirred under Ar for 30 min at rt, and then cooled to −78 °C. A solution of TMSOTf (2 μL, 0.011 mmol, 0.05 equiv) in dry DCM (in 200 μL) was added, and the reaction mixture was stirred for 1.5 h at −78 °C. The reaction was quenched by dropwise addition of Et_3N (57 μL, 0.412 mmol) in DCM (∼1 mL). The suspension was allowed to warm to rt, filtered through Celite, and washed with DCM. The organic phase was dried and concentrated. The residue was first subjected to chromatography on an MPLC column (SiO_2: 21 g, flow rate 20 mL/min with a stepwise gradient hexane/EtOAc 5:1 → 3:1) to furnish a fraction containing the disaccharides. Final purification was achieved by preparative HPLC (in three portions on column A, flow rate 15 mL/min, hexane/EtOAc 7:1) to give first α-anomer **20a** (238 mg, 69%), followed by β-anomer **20b** (46.6 mg, 13.5%) as a colorless oils. Analytical data for **20a**: R_f 0.4 (hexane/EtOAc); $[\alpha]_D^{20}$ −15.6 (c 0.9, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.04−8.01 (m, 2H, BzH2/H6), 7.99−7.96 (m, 2H, BzH2/H6), 7.60−7.56 (m, 1H, BzH4), 7.46−7.40 (m, 3H, BzH4, BzH3/H5), 7.38−7.36 (m, 2H, Ph*H*), 7.35−7.32 (m, 2H, Ph*H*), 7.31−7.14 (m, 27H, BzH3/H5, 25 × Ph*H*), 7.11−7.07 (m, 4H, Ph*H*), 6.87−6.84 (m, 2H, Ph*H*), 5.79 (dd, J = 3.6, 9.8 Hz, 1H, H-3), 5.53 (dd, J = 1.8, 3.7 Hz, 1H, H-2), 5.30 (app q, J = 9.7 Hz, 1H, H-4), 5.02 (d, J = 1.8 Hz, 1H, H-1′), 4.90 and 4.33 (2 d, 2 × J = 11.2 Hz, 2H, CH_2Ph), 4.88−4.84 (m, 2H, POCH_2, CH_2Ph), 4.78−4.64 (m, 4H, 2 × POCH_2, 2 × CH_2Ph), 4.68 (bs, 1H, H-1), 4.58−4.45 (m, 7H, 5 × CH_2Ph, POCH_2, H-6), 4.32 (d, 1H, CH_2Ph), 4.21 (app t, J = 9.5 Hz, 1H, H-4′), 4.10 (ddd, J = 1.3, 5.4, 6.6 Hz, 1H, H-6′), 3.94−3.84 (m, 4H, H-7a, H-5, H-7a′, H-3′), 3.82 (dd, J = 2.0, 3.0 Hz, 1H, H-2′), 3.79 (dd, J = 5.4, 10.0 Hz, 1H, H-7b′), 3.74 (dd, J = 1.5, 9.7 Hz, 1H, H-5′), 3.71 (dd, J = 6.0, 10.0 Hz, 1H, H-7b), 3.26 (s, 3H, OCH_3), 1.16−0.96 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.6 (C═O), 165.4 (C═O), 138.9, 138.8, 138.4, 138.21, 138.17, 135.6 (d, $J_{C,P}$ = 7.9 Hz, POCH_2PhC*1*), 135.4 (d, $J_{C,P}$ = 7.6 Hz, POCH_2PhC*1*), 133.3, 133.0, 130.0, 129.9, 129.45, 129.4, 128.45, 128.4, 128.36, 128.25, 128.22, 128.18, 128.1, 127.77, 127.76, 127.73, 127.68, 127.64, 127.59, 127.5, 127.42, 127.41, 127.34, 127.31, 127.27 (PhC), 98.4 (C-1), 98.25 (C-1′), 80.1 (C-3′), 75.1 (C-6′), 74.55 (CH_2Ph), 74.3 (C-2′), 74.15 (C-4′), 73.35 (CH_2Ph), 72.8 (CH_2Ph), 72.5 (CH_2Ph), 72.15 (C-5′), 71.7 (C-4), 71.7 (CH_2Ph), 71.1 (C-3), 71.0 (C-7′), 70.7 (C-2), 70.0 (d, $J_{C,P}$ = 8.7 Hz, C-5), 69.2 (d, $J_{C,P}$ = 5.5 Hz, POCH_2), 69.0 (C-6), 68.85 (d, $J_{C,P}$ = 5.4 Hz, POCH_2), 66.9 (C-7), 55.6 (OCH_3), 17.64, 17.58, 17.5, 17.4 (4 × FTIPDS-CH_3), 16.8, 16.7 (bs, 2 × FTIPDS-CH_3), 13.8, 13.4 (2 × FTIPDS-CH), 12.6 (d, $J_{C,F}$ = 16.5 Hz, 2 × FTIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −2.76. HRMS ($^+$ESI-TOF) m/z [M + NH_4]$^+$ calcd for $C_{90}H_{110}FO_{19}NPSi_2$ 1614.692, found 1614.6907. Analytical data for **20b**: R_f 0.4 (hexane/EtOAc 3:1); $[\alpha]_D^{20}$ −37.8 (c 1.0, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.03−8.00 (m, 4H, 2 × BzH2/H6), 7.59−7.55 (m, 1H, Bz H4), 7.46−7.39 (m, 5H, Bz H4, BzH3/H5, 2 × Ph*H*), 7.37−7.35 (m, 2H, Ph*H*), 7.33−7.15 (m, 26H, BzH3/H5, Ph*H*), 7.15 −7.11 (m, 3H, Ph*H*), 7.10−7.06 (m, 2H, Ph*H*), 6.82−6.79 (m, 2H, Ph*H*), 5.82 (dd, J = 3.5, 9.8 Hz, 1H, H-3), 5.56 (dd, J = 1.6, 3.6 Hz, 1H, H-2), 5.39 (app q, J = 9.8 Hz, 1H, H-4), 4.96−4.83 (m, 5H, 4 × CH_2Ph, POCH_2), 4.85 (bs, 1H, H-1), 4.78 (dd, $J_{H,P}$ = 8.6, J = 11.9 Hz, 1H, POCH_2), 4.66−4.58 (m, 3H, POCH_2, CH_2Ph, H-6), 4.56−4.45 (m, 5H, 4 × CH_2Ph, POCH_2Ph), 4.39 (d, J = 11.0 Hz, 1H, CH_2Ph), 4.29 (bs, 1H, H-1′), 4.26 (t, J = 9.5, 1H, H-4′), 4.20−4.16 (m, 2H, H-7a, H-6′), 4.11 (br d, 1H, H-5), 4.01 (dd, J = 7.3, 10.5 Hz, 1H, H-7a′), 3.83 (dd, J = 4.0, 10.5 Hz, 1H, H-7b′), 3.79 (d, J = 2.8 Hz, 1H, H-2′), 3.74 (dd, J = 8.4, 10.2 Hz, 1H, H-7b), 3.48 (dd, J = 2.7, 9.6 Hz, 1H, H-3′), 3.39 (dd, J = 2.0, 9.6 Hz, 1H, H-5′), 3.16 (s, 3H, OCH_3), 1.07−0.95 (m, 28H, FTIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.8 (C═O), 165.5 (C═O), 138.9, 138.8, 138.5, 138.45, 138.0, 135.4 (d, $J_{C,P}$ = 7.7 Hz, POCH_2PhC*1*), 135.38 (d, $J_{C,P}$ = 7.1 Hz, POCH_2PhC*1*), 133.3, 133.0, 130.1, 129.9, 129.41, 129.38, 128.5, 128.4, 128.33, 128.28, 128.25, 128.19, 128.15, 128.0, 127.85, 127.75, 127.7, 127.6, 127.53, 127.50, 127.4, 127.24, 127.23 (PhC), 102.3 (C-1′), 98.4 (C-1), 82.8 (C-3′), 76.6 (C-5′), 75.45 (C-6′), 74.7 (CH_2Ph), 74.2 (C-4′), 73.6 (CH_2Ph), 73.5 (C-2′), 73.3 (CH_2Ph), 72.2 (CH_2Ph), 72.0 (C-7′), 71.9 (CH_2Ph), 71.5 (d, $J_{C,P}$ = 5.5 Hz, C-4), 71.2 (C-3), 70.8 (C-2), 69.3 (d, $J_{C,P}$ = 5.5 Hz, POCH_2), 69.1 (d, $J_{C,P}$ = 7.7 Hz, C-5), 68.8 (d, $J_{C,P}$ = 5.5 Hz, POCH_2), 68.7 (C-6), 68.15 (C-7), 55.0 (OCH_3), 17.67, 17.66, 17.44, 17.37, 16.75, 16.70, 16.67 (8 × FTIPDS-CH_3), 13.7, 13.4 (2 × FTIPDS-CH), 12.6 (d, $J_{C,F}$ = 16.5 Hz, FTIPDS-CH), 12.5 ($J_{C,F}$ = 16.5 Hz, FTIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −2.42. HRMS ($^+$ESI-TOF) m/z [M + NH_4]$^+$ calcd for $C_{90}H_{110}FO_{19}NPSi_2$ 1614.6927, found 1614.6921.

*Methyl (2,3,4,6,7-Penta-O-benzyl-L-glycero-α-D-manno-heptopyranosyl)-(1→7)-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraisopropyl-1,3-disiloxane-1-yl)-3-O-(4-oxopentanoyl)-L-glycero-α-D-manno-heptopyranoside (**21a**) and Methyl (2,3,4,6,7-Penta-O-benzyl-L-glycero-β-D-manno-heptopyranosyl)-(1→7)-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraisopropyl-1,3-disiloxane-1-yl)-3-O-(4-oxopentanoyl)-L-glycero-α-D-manno-heptopyranoside (**21b**).* Acceptor **11** (25.0 mg, 26 μmol) and donor **18** (32.9 mg, 40 μmol, 1.5 equiv) were combined and coevaporated with dry toluene. The residue was dissolved in dry DCM (1.2 mL) and transferred into a flame-dried flask containing ground molecular sieves 4 Å (30 mg). The suspension was stirred under Ar for 30 min at rt and then cooled to −39 °C. A solution of TMSOTf (0.37 μL, 2 μmol) in dry DCM (0.15 mL) was added dropwise, and the suspension was stirred for 60 min. The reaction was quenched by dropwise addition of Et_3N (6.9 μL, 50 μmol) in DCM (0.5 mL) and was warmed to rt. The suspension was filtered over a plug of cotton and washed with DCM, and the filtrate was concentrated. The crude material (59.6 mg) was first purified on

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silica gel (SiO_2: 2 g cartridge, hexane/EtOAc 3:1→ 1:2) to give a disaccharide fraction (41.2 mg) that was further purified by preparative HPLC (column A, flow rate 10 mL/min, hexane/acetone 5:1) to provide pure α-anomer **21a** (24.2 mg, 58%) followed by elution of the β-anomer **21b** (5.9 mg, 14%) both as a colorless oils. Analytical data for **21a**: R_f = 0.22 (hexane/EtOAc 2:1); $[\alpha]_D^{20}$ −5.3 (*c* 0.7, toluene); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.07−8.05 (m, 2H, BzH2/H6), 7.62−7.58 (m, 1H, BzH4), 7.45−7.41 (m, 2H, BzH3/H5), 7.39−7.36 (m, 2H, PhH), 7.34−7.32 (m, 2H, PhH), 7.31−7.15 (m, 33H, PhH), 5.55 (dd, *J* = 3.6, 9.9 Hz, 1H, H-3), 5.41 (dd, *J* = 1.7, 3.6 Hz, 1H, H-2), 5.03 (ddd, *J* = 8.6, 9.8, 9.8 Hz, 1H, H-4), 5.01 (d, *J* = 1.7 Hz, 1H, H-1′), 4.96 (dd, *J* = 7.1, 11.8 Hz, 1H, POCH_2), 4.95−4.90 (m, 3H, POCH_2), 4.89 and 4.31 (2 d, *J* = 11.3 Hz, 1H, OCH_2), 4.85 and 4.53 (2d, *J* = 11.85 Hz, 2H, CH_2Ph), 4.73 and 4.69 (2 d, *J* = 12.2 Hz, 2H, CH_2Ph), 4.56 and 4.49 (2 d, *J* = 11.75 Hz, 2H, CH_2Ph), 4.56 (d, *J* = 1.7 Hz, 1H, H-1), 4.51 and 4.46 (2 d, *J* = 11.85 Hz, 1H, CH_2Ph), 4.47−4.44 (m, 1H, H-6), 4.20 (t, *J* = 9.5 Hz, 1H, H-4′), 4.09 (ddd, *J* = 1.4, 5.3, 6.8 Hz, 1H, H-6′), 3.89 (dd, *J* = 8.0, 9.8 Hz, 1H, H-7a), 3.88−3.83 (m, 3H, H-5, H-7a′, H-3′), 3.82 (dd, *J* = 1.9, 2.9 Hz, 1H, H-2′), 3.77 (dd, *J* = 5.5, 10.1 Hz, 1H, H-7b′), 3.72 (dd, *J* = 1.6, 9.8 Hz, 1H, H-5′), 3.67 (dd, *J* = 5.9, 9.8 Hz, 1H, H-7b), 3.21 (s, 3H, OCH_3), 2.55−2.45 (m, 2H, Lev-H2a/H2b), 2.43−2.31 (m, 2H, Lev-H3a/H3b), 1.98 (s, 3H, Lev-H5), 1.14−0.88 (m, 28H, FTIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.1 (Lev-C4), 171.9 (Lev-C1), 165.6 (PhC═O), 138.9, 138.7, 138.4, 138.2, 138.1, 135.7 (d, *J* = 7.9 Hz, $POCH_2PhC1$), 135.6 (d, *J* = 6.7 Hz, $POCH_2PhC1$), 133.1, 130.0, 129.4, 128.54, 128.48, 128.39, 128.37, 128.36, 128.22, 128.18, 127.9, 127.8, 127.72, 127.67, 127.64, 127.58, 127.5, 127.43, 127.40, 127.34, 127.31 (PhC), 98.4 (C-1), 98.2 (C-1′), 80.1 (C-3′), 75.1 (C-6′), 74.5 (CH_2Ph), 74.14 (C-2′), 74.09 (C-4′), 73.3 (CH_2Ph), 72.8 (CH_2Ph), 72.4 (CH_2Ph), 72.1 (C-5′), 71.8 (d, *J* = 6.7 Hz, C-4), 71.6 (CH_2Ph), 71.0 (C-7′), 70.6 (C-3), 70.2 (C-2), 69.8 (d, $J_{C,P}$ = 8.5 Hz, C-5), 69.4 (d, $J_{C,P}$ = 5.5 Hz, POCH_2), 69.2 (d, $J_{C,P}$ = 5.6 Hz, POCH_2), 68.8 (C-6), 66.9 (C-7), 55.6 (OCH_3), 37.7 (Lev-C3), 29.6 (Lev-C5), 27.9 (Lev-C2), 17.6, 17.55, 17.4, 17.35, 16.8, 16.73, 16.71 (8 × FTIPDS-CH_3), 13.7, 13.25 (2 × FTIPDS-CH), 12.58 and 12.56 (2 d, $J_{C,F}$ = 16.8 Hz, FTIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −3.21. HRMS ($^+$ESI-TOF) *m*/*z* [M + Na]$^+$ calcd for $C_{88}H_{108}FNaO_{20}PSi_2$ 1613.6586, found 1613.6575. Analytical data for **21b**: $[\alpha]_D^{20}$ −19.0 (*c* 1.4, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.06−8.04 (m, 2H, BzH2/H6), 7.60−7.57 (m, 1H, BzH4), 7.44−7.40 (m, 4H, BzH3/H5, 2PhH), 7.37−7.34 (m, 2H, PhH), 7.33−7.16 (m, 31H, PhH), 5.60 (dd, *J* = 3.6, 9.8 Hz, 1H, H-3), 5.43 (dd, *J* = 1.7, 3.6 Hz, 1H, H-2), 5.11 (ddd, *J* = 8.2, 9.8, 9.8 Hz, 1H, H-4), 4.97 (dd, $J_{H,P}$ = 7.3, *J* = 11.8 Hz, 1H, POCH_2), 4.95 and 4.82 (2 d, *J* = 12.4 Hz, 2H, CH_2Ph), 4.96−4.86 (m, 5H, 3 POCH_2, 2 CH_2Ph), 4.76 (d, *J* = 1.5 Hz, 1H, H-1), 4.60−4.57 (m, 1H, H-6), 4.60 (d, *J* = 11.7 Hz, 1H, CH_2Ph), 4.54−4.47 (m, 4H, 2 × CH_2Ph), 4.38 (d, *J* = 10.8 Hz, 1H, CH_2Ph), 4.26 (bs, 1H, H-1′), 4.25 (app t, *J* = 9.4, 1H, H-4′), 4.18−4.14 (m, 2H, H-6′, H-7a), 4.04 (bd, *J* = 10.0 Hz, 1H, H-5), 4.01 (dd, *J* = 7.2, 10.3 Hz, 1H, H-7a′), 3.83 (dd, *J* = 4.0, 10.3 Hz, 1H, H-7b′), 3.76 (d, *J* = 2.8 Hz, 1H, H-2′), 3.70 (dd, *J* = 8.5, 10.1 Hz, 1H, H-7b), 3.46 (dd, *J* = 2.9, 9.5 Hz, 1H, H-3′), 3.38 (dd, *J* = 2.0, 9.5 Hz, 1H, H-5′), 3.10 (s, 3H, OCH_3), 2.56−2.47 (m, 2H, Lev-H3a/H3b), 2.46−2.34 (m, 2H, Lev-H2a/H2b), 1.97 (s, 3H, Lev-H5), 1.05−0.87 (m, 28H, TIPDSF); ^{13}C NMR (151 MHz, $CDCl_3$) δ 206.2 (Lev-C4), 171.9 (Lev-C1), 165.7 (PhC═O), 138.9, 138.75, 138.5, 138.45, 138.0, 135.7 (d, $J_{C,P}$ = 8.0 Hz, $POCH_2PhC1$), 135.5 (d, *J* = 6.6 Hz, $POCH_2PhC1$), 133.4, 123.0, 129.4, 128.54, 128.46, 128.44, 128.39, 128.35, 128.26, 128.24, 128.15, 128.1, 128.0, 127.9, 127.7, 127.6, 127.52, 127.50, 127.4, 127.2 (PhC), 102.3 (C-1′), 98.4 (C-1), 82.7 (C-3′), 76.6 (C-5′), 75.4 (C-6′), 74.7 (CH_2Ph), 74.2 (C-4′), 73.5 (CH_2Ph), 73.4 (C-2′), 73.3 (CH_2Ph), 72.2 (CH_2Ph), 71.9 (C-7′), 71.8 (CH_2Ph), 71.65 (d, $J_{C,P}$ = 6.6 Hz, C-4), 70.6 (C-3), 70.5 (C-2), 69.4 (d, $J_{C,P}$ = 5.5 Hz, POCH_2), 69.2 (d, *J* = 5.5 Hz, POCH_2), 69.0 (d, *J* = 8.1 Hz, C-5), 68.5 (C-6), 68.2 (C-7), 54.9 (OCH_3), 37.7 (Lev-C3), 29.6 (Lev-C5), 28.0 (Lev-C2), 17.69, 17.66, 17.4, 17.35, 16.75, 16.70, 16.65 (FTIPDS-CH_3), 13.7, 13.3 (2 × FTIPDS-CH), 12.54 and 12.49 (2 d, $J_{F,C}$ = 16.5 Hz, FTIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −2.88. HRMS ($^+$ESI-TOF) *m*/*z* [M + Na]$^+$ calcd for $C_{88}H_{108}FNaO_{20}PSi_2$ 1613.6586, found 1613.6590.

*Methyl (2,3,4,6,7-Penta-O-benzyl-L-glycero-α-D-manno-hepto-pyranosyl)-(1→7)-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraisopropyl-1,3-disiloxane-1-yl)-L-glycero-α-D-manno-heptopyranoside (**22**).* Disaccharide **21a** (34 mg, 0.021 mmol) was dissolved in 6:4 pyridine/AcOH (1.2 mL). A solution of $N_2H_4{\cdot}H_2O$ (3.2 μL, 0.043 mmol, 2 equiv) in 6:4 pyridine/AcOH (50 μL) was added, and the solution was stirred at rt for 40 min. The reaction was quenched by addition of acetone (40 μL) and diluted with EtOAc (20 mL). The organic layer washed with satd aq $NaHCO_3$ (5 mL) and brine, dried ($NaSO_4$), concentrated, and coevaporated with toluene. The crude material (31.2 mg) was purified by column chromatography (SiO_2: 2 g cartridge, stepwise gradient hexane/EtOAc 4:1 → 2:1) to give **22** (26.7 mg, 84%) as a glasslike solid: R_f 0.65 (hexane/EtOAc 1:1); $[\alpha]_D^{20}$ +18.5 (*c* 1.3, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.07−8.04 (m, 2H, BzH2/H6), 7.58−7.55 (m, 1H, BzH4), 7.42−7.39 (m, 1H, BzH3/H5), 7.37−7.35 (m, 2H, PhH), 7.33−7.31 (m, 2H, PhH), 7.29−7.14 (m, 33H, PhH), 5.37 (dd, *J* = 1.7, 3.6 Hz, 1H, H-2), 5.05−4.98 (m, 4H, 2 × POCH_2), 4.86 and 4.30 (2 d, *J* = 11.1 Hz, 2H, CH_2Ph), 4.83 and 4.52 (2 d, J = 11.8 Hz, 2H, CH_2Ph), 4.81 (ddd, *J* = 6.1, 9.5, 9.5 Hz, 1H, H-4), 4.72 and 4.67 (2 d, *J* = 12.2 Hz, 2H, CH_2Ph), 4.70 (d, *J* = 5.0 Hz, 1H, 3-OH), 4.58 (d, *J* = 1.3 Hz, 1H, H-1), 4.54 and 4.47 (2 d, *J* = 11.6 Hz, 2H, CH_2Ph), 4.48 and 4.42 (2 d, *J* = 11.8 Hz, 2H, CH_2Ph), 4.35−4.29 (m, 2H, H-3, H-6), 4.19 (app t, *J* = 9.5 Hz, 1H, H-4′), 4.08 (ddd, *J* = 1.2, 5.5, 6.7 Hz, 1H, H-6′), 3.88−3.82 (m, 3H, H-7a, H-3′, H-7a′), 3.81−3.80 (m, 1H, H-2′), 3.75 (dd, *J* = 5.7, 9.9 Hz, 1H, H-7b′), 3.72 (dd, *J* = 1.4, 9.8 Hz, 1H, H-5′), 3.70 (bd, *J* = 10.0 Hz, 1H, H-5), 3.61 (dd, *J* = 6.2, 9.9 Hz, 1H, H-7b), 3.21 (s, 3H, OCH_3), 1.11−0.82 (m, 28H, FTIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.9 (C═O), 138.9, 138.7, 138.4, 138.2, 138.1,135.5 (d, $J_{C,P}$ = 6.9 Hz, $POCH_2PhC1$),135.3 (d, $J_{C,P}$ = 6.6 Hz, $POCH_2PhC1$), 133.15, 130.0, 129.8, 128.65, 128.57, 128.56, 128.34, 128.30, 128.26, 128.22, 128.2, 127.74, 127.73, 127.68, 127.60, 127.57, 127.5, 127.4, 127.35 (PhC), 98.5 (C-1), 98.3 (C-1′), 80.3 (C-3′), 76.55 (d, $J_{C,P}$ = 6.6 Hz, C-4), 75.0 (C-6′), 74.5 (CH_2Ph), 74.15 (C-2′), 74.1 (C-4′), 73.3 (CH_2Ph), 72.75 (CH_2Ph), 72.4 (CH_2Ph), 72.3 (C-2), 72.0 (C-5′), 71.7 (CH_2Ph), 70.7 (C-7′), 70.2 (d, $J_{C,P}$ = 5.3 Hz, $POCH_2Ph$), 69.7 (d, $J_{C,P}$ = 5.4 Hz, $POCH_2Ph$), 69.45 (d, $J_{C,P}$ = 11.0 Hz, C-5), 68.9, 68.9 (C-3, C-6), 67.4 (C-7), 55.6 (OCH_3), 17.6, 17.5, 17.3, 16.74, 16.69 (FTIPDS-CH_3), 13.6, 13.2 (2 × FTIPDS-CH), 12.55 and 12.53 (2 d, $J_{F,C}$ = 16.5 Hz, FTIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ 0.64. HRMS ($^+$ESI-TOF) *m*/*z* [M + Na]$^+$ calcd for $C_{83}H_{102}FNaO_{18}PSi_2$ 1515.6219, found 1515.6245.

*Methyl (2,3,4,6-Tetra-O-benzyl-α-D-glucopyranosyl)-(1→3)-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-6,7-O-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-heptopyranoside (**23**).* A suspension of acceptor **4** (100 mg, 0.120 mmol), donor **19** (130 mg, 0.180 mg, 1.50 equiv) and molecular sieves 4 Å (150 mg) in dry DCM (2.5 mL) was stirred for 20 min at rt and then cooled to −7 °C. A solution of TMSOTf (2.2 μL, 0.012 mmol, 0.10 equiv) in dry DCM (0.5 mL) was added. TLC control (toluene/EtOAc 5:1) indicated complete consumption of acceptor and donor after 5 min. The reaction was quenched by slow addition of Et_3N (33.4 μL, 0.241 mmol) in DCM (0.3 mL) and stirring for several min. The suspension was filtered through a bed of Celite and washed with DCM, and the filtrate was concentrated. The crude material was passed over a short bed of silica gel (SiO_2: 2 g cartridge, hexane/EtOAc 5:1) to furnish a disaccharide-containing fraction which was further purified by preparative HPLC on column A (hexane/EtOAc 6:1) to give first a fraction containing mainly the β-(1→3)-isomer (23 mg 14%): ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.00−7.97 (m, 2H, BzH2/H6), 7.48−7.45 (m, 1H, BzH4), 7.31−7.19 (m, 22H, BzH3/H5, PhH), 7.14−7.08 (m, 4H, PhH), 7.07−7.04 (m, 1H, PhH), 6.99−6.93 (m, 4H, PhH), 5.53 (dd, *J* = 2.2, 3.1 Hz, 1H, H-2), 5.22 (app q, *J* = 10.0 Hz, 1H, H-4), 5.16 (dd, $J_{H,P}$ = 6.2, *J* = 12.1 Hz, 1H, POCH_2), 5.04 (dd, $J_{H,P}$ = 7.2, 13.1 Hz, 1H, POCH_2), 5.03 (d, $J_{H,P}$ = 7.2 Hz, 2H, POCH_2), 4.86 (d, *J* = 1.9 Hz, 1H, H-1), 4.77−4.74 (m, 3H, H-3, 2 × CH_2Ph), 4.64 and 4.35 (2d, *J* = 11.0 Hz, 2H, CH_2Ph), 4.61 (d, *J* = 11.1 Hz, 1H, CH_2Ph), 4.58 (d, *J* = 7.7 Hz, 1H, H-1′), 4.55−4.52 (m, 1H, H-6), 4.514 (d, *J* = 11.9 Hz, 1H, CH_2Ph), 4.510 and 4.48 (2 d, *J* = 12.25 Hz, 2H, CH_2Ph), 4.15 (dd, *J* = 8.6, 12.4 Hz, 1H, H-7a), 3.86 (dd, *J* = 1.3, 12.4 Hz, 1H, H-7b), 3.82

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(dd, J = 0.9, 9.6 Hz, 1H, H-5), 3.71 (dd, J = 1.7, 10.8 Hz, 1H, H-6a′), 3.53−3.49 (m, 2H, H-6b′, H-3′), 3.45−3.42 (m, 1H, H-5′), 3.34 (s, 3H, OCH_3), 3.34 (dd, J = 7.8, 9.1 Hz, 1H, H-2′), 3.15 (t, J = 9.4 Hz, 1H, H-4′), 1.13−0.82 (m, 28H, FTIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.8 (C═O), 138.8, 138.6, 138.4, 138.3 (PhC), 136.4 (d, $J_{C,P}$ = 7.6 Hz, $POCH_2PhC1$), 136.1 (d, J = 7.7 Hz, $POCH_2PhC1$), 133.2, 130.0, 129.2, 128.4, 128.33, 128.30, 128.24, 128.16, 128.1, 127.9, 127.82, 127.79, 127.71, 127.68, 127.6, 127.5, 127.25, 126.8 (PhC), 98.4 (bs, C-1′), 98.3 (C-1), 84.4 (C-3′), 81.6 (C-2′), 77.7 (C-4′), 75.2 (CH_2Ph), 75.0 (C-5′), 74.8 (CH_2Ph), 74.4 (CH_2Ph), 73.7 (C-6), 73.2 (CH_2Ph), 73.0 (bs, C-4), 72.2 (d, $J_{C,P}$ = 6.3 Hz, C-5), 71.4 (bs, C-3), 68.9−68.7 (bs, 2 × $POCH_2$, C-6′), 68.2 (C-7), 67.8 (bs, C-2), 55.2 (OCH_3), 17.7, 17.5, 17.4, 17.31, 17.26, 17.24, 17.16 (8 × TIPDS-CH_3), 13.6, 13.4, 12.73, 12.71 (4 × TIPDS-CH); HRMS ($^+$ESI-TOF) m/z [M + Na]$^+$ calcd for $C_{75}H_{93}NaO_{17}PSi_2$ 1375.5581, found 1375.5601. Continued elution of the column gave α-isomer **23** (99.4 mg, 61%) as a colorless oil: $[\alpha]_D^{20}$ +20 (c 1.0, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.03−8.00 (m, 2H, Bz-H2/H6), 7.56 (t, J = 7.4 Hz, 1H, BzH4), 7.37 (t, J = 7.8 Hz, 2H, Bz-H3/H5), 7.33−7.30 (m, 2H, PhH), 7.28−7.16 (m, 24H, PhH), 7.09−7.05 (m, 2H, PhH), 6.96−6.91 (m, 2H, PhH), 5.38 (dd, J = 2.3, 3.2 Hz, 1H, H-2), 5.23 (d, J = 3.4 Hz, 1H, H-1′), 5.11−4.96 (m, 5H, 2 × $POCH_2$, H-4), 4.90 (d, J = 1.8 Hz, 1H, H-1), 4.79 and 4.53 (2d, J = 12.15 Hz, 2H, CH_2Ph), 4.75 (dd, J = 3.2, 9.4 Hz, 1H, H-3), 4.66 and 4.34 (2 d, J = 11.15 Hz, 2H, CH_2Ph), 4.62 and 4.47 (2 d, J = 10.8 Hz, 2H, CH_2Ph), 4.58 (d, J = 8.5 Hz, 1H, H-6), 4.46 and 4.23 (2 d, J = 12.15 Hz, 2H, CH_2Ph), 4.02 (dd, J = 8.6, 12.3 Hz, 1H, H-7a), 3.92 (d, J = 9.5 Hz, 1H, H-5), 3.92 (t, J = 9.4 Hz, 1H, H-3′), 3.77 (bd, J = 10.0 Hz, 1H, H-5′), 3.69 (d, J = 12.0 Hz, 1H, H-7b), 3.61 (d, J = 9.5 Hz, 1H, H-4′), 3.48 (dd, J = 3.5, 9.9 Hz, 1H, H-2′), 3.34 (s, 3H, OCH_3), 3.24 (dd, J = 2.6, 10.8 Hz, 1H, H-6a′), 3.17 (bd, J = 11.0 Hz, 1H, H-6b′), 1.07−0.99 and 0.90−0.86 (m, 20H and 8H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.8 (C═O), 138.9, 138.6, 138.5, 138.0, 136.01, 135.96 (PhC), 135.9 (d.i., 2 × $POCH_2PhC$), 133.2, 129.9, 129.6, 128.5, 128.45, 128.38, 128.3, 128.24, 128.19, 128.12, 128.09, 128.07, 127.93, 127.88, 127.8, 127.6, 127.5, 127.45, 127.37, 127.2 (PhC), 98.2 (C-1′), 97.7 (C-1), 81.2 (C-3′), 79.75 (C-2′), 77.2 (C-4′), 75.8 (C-3), 75.2 (CH_2Ph), 74.6 (d, $J_{C,P}$ = 6.9 Hz, C-4), 74.4 (CH_2Ph), 73.5 (C-6), 73.4 (CH_2Ph), 72.5 (C-2), 72.46 (CH_2Ph), 71.4 (bs, C-5), 71.3 (C-5′), 69.5 (d, $J_{C,P}$ = 5.6 Hz, $POCH_2$), 69.3 (d, $J_{C,P}$ = 4.9 Hz, $POCH_2$), 68.03, 67.99 (C-6′, C-7), 55.3 (OCH_3), 17.6, 17.5, 17.4, 17.34, 17.32, 17.25 (8 × TIPDS-CH_3), 13.35, 13.2, 12.7, 12.6 (TIPDS-CH); HRMS ($^+$ESI-TOF) m/z [M + Na]$^+$ calcd for $C_{75}H_{93}NaO_{17}PSi_2$ 1375.5581, found 1375.5562.

*Methyl (2,3,4,6,7-Penta-O-benzyl-L-glycero-α-D-manno-hepto-pyranosyl)-(1→3)-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-6,7-O-(1,1,3,3-tetraisopropyl-1,3-disiloxane-1,3-diyl)-L-glycero-α-D-manno-heptopyranoside (**24**).* Acceptor **4** (57 mg, 0.069 mmol) was coevaporated with dry toluene and dissolved in dry DCM (0.8 mL) in a flame-dried flask. Ground molecular sieves (4 Å, 40 mg) were added, and the suspension was stirred for 30 min at rt under Ar. A solution of TBDMSOTf (1.57 μL, 0.007 mmol, 0.10 equiv) in dry DCM (in 0.1 mL) was added dropwise. Then a solution of donor **18** (103 mg, 0.123 mmol, 1.8 equiv) in dry DCM (1 mL) was added continuously within 1 h via a syringe pump. Additional TBDMSOTf solution (~0.05 equiv) was added after 1.5 h, and the suspension was stirred for 1 h at rt. The reaction was quenched by dropwise addition of Et_3N (10 μL) in DCM (0.5 mL). The suspension was filtered over Celite and washed with DCM, and the filtrate was concentrated. The crude material was first purified by MPLC (SiO_2: 18 g, flow rate 15 mL/min, DCM/EtOAc 30:1) to give the anhydro byproduct **25** (17.3 mg, 25% of donor used) followed by a disaccharide-containing fraction (53.9 mg). Analytical data for **25**: NMR data were in full agreement with published values:[24] HRMS ($^+$ESI-TOF) m/z [M + NH_4]$^+$ calcd for $C_{35}H_{40}NO_6$ 570.2850, found 570.2846.

The disaccharide fraction was further purified by preparative HPLC (in three portions on column A, flow rate 15 mL/min, hexane/EtOAc 7:1) to furnish α-anomer **24** (36.3 mg, 36%) as an oil; R_f 0.56 (hexane/EtOAc 3:1): $[\alpha]_D^{20}$ −11.3 (c 1.6, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.07−8.03 (m, 2H, BzH2/H6), 7.58−7.54 (m, 1H, BzH4), 7.39−7.35 (m, 4H, BzH3/H5, 2 × PhH), 7.09 (m, 31H, PhH), 7.07−7.03 (m, 2H, PhH), 5.41 (d, J = 1.7 Hz, 1H, H-1′), 5.40 (dd, J = 2.0, 3.2 Hz, 1H, H-2), 5.03−4.94 (m, 4H, H-4, 3 × $POCH_2$), 4.92 (dd, $J_{H,P}$ = 7.0, J = 11.8 Hz, 1H, $POCH_2$), 4.82 and 4.47 (2 d, J = 11.85 Hz, 2H, CH_2Ph), 4.76 and 4.31 (2 d, J = 11.55 Hz, 2H, CH_2Ph), 4.76 (d, J = 1.9 Hz, 1H, H-1), 4.62 and 4.52 (2d, J = 12.1 Hz, 2H, CH_2Ph), 4.61 and 4.60 (2 d, J = 12.15 Hz, 2H, CH_2Ph), 4.55−4.45 (m, 1H, H-6), 4.43 (dd, J = 3.3, 9.5 Hz, 1H, H-3), 4.20 and 4.16 (2 d, J = 11.6 Hz, 2H, CH_2Ph), 4.19 (app t, J = 9.6 Hz, 1H, H-4′), 4.10 (dd, J = 8.6, 12.5 Hz, 1H, H-7a), 4.09−4.06 (m, 1H, H-6′), 4.03−4.01 (m, 1H, H-2′), 3.89 (dd, J = 7.4, 10.0 Hz, 1H, H-7a′), 3.87 (dd, J = 1.5, 9.8 Hz, 1H, H-5′), 3.80−3.75 (m, 3H, H-7b, H-7b′, H-3′), 3.66 (bd, J = 9.4 Hz, 1H, H-5), 3.28 (s, 3H, OCH_3), 1.07−0.82 (m, 28H, TIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.6 (C═O), 139.2, 139.1, 139.0, 138.7, 138.57 (PhC), 135.7 (d, $J_{C,P}$ = 7.7 Hz, $POCH_2PhC1$), 135.6 (d, $J_{C,P}$ = 6.6 Hz, $POCH_2PhC1$), 133.4, 130.0, 129.7, 128.6, 128.5, 128.42, 128.39, 128.37, 128.25, 128.1, 128.02, 128.00, 127.9, 127.2, 127.6, 127.53, 127.46, 127.4, 127.29, 127.27, 127.1, 127.05, 127.0, 126.8 (PhC), 100.35 (C-1′), 98.1 (C-1), 79.95 (C-3′), 75.6 (C-6′), 74.9 (C-2′), 74.5 (dd, $J_{C,P}$ = 6.6 Hz, C-4), 74.35 (C-3), 73.9 (C-4′), 73.7 (CH_2Ph), 73.6 (C-6), 73.23 (C-5′), 73.17 (CH_2Ph), 72.75 (CH_2Ph), 72.7 (C-2), 72.13 (CH_2Ph), 72.08 (d, $J_{C,P}$ = 5.5 Hz, C-5), 71.6 (C-7′), 71.4 (CH_2Ph), 69.4 (d, $J_{C,P}$ = 4.4 Hz, $POCH_2$), 69.3 (d, $J_{C,P}$ = 5.5 Hz, $POCH_2$), 68.2 (C-7), 55.1 (OCH_3), 17.6, 17.5, 17.4, 17.3, 17.24, 17.21, 17.1 (8 × TIPDS-CH_3), 13.6, 13.55, 12.73, 12.71 (4 × TIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −2.97; HRMS ($^+$ESI-TOF) m/z [M + NH_4]$^+$ calcd for $C_{83}H_{105}NO_{18}P\ Si_2$ 1490.6602, found 1490.6596.

*Methyl (2,3,4,6-Tetra-O-benzyl-α-D-glucopyranosyl)-(1→3)-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraiso-propyl-1,3-disiloxane-1-yl)-L-glycero-α-D-manno-heptopyranoside (**26**).* A solution of **23** (89.5 mg, 66.1 μmol) in dry DCM (3 mL) was treated with TREAT (216 μL, ~60 equiv of F^-) at 0 °C for 2.5 h according to general procedure 1. The residue (87 mg) was purified by column chromatography (SiO_2: 2 g cartridge, hexane/EtOAc 5:1 → 4:1 → 3:1) to give compound **26** (78.4 mg, 88%) as an oil: $[\alpha]_D^{20}$ +11.7 (c 1.0, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.02−8.00 (m, 2H, BzH2/H6), 7.56 −7.53 (m, 1H, BzH4), 7.38−7.34 (m, 2H, BzH3/H5), 7.30−7.27 (m, 4H, PhH), 7.26−7.15 (m, 22H, PhH), 7.12−7.08 (m, 2H, PhH), 6.96−6.93 (m, 2H, PhH), 5.38 (app t, J = 3.0 Hz, 1H, H-2), 5.18 (d, J = 3.5 Hz, 1H, H-1′), 5.09−5.05 (m, 3H, $POCH_2$), 5.04−4.99 (m, 2H, H-4, $POCH_2$), 4.95 (d, J = 2.6 Hz, 1H, H-1), 4.72 and 4.50 (2d, J = 12.2 Hz, 2H, CH_2Ph), 4.68−4.63 (m, 3H, H-3, CH_2Ph), 4.67 and 4.35 (2 d, J = 11.25 Hz, 2H, CH_2Ph), 4.52−4.47 (m, 2H, H-6, CH_2Ph), 4.45 and 4.21 (2 d, J = 12.1 Hz, 2H, CH_2Ph), 4.17 (dd, J = 2.4, 9.6 Hz, 1H, H-5), 3.90 (t, J = 9.4 Hz, 1H, H-3′), 3.78−3.73 (m, 2H, H-5′, H-7a), 3.72−3.67 (m, 1H, H-7b), 3.61 (t, J = 9.5 Hz, 1H, H-4′), 3.47 (dd, J = 3.5, 9.8 Hz, 1H, H-2′), 3.41 (s, 3H, OCH_3), 3.25 (dd, J = 2.7, 11.0 Hz, 1H, H-6a′), 3.11 (bd, J = 10.8 Hz, 1H, H-6b′), 1.06−0.92 (m, 28H, FTIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.8 (C═O), 138.85, 138.6, 138.4, 137.9, 135.9, 135.8 (2 × $POCH_2PhC1$), 133.2, 129.9, 129.6, 128.54, 128.48, 128.4, 128.3, 128.20, 128.16, 128.1, 128.01, 127.99, 127.96, 127.8, 127.6, 127.52, 127.4, 127.40, 127.29, 127.27 (PhC), 98.2 (C-1′), 97.9 (C-1), 81.3 (C-3′), 79.7 (C-2′), 77.2 (C-4′), 76.2 (C-3), 75.2 (CH_2Ph), 74.7 (d, $J_{C,P}$ = 6.4 Hz, C-4), 74.4 (CH_2Ph), 73.4 (CH_2Ph), 72.58 (C-2), 72.56 (CH_2Ph), 71.3 (C-5′), 71.0 (bs, C-6), 70.2 (C-5), 69.6 (d, $J_{C,P}$ = 5.6 Hz, $POCH_2$), 69.5 (d, $J_{C,P}$ = 5.3 Hz, $POCH_2$), 67.9 (C-6′), 63.4 (C-7), 55.4 (OCH_3), 17.4, 17.3, 17.2, 17.1, 16.7, 16.6 (8 × FTIPDS-CH_3), 13.5, 13.1, 12.6, 12.5 (4 × FTIPDS-CH); HRMS ($^+$ESI-TOF) m/z [M + Na]$^+$ calcd for $C_{75}H_{94}FNaO_{17}PSi_2$ 1395.5643, found 1395.5638.

*Methyl (2,3,4,6-Tetra-O-benzyl-α-D-glucopyranosyl)-(1→3)-[(2,3,4,6,7-penta-O-benzyl-L-glycero-α-D-manno-heptopyranosyl)-(1→7)]-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-6-O-(3-fluoro-1,1,3,3-tetraisopropyl-1,3-disiloxane-1-yl)-L-glycero-α-D-manno-heptopyranoside (**27**).* Acceptor **26** (33.2 mg, 24.2 μmol) and donor **18** (30.2 mg, 36.0 μmol, 1.5 equiv) were combined, coevaporated with dry toluene, dissolved in dry DCM (1.4 mL), and transferred into a flame-dried flask containing ground molecular sieves 4 Å (50 mg). The suspension was stirred under Ar for 30 min at rt and was then cooled to −40 °C. A solution of TMSOTf (0.22 μL, 1.2 μmol, 0.05 equiv) in dry DCM (0.1 mL) was added dropwise, and the reaction mixture was

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stirred under Ar while gradually raising the temperature to −35 °C during 1 h. Since TLC control (hexane/EtOAc 3:1) still indicated the presence of starting materials, additional TMSOTf solution (0.11 μL in 0.05 mL DCM) was added, and stirring was continued for 1 h. The suspension was warmed to 0 °C, the addition of promotor was repeated, and stirring was continued for 1 h. The reaction was quenched by dropwise addition of a solution of Et_3N (6.7 μL) in DCM (0.5 mL). The suspension was filtered through a plug of cotton, washed with DCM, and concentrated. Purification of the residue was performed first on silica gel (SiO_2: 2 g cartridge, hexane/EtOAc 6:1 → 4:1 → 3:1 → 0:1) to collect the trisaccharide-containing fraction (43.4 mg). Final purification was achieved by preparative HPLC (column A, hexane/EtOAc 5:1) to afford first the 7-*O*-TMS disaccharide acceptor (2.5 mg, data not shown) followed by **27** (24.7 mg, 51%) and fractions containing anhydro derivative **25** and the β-(1→7)-linked trisaccharide (8.9 mg, 18%, data not shown). Analytical data for **27**: R_f 0.55 (hexane/EtOAc 2:1); $[\alpha]_D^{20}$ +10.2 (*c* 1.1, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.04−8.01 (m, 2H, BzH2/H6), 7.58−7.54 (m, 1H, BzH4), 7.38−7.31 (m, 6H, BzH3/H5, 4 × Ph*H*), 7.29−7.13 (m, 47H, Ph*H*), 7.05−7.02 (m, 2H, Ph*H*), 6.94−6.90 (m, 2H, Ph*H*), 5.38 (dd, *J* = 3.4, 2.0 Hz, 1H, H-2), 5.18 (d, *J* = 3.5 Hz, 1H, H-1′), 5.13−4.95 (m, 5H, H-4, 2 × POCH_2), 5.05 (d, *J* = 1.7 Hz, 1H, H-1″), 4.90−4.86 (m, 2H, CH_2Ph), 4.81 (d, *J* = 1.6 Hz, 1H, H-1), 4.82−4.77 (m, 1H, H-6), 4.73−4.63 (m, 4H, 4 × CH_2Ph), 4.61 (dd, *J* = 3.3, 9.6 Hz, 1H, H-3), 4.57−4.40 (m, 9H, 9 × CH_2Ph), 4.35−4.31 (m, 2H, CH_2Ph), 4.23 (d, *J* = 12.0 Hz, 1H, CH_2Ph), 4.21 (app t, *J* = 9.5 Hz, 1H, H-4″), 4.13−4.10 (m, 1H, H-6″), 4.06 (br d, *J* = 9.9 Hz, 1H, H-5), 3.93−3.86 (m, 4H, H-7a″, H-3′, H-3″, H-7a), 3.83 (dd, *J* = 2.0, 2.7 Hz, 1H, H-2″), 3.78−3.73 (m, 3H, H-7b″, H-5′, H-5″), 3.68 (dd, *J* = 5.7, 9.9 Hz, 1H, H-7b), 3.60 (app t, *J* = 9.5 Hz, 1H, H-4′), 3.46 (dd, *J* = 3.5, 9.8 Hz, 1H, H-2′), 3.28 (s, 3H, OCH_3), 3.26−3.23 (m, 1H, H-6a′), 3.22−3.18 (m, 1H, H-6b′), 1.13−0.79 (m, 28H, FTIPDS); ^{13}C NMR (151 MHz, $CDCl_3$) δ 166.0 (C═O), 138.93, 138.86, 138.8, 138.7, 138.6, 138.4, 138.3, 137.9 (PhC), 136.0 (d, $J_{C,P}$ = 7.0 Hz, POCH_2PhC1), 135.9 (d, $J_{C,P}$ = 7.7 Hz, POCH_2PhC1), 133.2, 129.9, 129.6, 128.5, 128.45, 128.4, 128.34, 128.32, 128.25, 128.21, 128.18, 128.17, 128.1, 128.02, 127.97, 127.81, 127.76, 127.7, 127.62, 127.61, 127.56, 127.52, 127.48, 127.46, 127.45, 127.29, 127.28, 127.25, 127.21, 127.16 (PhC), 98.6 (C-1′), 98.1 (C-1″), 97.6 (C-1), 81.2 (C-3′), 80.5 (C-3″), 79.5 (C-2′), 77.2 (C-4′), 76.7 (C-3), 75.3 (C-6″), 75.15, 74.6 (2 × CH_2Ph), 74.3 (C-2″), 74.24 (CH_2Ph), 74.17 (C-4″), 73.9 (d, *J* = 6.7 Hz, C-4), 73.4, 73.3, 72.7 (3 × CH_2Ph), 72.6 (C-2), 72.4 (CH_2Ph), 72.34 (C-5″), 72.31, 71.65 (2 × CH_2Ph), 71.5 (C-7″), 71.4 (C-5′), 69.7 (C-5), 69.4 (d, $J_{C,P}$ = 5.4 Hz, POCH_2), 69.2 (d, $J_{C,P}$ = 4.9 Hz, POCH_2), 68.65 (C-6), 67.9 (C-6′), 66.8 (C-7), 55.6 (s, OCH_3), 17.6, 17.5, 17.4, 17.3, 16.8, 16.7 (FTIPDS-CH_3), 13.7, 13.4 (2 × FTIPDS-CH), 12.6 (d, $J_{F,C}$ = 16.5 Hz, FTIPDS-CH), 12.55 (d, $J_{F,C}$ = 16.9 Hz, FTIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −3.04; HRMS ($^+$ESI-TOF) *m*/*z* [M + Na]$^+$ calcd for $C_{117}H_{136}FNaO_{23}PSi_2$ 2037.8625, found 2037.8564.

*Alternative Preparation of Trisaccharide **27** from Acceptor **22**.* Compound **22** (38.5 mg, 25.8 μmol) and donor **19** (55.0 mg, 77.3 μmol, 3.0 equiv) were combined and coevaporated with dry toluene. The residue was dissolved in dry DCM (1.5 mL) and transferred into a flame-dried 10 mL flask containing ground molecular sieves 4 Å (50 mg). The suspension was stirred for 5 min at rt and then cooled to −22 °C. A solution of TBDMSOTf (0.29 μL, 1.3 μmol, 0.05 equiv) in dry DCM (0.1 mL) was added dropwise, and the reaction mixture was stirred under Ar for 2 h. The reaction was quenched by dropwise addition of Et_3N (16 μL, 26 μmol) in DCM (0.5 mL) and warmed to rt. The suspension was filtered over a plug of cotton, washed with DCM, and concentrated. The crude material was passed through a short silica gel column (SiO_2: 2 g, stepwise gradient of hexane/acetone 7:1→ 3:1) to afford a fraction containing the trisaccharides (50.7 mg). This material was further purified by preparative HPLC (column A, flow rate 15 mL/min, hexane/EtOAc 7:1 → 6:1) to afford pure α-anomer **27** (38.2 mg, 73.5%) as a colorless oil. Continued elution afforded the β-(1→3)-linked glucosyl isomer as colorless syrup (4.1 mg, 8%): ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.01−7.98 (m, 2H, BzH2/H6), 7.47−7.43 (m, 1H, BzH4), 7.38−7.35 (m, 2H, Ph*H*), 7.33−7.31 (m, 2H, Ph*H*), 7.28−7.10 (m, 46H, BzH3/H5, 44 × Ph*H*), 7.09−7.04 (m, 3H, Ph*H*), 7.00−6.95 (m, 4H, Ph*H*), 5.55 (dd, *J* = 2.1, 3.0 Hz, 1H, H-2), 5.23 (app q, *J* = 9.8 Hz, 1H, H-4), 5.18 (dd, $J_{H,P}$ = 6.0, *J* = 12.2 Hz, 1H, POCH_2), 5.03 (dd, $J_{H,P}$ = 7.1, *J* = 12.3 Hz, 1H, POCH_2), 5.01 (d, *J* = 1.5 Hz, 1H, H-1″), 4.98−4.96 (m, 2H, POCH_2Ph), 4.87 and 4.32 (2d, *J* = 11.2 Hz, 2H, CH_2Ph), 4.85 (d, *J* = 11.9 Hz, 1H, CH_2Ph), 4.81−4.76 (m, 2H, H-3, CH_2Ph), 4.75 and 4.60 (2 d, *J* = 11.2 Hz, 2H, CH_2Ph), 4.69 and 4.65 (2 d, *J* = 12.3 Hz, 2H, CH_2Ph), 4.65 (d, *J* = 1.7 Hz, 1H, H-1), 4.63 and 4.33 (2 d, *J* = 11.0 Hz, 2H, CH_2Ph), 4.61 (d, *J* = 7.7 Hz, 1H, H-1′), 4.55−4.50 (m, 3H, H-6, 2 × CH_2Ph), 4.48 and 4.42 (2 d, *J* = 11.7 Hz, 2H, CH_2Ph), 4.47 and 4.43 (2 d, *J* = 11.7 Hz, 2H, CH_2Ph), 4.41 and 4.34 (2 d, *J* = 12.0 Hz, 2H, CH_2Ph), 4.19 (app t, *J* = 9.6 Hz, 1H, H-4″), 4.10−4.07 (m, 1H, H-6″), 3.91 (dd, *J* = 8.3, 9.5 Hz, 1H, H-7a), 3.88−3.82 (m, 3H, H-5, H-7a″, H-3″), 3.77−3.74 (m, 2H, H-2″, H-7b″), 3.72 (dd, *J* = 1.4, 9.6 Hz, 1H, H-5″), 3.71−3.66 (m, 2H, H-7b, H-6a′), 3.56−3.50 (m, 2H, H-6b′, H-3′), 3.46−3.43 (m, 1H, H-5′), 3.32 (dd, *J* = 7.8, 9.2 Hz, 1H, H-2′), 3.21 (s, 3H, OCH_3), 3.19 (app t, *J* = 9.5 Hz, 1H, H-4′);^{13}C NMR (151 MHz, $CDCl_3$) δ 165.9 (C═O), 139.0, 138.82, 138.79, 138.6, 138.45, 138.24, 138.19, 138.1 (PhC), 136.4 (d, *J* = 8.9 Hz, POCH_2PhC1), 136.0 (d, *J* = 7.7 Hz, POCH_2PhC1), 133.2, 130.0, 129.2, 128.5, 128.42, 128.36, 128.34, 128.29, 128.22, 128.17, 128.1, 127.9, 127.83, 127.80, 127.76, 127.74, 127.72, 127.64, 127.61, 127.59, 127.57, 127.56, 127.53, 127.52, 127.50, 127.39, 127.36, 127.31, 127.29, 127.22, 127.19, 126.75 (PhC), 98.3 (d.i., C-1 and C-1′), 98.2 (C-1″), 84.3 (C-3′), 81.6 (C-2′), 80.1 (C-3″), 77.5 (C-4′), 75.18 (CH_2Ph), 75.16 (C-6″), 74.8 (C-5′), 74.75, 74.5 (2 × CH_2Ph), 74.33 (C-2), 74.31 (CH_2Ph), 74.2 (C-4″), 73.3, 73.2, 72.71 (3 × CH_2Ph), 72.69 (C-4), 72.4 (CH_2Ph), 72.2 (C-5″), 71.7 (CH_2Ph), 71.4 (C-3), 71.0 (C-7″), 70.1 (C-5), 69.2 (C-6), 68.83 (d, $J_{C,P}$ = 5.6 Hz, POCH_2), 68.77 (C-6′), 68.75 (d, $J_{C,P}$ = 5.0 Hz, POCH_2), 67.4 (C-2″), 67.1 (C-7), 55.5 (s, OCH_3), 17.70, 17.66, 17.5, 17.4, 16.8, 16.7 (FTIPDS-CH_3), 13.9 (2 × FTIPDS-CH), 13.3 (2 × FTIPDS-CH), 12.59 and 12.57 (2 d, $J_{F,C}$ = 16.5 Hz, FTIPDS-CH); ^{31}P NMR (243 MHz, $CDCl_3$) δ −2.69; HRMS ($^+$ESI-TOF) *m*/*z* [M + Na]$^+$ calcd for $C_{117}H_{136}FNaO_{23}PSi_2$ 2037.8625, found 2037.8579.

*Methyl 2,3-Di-O-benzoyl-4-O-(dibenzyloxyphosphoryl)-L-glycero-α-D-manno-heptopyranoside (**28**).* Pyridine (580 μL) was added to a solution of 70% HF−pyridine (205 μL) in an Eppendorf vial with external cooling. An aliquot of the HF−pyridine solution (0.4 mL, ∼33 equiv of F^-) was added to a solution of **6** (112 mg, 0.120 mmol) in dry THF (3.4 mL) in a Teflon vessel, and the solution was stirred at rt for 3 h. Additional aliquots (0.1 and 0.285 mL) were added in two portions, and stirring was continued for 75 min. The solution was poured into a stirred mixture of cold 50% aq satd $NaHCO_3$ and EtOAc. The aqueous layer was extracted twice with EtOAc, and the combined organic layers were washed with satd aq $NaHCO_3$ and brine, dried (Na_2SO_4), and concentrated. The residue was coevaporated with toluene and submitted to column chromatography (SiO_2: 2 g cartridge, Tol/EtOAc 5:1 → 3:1 → 2:1 → 1:1 → 2:3) to give **28** (60 mg, 72.3%) as a glasslike solid. Alternatively, heptoside **6** (35 mg, 37 μmol) was treated according to general procedure 1. The crude material (39.1 mg) was purified by chromatography (SiO_2: 2 g cartridge, Hex/EtOAc 1:2 → 1:3 → 1:4 → EtOAc) to give **28** (23.6 mg, 91%) as a glasslike solid: $[\alpha]_D^{20}$ −80 (*c* 0.3, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.08−8.06 (m, 2H, BzH2/H6), 7.85−7.83 (m, 2H, BzH2/H6), 7.64−7.61 (m, 1H, BzH4), 7.51−7.47 (m, 2H, BzH3/H5), 7.45−7.42 (m, 1H, BzH4), 7.31−7.27 (m, 3H, Ph*H*), 7.21−7.15 (m, 5H, BzH3/H5, 3 × Ph*H*), 7.09−7.06 (m, 2H, Ph*H*), 6.89−6.87 (m, 2H, Ph*H*), 5.81 (dd, *J* = 9.8, 3.6 Hz, 1H, H-3), 5.60 (dd, *J* = 3.5, 1.6 Hz, 1H, H-2), 5.13 (app q, *J* = 9.7 Hz, 1H, H-4), 4.92 (dd, *J* = 11.6, $J_{H,P}$ = 8.8 Hz, 1H, POCH_2), 4.90 (d, *J* = 1.8 Hz, 1H, H-1), 4.82 (dd, *J* = 11.7 Hz, $J_{P,H}$ = 8.3 Hz, 1H, POCH_2), 4.74−4.68 (m, 2H, CH_2Ph), 4.24 (d, *J* = 6.3 Hz, 1H, 6-OH), 4.12−4.08 (m, 1H, H-6), 3.94 (dd, *J* = 11.1, 7.8 Hz, 1H, H-7a), 3.90 (dd, *J* = 9.8, 1.5 Hz, 1H, H-5), 3.70−3.65 (m, 1H, H-7b), 3.44 (s, 3H, OCH_3), 2.12 (d, *J* = 8.7 Hz, 1H, 7-OH); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.4 (C═O), 165.3 (C═O), 135.1 (d, $J_{C,P}$ = 6.5 Hz, POCH_2PhC1), 134.9 (d, $J_{C,P}$ = 5.7 Hz, POCH_2PhC1), 133.6, 133.1, 129.95, 129.8, 129.30, 129.26, 128.65, 128.54, 128.47, 128.38, 128.3, 127.9, 127.7 (PhC), 98.8 (C-1), 71.6 (d, $J_{C,P}$ = 5.3 Hz, C-4), 71.0 (d, $J_{C,P}$ = 3.7 Hz, C-5), 70.6 (C-2), 70.1 (d, $J_{C,P}$ = 6.2 Hz, POCH_2), 70.0 (d, $J_{C,P}$ = 4.2 Hz, C-3), 69.8 (d, $J_{C,P}$ = 5.6

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Hz, $POCH_2$), 68.3 (C-7), 55.4 (OCH_3); HRMS ($^+$ESI-TOF) m/z [M + H]$^+$ calcd for $C_{36}H_{38}O_{12}P$ 693.2095, found 693.2101.

*Methyl 2,3-Di-O-benzoyl-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphoric Acid (**29**).* A solution of dibenzylphosphate **28** (117 mg, 0.169 mol) in MeOH (8 mL) was treated with 10% Pd/C (23 mg) for 2 h according to general procedure 2. The filtrate was concentrated to give **29** (87 mg, quant) as a glasslike solid: $[\alpha]_D^{20}$ −55.1 (*c* 0.25, MeOD); ^{1}H NMR (600 MHz, MeOD) δ 8.07−8.04 (m, 2H, BzH2/6), 7.98−7.95 (m, 2H, BzH2/6), 7.65−7.60 (m, 1H, BzH4), 7.54−7.50 (m, 1H, BzH4), 7.50−7.45 (m, 2H, BzH3/5), 7.37−7.32 (m, 2H, BzH3/5), 5.62−5.60 (m, 2H, H-2, H-3), 5.06 (app q, *J* = 10.3 Hz, 1H, H-4), 4.91 (bs, 1H, H-1), 4.17 (app t, *J* = 7.0 Hz, 1H, H-6), 4.02 (bd, *J* = 9.8 Hz, 1H, H-5), 3.79 (dd, *J* = 10.5, 6.8 Hz, 1H, H-7a), 3.76 (dd, *J* = 10.5, 7.1 Hz, 1H, H-7b), 3.50 (s, 3H, OCH_3); ^{13}C NMR (151 MHz, MeOD) δ 167.2, 166.9 (2 × C═O), 134.7, 134.16, 131.1, 131.0, 130.7, 129.6, 129.2 (PhC), 100.1 (C-1), 72.7 (d, $J_{C,P}$ = 2.2 Hz, C-3), 71.6 (d, $J_{C,P}$ = 5.5 Hz, C-5), 71.5 (C-2), 71.1 (d, $J_{C,P}$ = 4.9 Hz, C-4), 69.8 (C-6), 63.3 (C-7), 55.8 (OCH_3); HRMS ($^-$ESI-TOF) m/z calcd for $C_{22}H_{25}O_{12}P$ [M − H]$^-$ 511.1011, found 511.1013; HRMS ($^+$ESI-TOF) m/z [M + H]$^+$ calcd for $C_{22}H_{26}O_{12}P$ 513.1156, found 513.1159.

*Methyl L-glycero-α-D-manno-Heptopyranoside 4-O-Phosphate Monosodium Salt (**30**).* A solution of **29** (74 mg, 0.144 mmol) in MeOH (5 mL) was treated with 0.1 M methanolic NaOMe solution (13 mL). The solution (pH of ∼11) was stirred for 10 h at rt and made neutral by addition of cation-exchange resin (H^+-form). The resin was filtered off, and the filtrate was concentrated. The residue was dissolved in water, extracted with Et_2O and the aqueous phase was passed through a PD-10 column (water). Product containing fractions were pooled and lyophilized to give 47 mg (94%) of compound **30**: $[\alpha]_D^{21}$ +73.6 (*c* 0.35, H_2O) [lit.[43] $[\alpha]_D^{20}$ +60.1 (*c* 0.22, H_2O); lit.[44] $[\alpha]_D^{20}$ +30 (*c* 1.0, H_2O)]; NMR data agree with ref 44. A different chemical shift of C-4 has been reported in ref 43 (72.39 ppm): ^{13}C NMR (151 MHz, D_2O) δ 101.5 (C-1), 71.9 (C-3), 71.4 (d, $J_{C,P}$ = 6.9 Hz, C-5), 70.35 (C-2), 69.9 (d, $J_{C,P}$ = 4.4 Hz, C-4), 69.25 (C-6), 63.3 (C-7), 55.6 (OCH_3); ^{31}P NMR (243 MHz, D_2O) δ 4.87; HRMS ($^-$ESI-TOF) m/z calcd for $C_8H_{17}O_{10}P$ [M − H]$^-$ 303.0487, found 303.0483; HRMS ($^+$ESI-TOF) m/z [M + H]$^+$ calcd for $C_8H_{18}O_{10}P$ 305.0632, found 305.0634.

*Methyl (2,3,4,6,7-Penta-O-benzyl-L-glycero-α-D-manno-hepto-pyranosyl)-(1→7)-2,3-di-O-benzoyl-4-O-dibenzyloxyphosphoryl-L-glycero-α-D-manno-heptopyranoside (**31**).* Disaccharide **20a** (223.5 mg, 139.9 μmol) was coevaporated with toluene, dissolved in dry DCM (6 mL), and transferred into a Teflon-flask. HF−pyridine 70% (188 μL, ∼51 equiv of F^-) was added dropwise to the solution, and the mixture was vigorously stirred at rt for 3 h. The solution was added dropwise into a stirred mixture of ice-cold satd aq $NaHCO_3$ (40 mL) and EtOAc (30 mL). The aqueous layer was extracted with EtOAc (30 mL), and the combined organic layer was washed with H_2O and brine (10 mL), dried (Na_2SO_4), and concentrated. The residue (208 mg) was purified by chromatography (2 g cartridge, hexane/EtOAc 5:1 → 3:1 → 2:1) to afford compound **31** (150 mg, 80%) as a colorless oil: R_f 0.27 (hexane/EtOAc 3:2); $[\alpha]_D^{20}$ −19.5 (*c* 1.2, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.08−8.06 (m, 2H, BzH2/H6), 7.87−7.84 (m, 2H, Bz, H2/H6), 7.64−7.60 (m, 1H, BzH4), 7.50−7.46 (m, 2H, BzH3/H5), 7.46−7.42 (m, 1H, BzH4), 7.39−7.37 (m, 2H, PhH), 7.35−7.32 (m, 2H, PhH), 7.30−7.18 (m, 26H, BzH3/H5, PhH), 7.18−7.16 (m, 1H, PhH), 7.14−7.12 (m, 2H, PhH), 7.09−7.05 (m, 2H, PhH), 6.89−6.87 (m, 2H, PhH), 5.78 (dd, *J* = 3.5, 9.9 Hz, 1H, H-3), 5.55 (dd, *J* = 1.6, 3.4 Hz, 1H, H-2), 5.12 (app q, *J* = 9.7 Hz, 1H, H-4), 5.04 (d, *J* = 1.7 Hz, 1H, H-1′), 4.91 (d, *J* = 10.9 Hz, 1H, CH_2Ph), 4.89 (dd, $J_{H,P}$ = 8.1 Hz, *J* = 11.6 Hz, 1H, $POCH_2$), 4.81 (d, *J* = 11.9 Hz, 1H, CH_2Ph), 4.79 (dd, $J_{H,P}$ = 7.8 Hz, *J* = 11.7 Hz, 1H, $POCH_2$), 4.74 (d, *J* = 1.2 Hz, 1H, H-1), 4.74 (d, *J* = 12.3 Hz, 1H, CH_2Ph), 4.72−4.66 (m, 3H, $POCH_2$Ph, CH_2Ph), 4.61 (d, *J* = 11.8 Hz, 1H, CH_2Ph), 4.55 (d, *J* = 11.7 Hz, 1H, CH_2Ph), 4.53 (d, *J* = 11.5 Hz, 1H, CH_2Ph), 4.51 (bs, 2H, CH_2Ph), 4.36 (d, *J* = 10.7 Hz, 1H, CH_2Ph), 4.21 (app t, *J* = 9.5 Hz, 1H, H-4′), 4.17−4.10 (m, 2H, H-6, H-6′), 3.90 (dd, *J* = 3.0, 9.2 Hz, 1H, H-3′), 3.85−3.81 (m, 2H, H-2′, H-7a′), 3.80−3.73 (m, 4H, H-5′, H-7b′, H-7a, OH), 3.70 (dd, *J* = 1.3, 9.7 Hz, 1H, H-5), 3.62 (dd, *J* = 7.3, 10.5 Hz, 1H, H-7b), 3.25 (s, 3H, OCH_3); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.4 (C═O), 165.3 (C═O), 138.9, 138.7, 138.34, 138.28, 138.1, 135.13 (d, $J_{C,P}$ = 7.4 Hz, $POCH_2PhC1$), 135.07 (d, $J_{C,P}$ = 6.6 Hz, $POCH_2PhC1$), 133.5, 133.1, 129.95, 129.8, 129.4, 129.3, 128.64, 128.61, 128.56, 128.44, 128.41, 128.38, 128.35, 128.29, 128.28, 128.23, 128.21, 127.8, 127.75, 127.73, 127.69, 127.64, 127.62, 127.5, 127.45, 127.41, 127.37, 127.3 (PhC), 98.7 (C1), 98.4 (C-1′), 80.2 (C-3′), 74.9 (C-6′), 74.5 (CH_2Ph), 74.2, 74.15 (C-2′, C-4′), 73.3 (CH_2Ph), 72.7 (CH_2Ph), 72.4 (CH_2Ph), 71.8 (CH_2Ph), 71.6 (C-5′), 71.4 (d, $J_{C,P}$ = 5.2 Hz, C-4), 70.6 (C-2), 70.4 (d, $J_{C,P}$ = 3.6 Hz, C-5), 70.1 (C-7′), 70.0 (d, $J_{C,P}$ = 3.6 Hz, C-3), 69.9 (d, $J_{C,P}$ = 5.9 Hz, $POCH_2$), 69.7 (d, $J_{C,P}$ = 5.6 Hz, $POCH_2$), 67.4 (C-7), 66.5 (C-6), 55.5 (OCH_3); ^{31}P NMR (243 MHz, $CDCl_3$) δ −0.34. HRMS ($^+$ESI-TOF) m/z [M + NH_4]$^+$ calcd for $C_{78}H_{83}O_{18}NP$ 1352.5342, found 1352.5315.

*Methyl (L-glycero-α-D-manno-Heptopyranosyl)-(1→7)-2,3-di-O-benzoyl-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphate Monotriethylammonium Salt (**32**).* A suspension of heptobioside **31** (147 mg, 0.110 mmol) in dry MeOH (4.8 mL) and Pd/C (14 mg) was treated for 7 h according to general procedure 2. The filtrate was treated with Et_3N (31 μL, 0.22 mmol) and concentrated to afford the target compound as mono-Et_3N species **32** (84.1 mg, 95%) as a colorless oil: R_f 0.1 ($CHCl_3$/MeOH/H_2O 14:6:1); $[\alpha]_D^{20}$ −15.4 (*c* 0.5, MeOH); ^{1}H NMR (600 MHz, MeOD) δ = 8.06−8.04 (m, 2H, BzH2/H6), 8.02−7.99 (m, 2H, BzH2/H6), 7.63−7.59 (m, 1H, BzH4), 7.51−7.45 (m, 3H, BzH4, BzH3/H5), 7.35−7.31 (m, 2H, BzH3/H5), 5.60 (dd, *J* = 1.6, 3.4 Hz, 1H, H-2), 5.54 (dd, *J* = 3.4, 9.9 Hz, 1H, H-3), 4.93 (app q, *J* = 9.9 Hz, 1H, H-4), 4.90 (d, *J* = 1.4 Hz, 1H, H-1), 4.87 (d, *J* = 1.4 Hz, 1H, H-1′), 4.46−4.42 (m, 1H, H-6), 3.99−3.96 (m, 1H, H-6′), 3.91−3.88 (m, 2H, H-5, H-7a), 3.86 (dd, *J* = 1.6, 3.2 Hz, 1H, H-2′), 3.85 (app t, *J* = 9.7 Hz, 1H, H-4′), 3.74−3.65 (m, 4H, H-3′, H-7b, H-7a′, H-7b′), 3.63 (dd, *J* = 1.7, 9.7 Hz, 1H, H-5′), 3.50 (s, 3H, OCH_3), 3.07 (q, *J* = 7.3 Hz, 6H, NCH_2CH_3), 1.25 (t, *J* = 7.3 Hz, 9H, NCH_2CH_3); ^{13}C NMR (151 MHz, MeOD) δ 167.5 (C═O), 167.0 (C═O), 134.6, 134.0, 131.3, 131.1, 131.0, 130.8, 129.6, 129.15 (PhC), 102.3 (C-1′), 100.3 (C-1), 73.4 (d, $J_{C,P}$ = 3.1 Hz, C-5), 73.04 (d, $J_{C,P}$ = 3.5 Hz, C-3), 72.99 (C-5′), 72.8 (C-3′), 72.1 (C-2′), 71.7 (C-2), 71.0 (C-6′), 69.45 (d, $J_{C,P}$ = 5.6 Hz, C-4), 68.8 (C-7), 68.1 (C-6), 67.9 (C-4′), 64.7 (C-7′), 55.85 (OCH_3), 47.7 (NCH_2CH_3), 9.55 (NCH_2CH_3); ^{31}P NMR (243 MHz, MeOD) δ 1.98; HRMS ($^-$ESI-TOF) m/z [M − H]$^-$ calcd for $C_{29}H_{36}O_{18}P$ 703.1645, found 703.1642.

*Methyl (L-glycero-α-D-manno-Heptopyranosyl)-(1→7)-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphate Monosodium Salt (**33**).* Dibenzoate **32** (16.8 mg, 20.9 μmol) was dissolved in dry MeOH (1.0 mL) and 1 M methanolic NaOMe (0.15 mL, 146 μmol) was added, leading to the formation of a turbid emulsion. The reaction mixture was stirred for 19 h at rt and subjected to HPLC−MS analysis (method B) which indicated ∼30% of unchanged **32**. Additional reagent (0.15 mL, 146 μmol) and MeOH (0.5 mL) were added, and stirring was continued for 8 h. The pH of reaction mixture was adjusted to ∼5 by addition of cation-exchange resin (Dowex, H^+-form). The resin was filtered off and washed with MeOH, and the filtrate was made nearly neutral by adding 0.1 M NaOMe to give a pH of∼7−8. The solution was concentrated, and the residue (∼13.4 mg) was dissolved in D_2O (1 mL) and washed twice with chloroform (1 mL). The combined organic layers were re-extracted with D_2O (0.8 mL), and the combined aqueous phases were concentrated to remove residual $CHCl_3$. A solution of 1 M methanolic NaOMe (40 μL) was added, and the mixture was stirred overnight at rt and processed as described above. The combined aqueous layers were neutralized by adding 0.1 M NaOMe (pH ∼7−8), purged with a stream of argon, and lyophilized. Since NMR analysis indicated ∼5% of residual sodium benzoate in the material, the extraction process was repeated to give pure compound **33** (10.2 mg, 94.4%): $[\alpha]_D^{20}$ +71.2 (*c* 1.5, H_2O); ^{1}H NMR (600 MHz, D_2O, pH ∼6−7) δ 4.91 (d, *J* = 1.7 Hz, 1H, H-1′), 4.75 (d, *J* = 1.6 Hz, 1H, H-1), 4.29−4.26 (app q, *J* = 9.7 Hz, 1H, H-4), 4.27−4.25 (m, 1H, H-6), 4.03 (ddd, *J* = 1.7, 5.5, 7.4 Hz, 1H, H-6′), 3.98 (dd, *J* = 1.6, 3.0 Hz, 1H, H-2′), 3.93 (dd, *J* = 1.7, 3.6 Hz, 1H, H-2), 3.89 (dd, *J* = 3.5, 9.4 Hz, 1H, H-3), 3.86−3.81 (m, 2H, H-3′, H-4′),

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3.77 (dd, J = 4.2, 10.9 Hz, 1H, H-7a), 3.73 (dd, J = 7.6, 11.2 Hz, 1H, H-7a′), 3.71−3.67 (m, 2H, H-7b, H-7b′), 3.63−3.59 (m, 2H, H-5, H-5′), 3.38 (s, 3H, OCH_3); ^{13}C NMR (151 MHz, D_2O) δ 101.6 (C-1), 101.4 (C-1′), 72.2 (C-5′), 71.7 (d, $J_{C,P}$ = 7.0 Hz, C-5), 71.64 (C-3), 71.57 (C-3′), 70.8 (C-2′), 70.4 (C-2), 70.3 (d, $J_{C,P}$ = 4.8 Hz, C-4), 69.6 (C-6′), 69.3 (C-7), 67.7 (C-6), 66.9 (C-4′), 63.8 (C-7′), 55.6 (OCH_3); ^{31}P NMR (243 MHz, D_2O) δ 3.81; HRMS ($^-$ESI-TOF) m/z [M-H]$^-$ calcd for $C_{15}H_{27}O_{16}P$ 495.1120, found 495.1122.

*Methyl (2,3,4,6-Tetra-O-benzyl-α-D-glucopyranosyl)-(1→3)-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-L-glycero-α-D-manno-heptopyranoside (**34**).* Compound **23** (24.6 mg, 18.2 μmol) was treated and processed according to general procedure 1. The crude material was purified by column chromatography (SiO_2: 2 g cartridge, stepwise gradient of hexane/EtOAc 1:1→1:3) to give pure **34** (16 mg, 79%) as a syrup: $[\alpha]_D^{20}$ −12.0 (c 1.1, $CHCl_3$); ^1H NMR (600 MHz, $CDCl_3$) δ 8.02−7.99 (m, 2H, BzH2/H6), 7.57 (dd, J = 1.2, 7.5 Hz, 1H, BzH4), 7.41−7.38 (m, 2H, BzH3/H5), 7.29−7.17 (m, 23H, Ph*H*), 7.13−7.07 (m, 3H, Ph*H*), 7.05−7.02 (m, 2H, Ph*H*), 6.94−6.91 (m, 2H, Ph*H*), 5.47−5.46 (m, 1H, H-2), 5.25−5.18 (m, 2H, POCH_2), 5.06 −5.01 (m, 3H, H-4, H-1′, POCH_2), 4.95 (dd, J = 7.7, 11.8 Hz, 1H, POCH_2), 4.93 (d, J = 1.8 Hz, 1H, H-1), 4.63 and 4.35 (2d, J = 11.2 Hz, 2H, CH_2Ph), 4.62 and 4.58 (2 d, J = 12.0 Hz, 2H, CH_2Ph), 4.53 (bd, J = 5.3 Hz, 1H, 6-OH), 4.48 and 4.26 (2 d, J = 12.1 Hz, 2H, CH_2Ph), 4.45 and 4.30 (2 d, J = 10.95 Hz, 2H, CH_2Ph), 4.26 (dd, J = 3.0, 9.4 Hz, 1H, H-3), 4.20−4.16 (m, 1H, H-6), 3.89 (br dd, J = 8.2, 10.8 Hz, 1H, H-7a), 3.83 (dd, J = 8.8, 9.8 Hz, 1H, H-3′), 3.79 (dd, J = 1.5, 9.6 Hz, 1H, H-5), 3.67 (dt, J = 2.1, 10.1 Hz, 1H, H-5′), 3.64−3.59 (m, 1H, H-7b), 3.62 (dd, J = 8.7, 10.0 Hz, 1H, H-4′), 3.50 (dd, J = 3.7, 9.8 Hz, 1H, H-2′), 3.39 (s, 3H, OCH_3), 3.25 (dd, J = 2.5, 11.0 Hz, 1H, H-6a′), 3.21 (dd, J = 1.7, 10.9 Hz, 1H, H-6b′), 2.04 (bd, J = 8.5 Hz, 1H, 7-OH); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.75 (C═O), 138.7, 138.55, 138.2, 137.85 (PhC), 135.7 (d, $J_{C,P}$ = 6.2 Hz, POCH_2PhC1), 135.3 (d, $J_{C,P}$ = 7.1 Hz, POCH_2PhC1), 133.4, 129.8, 129.4, 128.62, 128.60, 128.56, 128.4, 128.23, 128.16, 128.1, 127.95, 127.9, 127.82, 127.78, 127.7, 127.5, 127.4, 127.34, 127.32, 127.30 (PhC), 99.1 (C-1′), 98.1 (C-1), 81.4 (C-3′), 80.05 (C-2), 77.9 (d, J = 5.0 Hz, C-3), 77.1 (C-4′), 75.1 (CH_2Ph), 74.4 (CH_2Ph), 73.4 (CH_2Ph), 73.1 (CH_2Ph), 72.3 (C-2), 72.1 (d, $J_{C,P}$ = 5.1 Hz, C-4), 71.53 (C-5′), 71.47 (d, $J_{C,P}$ = 2.2 Hz, C-5), 70.02, 69.99 (2 × POCH_2), 68.3 (C-6), 67.8 (C-6′), 63.15 (C-7), 55.4 (OCH_3); ^{31}P NMR (243 MHz, $CDCl_3$) δ 0.60; HRMS ($^+$ESI-TOF) m/z [M + H]$^+$ calcd for $C_{63}H_{68}O_{16}P$ 1111.4239, found 1111.4237.

*Methyl (α-D-Glucopyranosyl)-(1→3)-2-O-benzoyl-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphate Triethylammonium Salt (**35**).* A suspension of disaccharide **34** (25 mg, 22.5 μmol) and 10% Pd/C (2.5 mg) was hydrogenated for 7 h at rt and processed as described in general procedure 2. A solution of Et_3N (4 μL) in MeOH (100 μL) was added, and the filtrate was concentrated to afford compound **35** (14.3 mg, 95%) as a syrup: $[\alpha]_D^{20}$ +60.6 (c 1.4, MeOH); ^1H NMR (600 MHz, MeOD) δ 8.13−8.10 (m, 2H, BzH2/H6), 7.63−7.60 (m, 1H, BzH4), 7.50−7.46 (m, 2H, BzH3/H5), 5.39 (dd, J = 1.6, 3.3 Hz, 1H, H-2), 5.13 (d, J = 4.0 Hz, 1H, H-1′), 4.78 (bs, 1H, H-1), 4.78 (app q, J = 10.1 Hz, 1H, H-4), 4.21 (dt, J = 1.5, 6.8 Hz, 1H, H-6), 4.16 (dd, J = 3.4, 9.8 Hz, 1H, H-3), 3.80 (dd, J = 1.5, 9.9 Hz, 1H, H-5), 3.73 (dd, J = 7.1, 10.8 Hz, 1H, H7-a), 3.68 (dd, J = 6.8, 11.0 Hz, 1H, H-7b), 3.66 (dd, J = 2.3, 12.2 Hz, 1H, H-6a), 3.60 (dd, J = 3.7, 12.0 Hz, 1H, H-6b), 3.56 (app t, J = 9.5 Hz, 1H, H-3′), 3.55−3.52 (m, 1H, H-5′), 3.42 (s, 3H, OCH_3), 3.37 (dd, J = 3.9, 9.8 Hz, 1H, H-2′), 3.34 (app t, J = 9.5 Hz, 1H, H-4′), 3.15 (q, J = 7.3 Hz, 7H, NCH_2CH$_3$), 1.29 (t, J = 7.3 Hz, 11H, NCH$_2$CH_3); ^{13}C NMR (151 MHz, MeOD) δ 167.5 (C═O), 134.5, 131.13, 131.06, 129.6, 103.4 (C-1′), 99.95 (C-1), 79.4 (d, $J_{C,P}$ = 2.5 Hz, C-3), 74.5 (C-3′), 74.4 (C-2), 74.1 (C-5′), 73.8 (C-2′), 72.7 (d, $J_{C,P}$ = 3.4 Hz, C-5), 70.7 (C-4′), 70.6 (d, $J_{C,P}$ = 4.9 Hz, C-4), 69.9 (C-6), 63.1 (C-7), 61.8 (C-6′), 55.6 (OCH_3), 47.6 (NCH$_2$CH$_3$), 9.3 (NCH$_2$CH$_3$); ^{31}P NMR (243 MHz, MeOD) δ 1.97. HRMS ($^-$ESI-TOF) m/z [M − H]$^-$ calcd for $C_{21}H_{30}O_{16}P$ 569.1277, found 569.1277.

*Methyl (α-D-Glucopyranosyl)-(1→3)-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphate Disodium Salt (**36**).* A solution of **35** (13.6 mg, 20.2 μmol) in dry MeOH (1.0 mL) was treated with 1 M NaOMe (100 μL, ∼100 μmol) for 14 h at rt. The pH of the solution was adjusted to pH ∼7−8 by adding cation-exchange resin (H^+-form), the resin was filtered off, and the filtrate was concentrated. The residue was dissolved in D_2O and was thoroughly washed with Et_2O. The combined aqueous layers were acidified with cation-exchange resin and filtered. The filtrate was treated with 0.4 M methanolic NaOMe (0.1 mL) and lyophilized to give 36 (10.7 mg, quant) as a colorless amorphous solid: $[\alpha]_D^{21}$ +87.5 (c 1.1, D_2O); ^1H NMR (600 MHz, D_2O, pH ∼10) δ 5.19 (d, J = 3.9 Hz, 1H, H-1′), 4.67 (d, J = 1.2 Hz, 1H, H-1), 4.32 (q, J = 10.1 Hz, 1H, H-4), 4.12 (ddd, J = 1.9, 5.4, 7.5 Hz, 1H, H-6), 4.02 (dd, J = 1.6, 3.2 Hz, 1H, H-2), 3.87 (dd, J = 3.3, 9.9 Hz, 1H, H-3), 3.81−3.77 (m, 3H, H-5′, H-3′, H-6a′), 3.76−3.72 (m, 2H, H-6b′, H-7a), 3.70 (dd, J = 5.2, 11.4 Hz, 1H, H-7b), 3.64 (dd, J = 1.7, 10.0 Hz, 1H, H-5), 3.38 (dd, J = 3.8, 9.8 Hz, 1H, H-2′), 3.35 (app t, J = 9.0, 1H, H-4′), 3.34 (s, 3H, OCH_3).^{13}C NMR (151 MHz, D_2O): δ 102.3 (C-1′), 102.0 (C1), 80.1 (d, $J_{C,P}$ = 2.2 Hz, C-3), 74.3 (C-3′), 73.3 (C-5′), 73.04 (d, $J_{C,P}$ = 3.4 Hz, C-5), 72.96 (C-2′), 71.6 (C-2), 70.5 (C-4′), 69.4 (C-6), 68.5 (d, $J_{C,P}$ = 4.8 Hz, C-4), 63.0 (C-7), 61.6 (C-6′), 55.7 (OCH_3); ^{31}P NMR (243 MHz, D_2O) δ 4.70; HRMS ($^-$ESI-TOF) m/z [M − H]$^-$ calcd for $C_{14}H_{26}O_{15}P$ 465.1015, found 465.1013.

*Methyl (2,3,4,6,7-Penta-O-benzyl-L-glycero-α-D-manno-heptopyranosyl)-(1→3)-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-L-glycero-α-D-manno-heptopyranoside (**37**).* Compound **24** (53 mg, 36.0 μmol) was treated as described in general procedure 1. The crude material (45 mg) was purified by column chromatography (SiO_2: 2 g cartridge, Hex/EtOAc 1:3 → 1:4) to afford **37** (37.7 mg, 83.6%) as a colorless oil: R_f 0.20 (hexane/EtOAc 1:2); $[\alpha]_D^{20}$ −42.4 (c 1.2, $CHCl_3$); ^1H NMR (600 MHz, $CDCl_3$) δ 8.14−8.12 (m, 2H, BzH2/H6), 7.63−7.59 (m, 1H, BzH4), 7.49−7.45 (m, 2H, BzH3/H5), 7.40−7.37 (m, 2H, Ph*H*), 7.36−7.12 (m, 26H, Ph*H*), 7.07−7.01 (m, 5H, Ph*H*), 6.93 −6.90 (m, 2H, Ph*H*), 5.54 (dd, J = 1.4, 3.1 Hz, 1H, H-2), 5.32 (d, J = 1.4 Hz, 1H, H-1′), 5.08 (dd, $J_{H,P}$ = 8.7, 11.5 Hz, 1H, POCH_2), 5.05−5.00 (m, 2H, 2 × POCH_2), 4.92 (app q. J = 9.7 Hz, 1H, H-4), 4.81 and 4.36 (2 d, J = 11.6 Hz, 2H, CH_2Ph), 4.80 and 4.47 (2 d, J = 11.8 Hz, 2H, CH_2Ph), 4.76 (dd, $J_{H,P}$ = 6.4, J = 11.9 Hz, 1H, POCH_2), 4.69 (d, J = 1.3 Hz, 1H, H-1), 4.66 and 4.55 (2 d, J = 12.2 Hz, 2H, CH_2Ph), 4.54 (d, J = 5.7 Hz, 1H, 6-OH), 4.44−4.40 (m, 3H, CH_2Ph, H-3), 4.17 (app t, J = 9.6, 1H, H-4′), 4.17−4.15 (m, 1H, H-6′), 4.08 (d, J = 11.5 Hz, 1H, CH_2Ph), 4.08−4.04 (m, 1H, H-6), 4.02 (dd, J = 1.1, 9.8 Hz, 1H, H-5′), 3.96−3.90 (m, 2H, CH_2Ph, H-7a), 3.88 (dd, J = 6.7, 9.9 Hz, 1H, H-7a′), 3.83 (dd, J = 5.5, 9.8 Hz, 1H, H-7b′), 3.71 (dd, J = 1.2, 9.8 Hz, 1H, H-5), 3.65 (dd, J = 2.9, 9.5 Hz, 1H, H-3′), 3.65−3.60 (m, 1H, H-7b), 3.59 (dd, J = 1.8, 2.8 Hz, 1H, H-2′), 2.06 (bd, J = 9.6 Hz, 1H, 7-OH); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.1 (C═O), 139.1, 138.9, 138.8, 138.6, 138.5 (PhC), 135.1 (d, $J_{C,P}$ = 7.7 Hz, POCH_2PhC1), 135.0 (d, $J_{C,P}$ = 6.6 Hz, POCH_2PhC1), 133.4, 130.0, 129.7, 128.9, 128.75, 128.65, 128.6, 128.3, 128.12, 128.09, 128.07, 128.03, 127.96, 127.55, 127.39, 127.36, 127.34, 127.31, 127.27, 127.23, 127.17, 127.1, 126.95, 126.8 (PhC), 99.6 (C-1′), 99.0 (C-1), 80.1 (C-3′), 75.21 (C-6′), 75.17 (C-2′), 73.95 (d, $J_{C,P}$ = 5.5 Hz, C-4), 73.83 (C-4′), 73.78 (CH_2Ph), 73.2 (CH_2Ph), 72.90 (C-5′), 72.88 (CH_2Ph), 72.3 (C-2), 72.1 (CH_2Ph), 71.8 (CH_2Ph), 71.7 (d, $J_{C,P}$ = 4.4 Hz, C-3), 71.1 (d, $J_{C,P}$ = 3.3 Hz, C-5), 71.0 (C-7′), 70.3 (d, $J_{C,P}$ = 5.5 Hz, POCH_2), 69.9 (dt, $J_{C,P}$ = 4.4 Hz, POCH_2), 68.1 (C-6), 63.1 (C-7), 55.15 (OCH_3); ^{31}P NMR (243 MHz, $CDCl_3$) δ 1.72; HRMS ($^+$ESI-TOF) m/z [M + NH_4]$^+$ calcd for $C_{71}H_{79}NO_{17}P$ 1248.5080, found 1248.5088.

*Methyl (L-glycero-α-D-manno-Heptopyranosyl)-(1→3)-2-O-benzoyl-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphoric Acid (**38**).* A suspension of heptoside **37** (36.5 mg, 29.6 μmol) and Pd/C (10 w%, 8.4 mg) in dry MeOH (1.8 mL) was processed according to general procedure 2. The filtrate was concentrated to afford **38** as a syrup (18.3 mg, ∼quant): R_f 0.13 ($CHCl_3$/MeOH/H_2O 10:5:1); ^1H NMR (600 MHz, MeOD, pH ∼2) δ 8.12−8.09 (m, 2H, BzH2/H6), 7.64−7.60 (m, 1H, BzH4), 7.51−7.47 (m, 2H, BzH3/H5), 5.45 (dd, J = 1.7, 3.2 Hz, 1H, H-2), 5.11 (s, 1H, H-1′), 4.88−4.82 (m, H-4), 4.82 (d, J = 1.6 Hz, 1H, H-1), 4.28 (dd, J = 3.3, 9.5 Hz, 1H, H-3), 4.15−4.09 (m, 1H, H-6), 4.02−3.97 (m, 2H, H-6′, H-2′), 3.85 (bd, J = 9.8 Hz, 1H, H-5), 3.84 (app t, J = 9.7 Hz, 1H, H-4′), 3.77−3.68 (m, 4H, H-7a, H-7b, H-7a′, H-7b′), 3.70 (dd, J = 1.5, 9.8 Hz, 1H, H-5′), 3.53

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(dd, J = 3.2, 9.5 Hz, 1H, H-3′), 3.44 (s, 3H, OCH_3); ^{13}C NMR (151 MHz, MeOD) δ 167.1 (*C*═O), 134.55, 131.05, 131.0, 129.6, 103.85 (C-1′), 100.1 (C-1), 75.2 (C-3), 74.2 (C-5′), 73.83 (C-2), 73.80 (C-4), 72.4 (C-3′), 71.8 (d, $J_{C,P}$ = 4.4 Hz, C-5), 71.6 (C-2′), 71.1 (C-6′), 69.8 (C-6), 67.7 (C-4′), 65.4, 63.2 (C-7, C-7′), 55.7 (OCH_3); ^{31}P NMR (243 MHz, D_2O) δ 0.80; HRMS ($^-$ESI-TOF) m/z [M − H]$^-$ calcd for $C_{22}H_{33}O_{17}P$ 599.1383, found 599.1382.

*Methyl (L-glycero-α-D-manno-Heptopyranosyl)-(1→3)-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphate Monosodium Salt (**39**).* A solution of 1 M methanolic NaOMe (0.29 mL, 0.290 mmol) was added to a solution of **38** (17.6 mg, 29.3 μmol) in dry MeOH (1.8 mL) to give a pH ≥ 12. The turbid emulsion was stirred for 41 h at rt. Additional reagent (0.29 mL) and MeOH (1.8 mL) were added, and stirring was continued for 24 h. Another portion (4 mL MeOH and 0.6 mL 1 M NaOMe) was then added, and stirring was continued for 3 more days. The solution was acidified by adding cation-exchange resin (H^+-form), the resin was filtered off, washed with MeOH, and the filtrate was concentrated. The residue was partitioned between water and chloroform to remove methyl benzoate. The aqueous layer was neutralized by addition of 1 M NaOMe solution and submitted to lyophilization to yield a white powder (14.7 mg, 97%). Since the product contained ∼1% of residual **38**, hydrolysis of an aqueous solution was continued using 1 M NaOMe in MeOH (57 μL) overnight at rt. Workup as described afforded compound **39** (12.0 mg, 79%) as a colorless powder: $[\alpha]_D^{20}$ +86.3 (*c* 0.8, D_2O) [lit.[29] $[\alpha]_D^{20}$ +85 (*c* 0.8, H_2O)]; NMR data agree with published values;[29] ^{31}P NMR (243 MHz, D_2O) δ 2.71; HRMS ($^-$ESI-TOF) m/z [M − H]$^-$ calcd for $C_{15}H_{28}O_{16}P$ 495.1120, found 495.1122.

*Methyl (2,3,4,6-Tetra-O-benzyl-α-D-glucopyranosyl)-(1→3)-[(2,3,4,6,7-penta-O-benzyl-L-glycero-α-D-manno-heptopyranosyl)-(1→7)]-2-O-benzoyl-4-O-dibenzyloxyphosphoryl-L-glycero-α-D-manno-heptopyranoside (**40**).* A solution of HF−pyridine 70% (26.4 μL, ∼55 equiv of F^-) was added dropwise to a solution of trisaccharide **27** (37.3 mg, 18.5 μmol, predried by coevaporation with toluene) in dry DCM (2.5 mL) in a Teflon flask under vigorous stirring. The solution was stirred for 1 h at rt and was added dropwise into a stirred mixture of ice-cold satd aq $NaHCO_3$ (15 mL) and EtOAc (30 mL). The aqueous layer was extracted with EtOAc (15 mL), and the combined organic layer was washed with brine (15 mL), dried (Na_2SO_4) ,and concentrated. The residue (37 mg) was purified by chromatography (SiO_2: 2 g cartridge, hexane/EtOAc 2:1 → 3:2 → 1:1) to give compound **40** (26.5 mg, 82%) as a colorless oil: R_f 0.25 (hexane/EtOAc 2:1); $[\alpha]_D^{20}$ +3.9 (*c* 1.3, $CHCl_3$); ^1H NMR (600 MHz, $CDCl_3$) δ 8.02−7.99 (m, 2H, BzH2/H6), 7.59−7.55 (m, 1H, BzH4), 7.41−7.35 (m, 4H, BzH3/H5, 2 × Ph*H*), 7.34−7.14 (m, 46H, Ph*H*), 7.12−7.06 (m, 3H, Ph*H*), 7.05−7.01 (m, 2H, Ph*H*), 6.94−6.91 (m, 2H, Ph*H*), 5.44 (dd, J = 3.1, 1.9 Hz, 1H, H-2), 5.22 (dd, J = 11.8 Hz, $J_{H,P}$ = 7.8 Hz, 1H, POCH_2), 5.19 (dd, J = 11.8 Hz, $J_{H,P}$ = 9.0 Hz, 1H, POCH_2), 5.07−5.01 (m, 4H, H-4, POCH_2, H-1′, H-1″), 4.94 (dd, J = 11.7 Hz, $J_{H,P}$ = 7.1 Hz, 1H, POCH_2), 4.90 (d, J = 11.2 Hz, 1H, CH_2Ph), 4.82 and 4.53 (2 d, J = 11.95 Hz, 2H, CH_2Ph), 4.82 (d, J = 1.7 Hz, 1H, H-1), 4.73 and 4.67 (2 d, J = 12.35 Hz, 2H, CH_2Ph), 4.64 and 4.58 (2 d, J = 12.0 Hz, 2H, CH_2Ph), 4.63 (d, J = 11.2 Hz, 1H, CH_2Ph), 4.59 and 4.54 (2 d, J = 11.75 Hz, 2H, CH_2Ph), 4.52−4.47 (m, 3H, CH_2Ph), 4.45 and 4.30 (2 d, J = 10.95 Hz, 2H, CH_2Ph), 4.38−4.33 (m, 2H, CH_2Ph), 4.28−4.15 (m, 5H, CH_2Ph, H-6, H-3, H-4″, 6-OH), 4.13−4.10 (m, 1H, H-6″), 3.91 (dd, J = 9.2, 3.1 Hz, 1H, H-3″), 3.86−3.82 (m, 3H, H-3′, H-2″, H-7a″), 3.78 (dd, J = 9.7, 1.7 Hz, 1H, H-5″), 3.76 (dd, J = 9.8, 6.1 Hz, 1H, H-7b″), 3.73 (dd, J = 10.4, 5.6 Hz, 1H, H-7a), 3.68−3.59 (m, 4H, H-5′, H-5, H-4′, H-7b), 3.50 (dd, J = 9.8, 3.6 Hz, 1H, H-2″), 3.25 (dd, J = 11.0, 2.3 Hz, 1H, H-6a′), 3.24 (s, 3H, OCH_3), 3.22 (dd, J = 11.1, 1.7 Hz, 1H, H-6b′); ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.7 (PhC═O), 138.9, 138.7, 138.55, 138.37, 138.36, 138.21, 138.17, 137.8 (PhC), 135.7 (d, J = 6.6 Hz, $POCH_2PhC1$), 135.3 (d, J = 7.7 Hz, $POCH_2PhC1$), 133.4, 129.8, 129.5, 128.62, 128.59, 128.56, 128.4, 128.3, 128.24, 128.21, 128.15, 128.1, 127.9, 127.81, 127.76, 127.71, 127.69, 127.53, 127.51, 127.48, 127.43, 127.42, 127.33, 127.30, 127.27 (PhC), 99.15 (C-1′), 98.4 (C-1″), 98.0 (C-1), 81.4 (C-3′), 80.4 (C-3″), 79.9 (C-2′), 77.9 (d, $J_{P,C}$ = 5.5 Hz, C-3), 77.1 (C-4′), 75.09 (CH_2Ph), 75.0 (C-6″), 74.53 (CH_2Ph), 74.4 (CH_2Ph), 74.25 (C-4″), 74.1 (C-2″), 73.4 (CH_2Ph), 73.3 (CH_2Ph), 73.0 (CH_2Ph), 72.7 (CH_2Ph), 72.28 (C-2), 72.26 (CH_2Ph), 71.9 (d, $J_{P,C}$ = 4.4 Hz, C-4), 71.8 (CH_2Ph), 71.7 (C-5″), 71.5 (C-5′), 71.1 (d, $J_{P,C}$ = 2.2 Hz, C-5), 70.3 (C-7″), 70.0 (d, $J_{P,C}$ = 5.8 Hz, POCH_2), 69.9 (d, $J_{P,C}$ = 5.5 Hz, POCH_2), 67.7 (C-6′, C-7), 66.6 (C-6), 55.5 (OCH_3); ^{31}P NMR (243 MHz, $CDCl_3$) δ 0.45; HRMS ($^+$ESI-TOF) m/z [M + Na]$^+$ calcd for $C_{105}H_{109}NaO_{22}P$ 1775.704, found 1775.7015.

*Methyl (α-D-Glucopyranosyl)-(1→3)-[(L-glycero-α-D-manno-heptopyranosyl)-(1→7)]-2-O-benzoyl-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphate Monotriethylammonium Salt (**41**).* A suspension of heptoside **40** (27.5 mg, 15.7 μmol) and 10% Pd/C (6.3 mg) in dry MeOH (2.75 mL) was hydrogenated at atmospheric pressure for 5.5 h at rt. The suspension was filtered through Celite and was washed repeatedly with MeOH. Triethylamine (2.6 μL, 18.8 μmol) was added to the filtrate, and the filtrate was concentrated to afford **41** (13.6 mg, quantitative) as a colorless oil: R_f 0.32 (DCM/MeOH/H_2O 5:4:1); $[\alpha]_D^{20}$ +72.3 (*c* 1.4, MeOD); ^1H NMR (600 MHz, MeOD) δ 8.12−8.09 (m, 2H, BzH2/H6), 7.63−7.60 (m, 1H, BzH4), 7.50−7.47 (m, 2H, BzH3/H5), 5.39 (dd, J = 3.3, 1.7 Hz, 1H, H-2), 5.12 (d, J = 4.0 Hz, 1H, H-1″), 4.85 (d, J = 1.6 Hz, 1H, H-1′), 4.79 (d, J = 1.6 Hz, 1H, H-1), 4.79 (app q, J = 10.2 Hz, 1H, H-4), 4.38−4.33 (m, 1H, H-6), 4.16 (dd, J = 9.8, 3.4 Hz, 1H, H-3), 3.95 (app td, J = 6.6, 1.4 Hz, 1H, H-6′), 3.85−3.80 (m, 3H, H-4′, H-2′, H-7a), 3.75 (dd, J = 10.0, 1.4 Hz, 1H, H-5), 3.71 (dd, J = 9.6, 3.4 Hz, 1H, H-3′), 3.68−3.63 (m, 3H, H-7a′, H-7b, H-6a″), 3.63−3.58 (m, 3H, H-7b′, H-5′, H-6b″), 3.56 (app t, J = 9.4 Hz, 1H, H-3″), 3.54−3.51 (m, 1H, H-5″), 3.43 (s, 3H, OCH_3), 3.37 (dd, J = 9.7, 3.9 Hz, 1H, H-2″), 3.33 (app t, J = 9.2 Hz, 1H, H-4″), 3.17 (q, J = 7.3 Hz, 6H, NCH_2CH$_3$), 1.30 (t, J = 7.3 Hz, 9H, NCH$_2$CH_3); ^{13}C NMR (151 MHz, MeOD) δ 167.5 (PhC═O), 134.5, 131.09, 131.06, 129.6, 103.5 (C-1″), 102.3 (C-1′), 99.95 (C-1), 79.3 (d, $J_{P,C}$ = 2.9 Hz, C-3), 74.5 (C-3″), 74.3 (C-2), 74.15 (C-5″), 73.8 (C-2″), 73.4 (d, $J_{P,C}$ = 3.8 Hz, C-5), 72.9 (C-5′), 72.8 (C-3′), 72.1 (C-2′), 70.9 (C-6′), 70.7 (C-4″), 70.5 (d, $J_{P,C}$ = 5.3 Hz, C-4), 68.9 (C-7), 68.3 (C-6), 67.85 (C-4′), 64.6 (C-7′), 61.8 (C-6″), 55.8 (OCH_3), 47.75 (NCH_2CH$_3$), 9.3 (NCH_2CH_3); ^{31}P NMR (243 MHz, MeOD) δ 1.82. HRMS ($^-$ESI-TOF) m/z [M − H]$^-$ calcd for $C_{28}H_{42}O_{22}P$ 761.1911, found 761.1917.

*Methyl (α-D-Glucopyranosyl)-(1→3)-[(L-glycero-α-D-manno-heptopyranosyl)-(1→7)]-L-glycero-α-D-manno-heptopyranoside 4-O-Phosphate Monosodium Salt (**42**).* A solution of benzoate **41** (13.6 mg, 15.7 μmol) in dry MeOH (2.7 mL) was stirred with 1 M methanolic NaOMe (0.24 mL, 240 μmol) for 30 min at rt. D_2O (1.2 mL) was then added to dissolve the formed precipitate. Stirring was continued for 5.5 h, and the solution was made neutral (pH ≈ 7) by addition of cation-exchange resin (H^+ form). The resin was filtered off and washed with MeOH, and the filtrate was concentrated. The residue was dissolved in D_2O and filtered over a bed of cation-exchange resin (H^+-form). The filtrate was thoroughly extracted with Et_2O. The combined organic layers were extracted with D_2O, and the aqueous layer was reextracted with Et_2O. The combined aqueous layers were neutralized by addition of 0.1 M NaOH (pH ≈ 7) and lyophilized to give compound **42** (9.5 mg, 89%) as a white powder: R_f 0.14 (DCM/MeOH/H_2O 5:4:1); $[\alpha]_D^{20}$ +98.6 (*c* 1.0, D_2O); ^1H NMR (600 MHz, D_2O, pH ≈ 7) δ 5.19 (d, J = 3.9 Hz, 1H, H-1″), 4.88 (d, J = 1.6 Hz, 1H, H-1′), 4.68 (d, J = 1.5 Hz, 1H, H-1), 4.32 (app q, J = 10.1 Hz, 1H, H-4), 4.26 (ddd, J = 8.4, 3.9, 1.9 Hz, 1H, H-6), 4.03 (dd, J = 3.3, 1.7 Hz, 1H, H-2), 4.02−3.99 (m, 1H, H-6′), 3.97−3.96 (m, 1H, H-2′), 3.86 (dd, J = 9.9, 3.3 Hz, 1H, H-3), 3.83−3.77 (m, 5H, H-4′, H-6a″, H-3′, H-5″, H-3″), 3.76−3.69 (m, 3H, H-7a, H-6b″, H-7a′), 3.66 (dd, J = 11.3, 5.1 Hz, 1H, H-7b′), 3.65 (dd, J = 11.0, 8.5 Hz, 1H, H-7b), 3.63 (dd, J = 9.9, 1.9 Hz, 1H, H-5), 3.60−3.56 (m, 1H, H-5′), 3.39 (dd, J = 9.9, 3.9 Hz, 1H, H-2″), 3.36 (app t, J = 9.5 Hz, 1H, H-4″), 3.35 (s, 3H, OCH_3); ^{13}C NMR (151 MHz, D_2O) δ 102.3 (C-1″), 102.0 (C-1), 101.5 (C-1′), 80.1 (d, $J_{P,C}$ = 2.3 Hz, C-3), 74.3 (C-3″), 73.4 (d, $J_{P,C}$ = 3.3 Hz, C-5), 73.3 (C-5″), 72.95 (C-2″), 72.4 (C-5′), 71.8 (C-3′), 71.5 (C-2), 70.9 (C-2′), 70.5 (C-4″), 69.9 (C-6′), 68.9 (C-7), 68.5 (d, $J_{P,C}$ = 4.7 Hz, C-4), 67.9 (C-6), 67.1 (C-4′), 64.1 (C-7′), 61.6 (C-6″), 55.8 (OCH_3); ^{31}P NMR (243 MHz, D_2O) δ 4.53;

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HRMS ($^-$ESI-TOF) m/z $[M - H]^-$ calcd for $C_{21}H_{38}O_{21}P$ 657.1649, found 657.1643.

■ ASSOCIATED CONTENT

Supporting Information

^1H NMR and ^{13}C NMR spectra for known and new compounds (**2**, **4**−**11**, **14**−**18**, and **20**−**42**) and β-isomeric byproducts. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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