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Synthesis of a Trisaccharide Repeating Unit of the O-Antigen from *Burkholderia multivorans* and Its Oligomers

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Keywords: Synthesis design / Total synthesis / Diastereoselectivity / Carbohydrates / Glycosylation / Medicinal chemistry

Burkholderia multivorans is a Gram-negative bacterium, and an important opportunistic human pathogen that can cause fatal infections. Its O-antigens are useful templates for the development of carbohydrate-based vaccines. A highly convergent and efficient strategy was developed for the synthesis of tri-, hexa-, and nonasaccharide fragments of the O-antigen of *B. multivorans* species Y. In these syntheses, a trisaccharyl thioglycoside, which was assembled from thiomannoside acceptor and rhamnosyl and mannosyl trichloroacetimidate donors, was used as a key building block. Glycosylation of 3-azidopropanol with the trisaccharyl donor followed by global deprotection gave the target trisaccharide. The trisaccharyl donor was also used to elongate the carbohydrate chain to obtain the dimer and trimer in a [3+3] and [3+3+3] manner. All of the synthetic targets have a free amino group at their reducing end to facilitate further derivatization, such as conjugation with other functional biomolecules.

Introduction

The *Burkholderia cepacia* complex (Bcc) is a group of closely related Gram-negative bacteria with similar phenotypes but distinctly different genotypes.[1,2] The Bcc bacteria occur widely in nature, and may have a large number of applications,[3–6] as they have antimicrobial, nitrogen-fixing, and other useful biological activities. Although the Bcc bacteria have potentially beneficial effects, they are also opportunistic human pathogens that can cause fatal infections in vulnerable populations, such as those with chronic granulomatous disease (CGD) or with cystic fibrosis (CF).[3,7–10] Occasionally, Bcc infection can result in rapid and clinically uncontrollable "cepacia syndrome" in CF patients, resulting in necrotizing pneumonia and septicaemia, which give rise to high rates of mortality.[7] Of all the Bcc bacteria found in CF patients, *Burkholderia multivorans* is one of the two most frequently found and most pathogenic species. It accounts for about 40% of Bcc infections in the United States,[11] and the number of *B. multivorans* infections is growing steadily. On the other hand, the pathogenic mechanism of Bcc infection remains unclear, and there is also a lack of effective therapies against it.[12] Consequently, detailed studies of Bcc, and new strategies for the effective prevention and treatment of Bcc infection are urgently needed.

For the development of new protective and therapeutic strategies against Gram-negative bacteria, their cell-surface O-polysaccharides (OPSs), also known as O-antigens, are useful targets. The OPS is a prominent part of the lipopolysaccharide (LPS), the major component of the bacterial cell glycocalyx, and plays an important role in bacterial immunology, such as protecting bacteria against the host's immune system and so on.[13,14] O-Antigens are exposed on the bacterial cell surface, and thus are considered to be attractive antigens for the development of bacterial vaccines.[15–17]

A number of Bcc O-antigens have been characterized to date.[18] For example, Silipo and coworkers have recently isolated and characterized two O-antigens from *B. multivorans* strain C1576, with the following repeating-unit structures: →2)-α-D-Man-(1→2)-α-D-Rha-(1→3)-α-D-Man-(1→ (species Y), and →2)-α-D-Man-(1→2)-α-D-Aco-(1→3)-α-D-Rha-(1→ (species X; D-Aco = D-acofriose; Figure 1, a).[19] Recently, synthetic oligosaccharide fragments of bacterial polysaccharides have received considerable attention as structurally defined antigens for the development of carbohydrate-based antibacterial vaccines.[20–23] It has also been found that the lengths[20–22] and sequences[23] of oligosaccharides play a critical role in their immunogenicity. To facilitate a systematic and in-depth immunological study of *B. multivorans* and the application of its O-antigen for vaccine development, we describe in this paper the chemical synthesis of a trisaccharide repeating unit **1** of the species Y O-antigen, and of its dimer **2** and trimer **3** (Figure 1, b). The oligosaccharide repeating unit structure of a polysaccharide can be represented in different ways, and each possible structure may have its own activity. This effect may be less significant for oligomers of the repeating unit. This is why

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2 and **3** were designed and synthesized in addition to repeating unit **1**, which was selected merely because it is the form described in the literature. The synthetic targets (i.e., **1**–**3**) were designed to have a free amino group linked to their reducing end, which would enable their regioselective modification, such as coupling with carrier molecules for the development of conjugate vaccines and for other immunological studies.

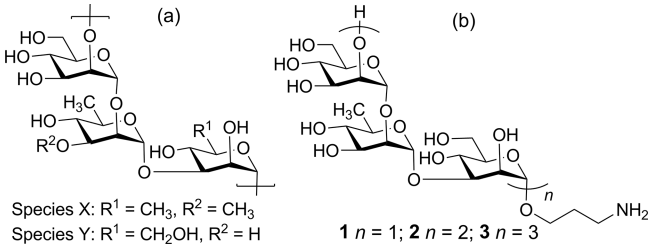


Figure 1. The structures of (a) *B. Multivorans* O-antigens, and (b) synthetic targets **1**–**3**.

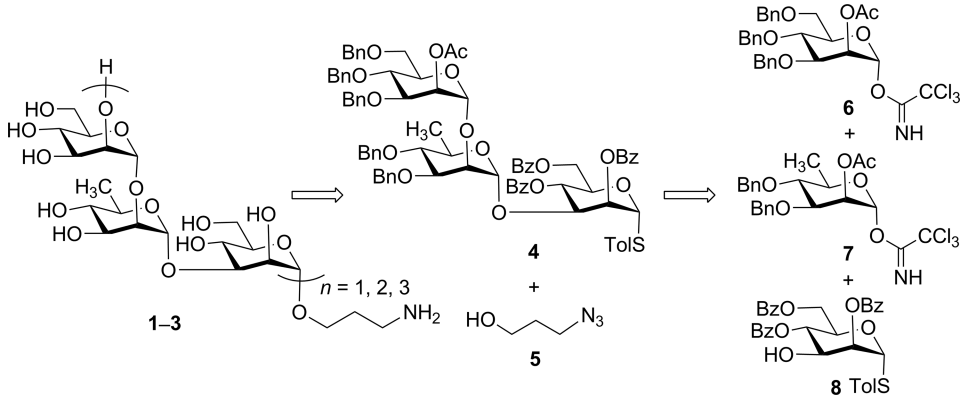
Results and Discussion

As shown in Scheme 1, retrosynthetic disconnection of target molecules **1**–**3** resulted in trisaccharyl thioglycoside **4**. Compound **4** could act as a common glycosyl donor for the glycosylation of **5**,[24] to introduce a latent amino group at the reducing end of the carbohydrate chain, and for oligomerization. In turn, trisaccharide **4** could be assembled from monosaccharide building blocks **6**,[25] **7**, and **8**. To facilitate stereoselective 1,2-*trans* glycosylation based on neighboring-group participation, we planned to use benzoyl and acetyl groups to protect the 2-O-positions in **6**–**8**. The acetyl groups at the 2-O-positions of the D-rhamnosyl and D-mannosyl units could be selectively removed under acidic conditions to allow further glycosylation at these positions.

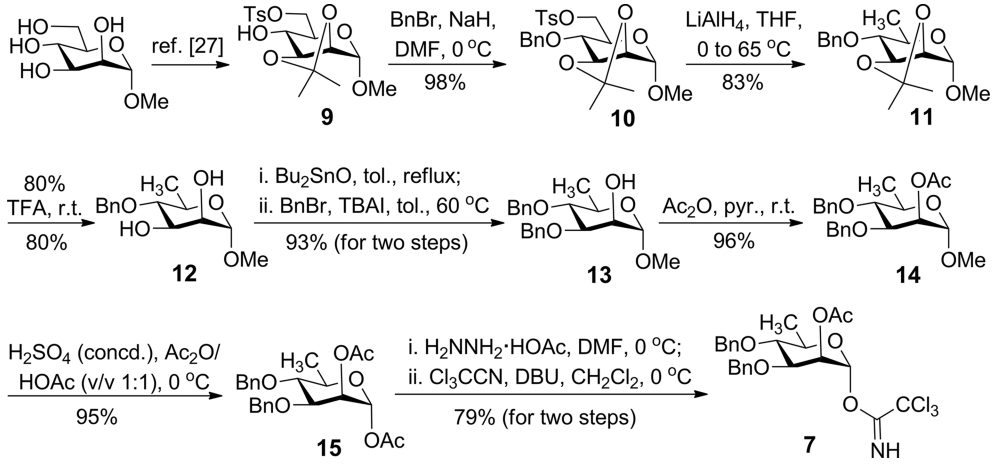
The synthesis began with the preparation of mannosyl donor **6** according to a reported procedure.[25] Next, the synthesis of rhamnosyl donor **7** started from **9**[26,27] (Scheme 2). Benzylation of **9** with benzyl bromide and sodium hydride in DMF gave fully protected tosylate **10** in an excellent 98% yield. The tosyl group in **10** was then smoothly reduced with lithium aluminium hydride ($LiAlH_4$) in THF[28] to give 6-deoxy sugar **11** in 83% yield. The chemical shift of the 6-H signal (d, J = 6.2 Hz) at δ = 1.28 ppm in the ^{1}H NMR spectrum of **11** indicated the formation of a new methyl group. Removal of the isopropylidene group in **11** by treatment with TFA (80% aq.) was followed by regioselective benzylation of the resulting 2,3-diol (i.e., **12**) using Bu_2SnO[29] and benzyl bromide (→**13**), and then acetylation to protect the remaining hydroxyl group to give fully protected rhamnose derivative **14**. The downfield-shifted 2-H signal in the ^{1}H NMR spectrum of acetylated **14** compared to that of **13** confirmed that the benzylation of **12** had proceeded with the correct regioselectivity. Acetolysis of methyl glycoside **14** with 1% concentrated H_2SO_4 in AcOH and Ac_2O (1:1 v/v)[30] at 0 °C gave **15** as a predominantly α product in an excellent yield (95%). Finally, **15** was converted into **7** in two steps, including selective removal of the anomeric acetyl group with hydrazine acetate,[31] and then trichloroacetimidation[32] of the resulting hemiacetal with trichloroacetonitrile and 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in CH_2Cl_2 at 0 °C.

Mannosyl thioglycoside **8** was prepared by the procedure outlined in Scheme 3. First, *p*-tolyl 1-thio-α-D-mannopyranoside **16**[33] was converted into **17** by a tin-complex-directed[29] regioselective 3-*O*-allylation in 55% yield. Compound **17** was then benzoylated to give fully protected mannose derivative **18**. The downfield-shifted chemical shifts of the 2-H and 4-H signals at δ = 5.83 ppm, and of 6a-H and 6b-H signals at δ = 4.63 and 4.47 ppm, in the ^{1}H NMR spectrum of **18** confirmed that the 3-*O*-allylation had proceeded with the correct regioselectivity. Deallylation of **18** with palladium chloride (0.5 equiv.) in methanol[34] smoothly gave **8** in a good yield (63%).

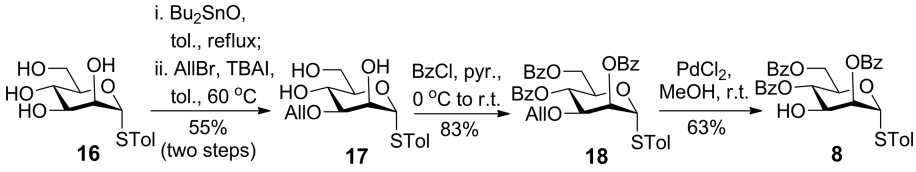
With monosaccharyl building blocks **6**–**8** in hand, key trisaccharyl thioglycoside **4** was assembled by stepwise glycosylation (Scheme 4). The reaction of **8** with **7** promoted by trimethylsilyl triflate (TMSOTf) at –78 °C gave **19**



Scheme 1. Retrosynthetic analysis of target molecules **1**–**3**.



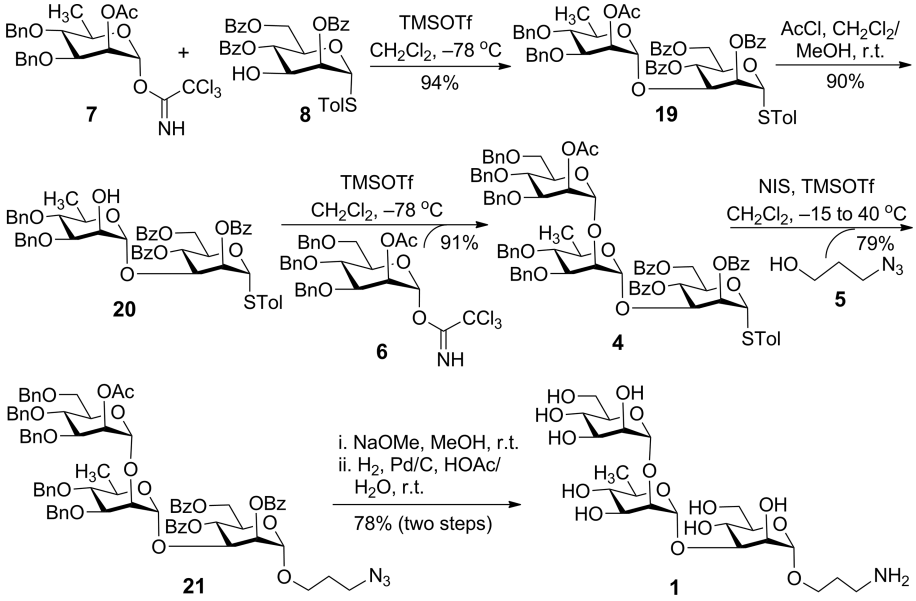
Scheme 2. Synthesis of rhamnosyl building block **7**; TFA = trifluoroacetic acid; TBAI = tetrabutylammonium iodide.



Scheme 3. Synthesis of mannosyl building block **8**; All = allyl.

in high yield (94%) and high stereoselectivity as a result of neighboring-group participation. The ^{1}H-coupled gHSQC spectrum of **19** showed that the $^1J_{C\text{-}1,H\text{-}1}$ coupling constant was 171.6 Hz, indicating an α configuration for the newly formed glycosidic bond.[35] Selective removal of the 2-*O*-acetyl group in **19** was achieved with 5% acetyl chloride (AcCl)[36] in CH_2Cl_2 and MeOH (1:1 v/v) to give **20** in 90% yield. The upfield shift of the 2-H signal at δ = 3.72 ppm in the ^{1}H NMR spectrum of **20**, as compared to that of **19** (δ = 5.02 ppm), proved the regiochemistry of the deacylation reaction. Next, **20** was coupled with **6**[25] in a reaction promoted by TMSOTf to give trisaccharide **4** in 91% yield. This key intermediate was used as a common glycosyl donor for the construction of all three synthetic targets **1**–**3**.

A glycosylation reaction between **4** and 3-azido-1-propanol **5**,[24] using *N*-iodosuccinimide (NIS) and a catalytic amount of TMSOTf as promoters, gave trisaccharyl glycos-

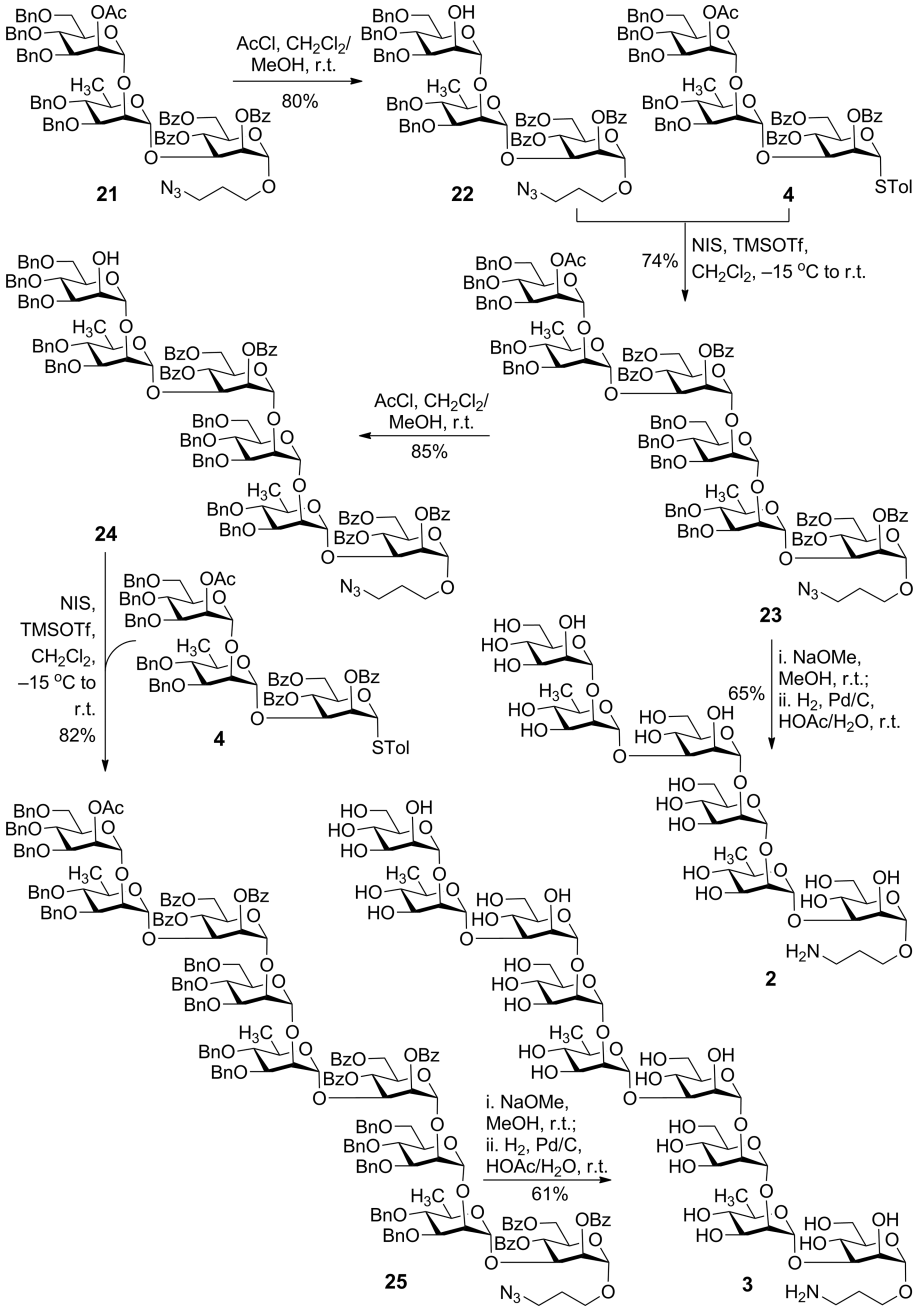


Scheme 4. Synthesis of trisaccharide **1**.

ide **21** in 79% yield. Finally, deacylation of **21** with sodium methoxide, followed by hydrogenolytic debenzylation in acetic acid (10% aq.) with Pd/C (10%) as the catalyst gave the desired trisaccharide (i.e., **1**), which was purified by size-exclusion chromatography on a Bio-Gel P-2 column.

Alternatively, selective deacetylation of **21** with AcCl in CH_2Cl_2 and MeOH (1:1 v/v) gave trisaccharide **22**, which could be used as a glycosyl acceptor for the synthesis of **2** and **3** (Scheme 5). Glycosylation of **22** with **4** using NIS and TMSOTf in CH_2Cl_2 gave hexasaccharide **23** in good yield (74%). Again, the $^1J_{C\text{-}1,H\text{-}1}$ coupling constants in the ^{1}H-coupled gHSQC spectrum of **23** were over 171 Hz, which confirmed the α configuration of all of the glycosidic linkages in **23**. Target compound **2** was obtained by global deprotection in two steps, as described for the deprotection of **1**, in 65% overall yield.

Similarly, treatment of **23** with 5% AcCl in CH_2Cl_2 and MeOH (1:1 v/v) removed the acetyl group selectively to give **24** in 85% yield. The coupling reaction between **24** and **4** was also carried out with NIS and TMSOTf as promoters to give fully protected nonasaccharide **25** in a very good yield (82%). Compound **25** was finally subjected to global deprotection as described above to give compound **3**. All the synthetic targets, as well as the synthetic intermediates involved, were fully characterized by 1D and 2D ^{1}H and ^{13}C NMR spectrometry, and mass spectrometry.



Scheme 5. Synthesis of hexasaccharide **2** and nonasaccharide **3**.

Conclusions

In summary, we have described the first synthesis of a trisaccharide repeating unit of the O-antigen of *B. multivorans* (species Y), as well as a highly convergent and efficient strategy for the assembly of oligomers of this repeating unit. In these syntheses, trisaccharyl thioglycoside **4** was the key and common building block, which was used as a glycosyl donor not only for the glycosylation of aglycon **5** to prepare **1**, but also for elongation of the carbohydrate chain to achieve the convergent [3 + 3] and [3 + 6] construction of the target hexa- and nonasaccharides. Trisaccharide **4** was prepared by the stepwise assembly of monosaccharide building blocks **6**–**8**. All of the glycosylation reactions, including those of complex oligosaccharides, were highly efficient and stereoselective, probably due to the presence of acyl groups at the 2-O-position of the designed building blocks, which guaranteed 1,2-*trans*-glycosylation as a result of neighboring-group participation. Moreover, synthetic targets **1**–**3** have a 3-aminopropyl linker at their reducing end, which allows further modifications through the unique and reactive free amino group, such as coupling with biomolecules to generate glycoconjugates that could be used in biological studies. We are currently working on coupling **1**–**3** with immunologically active carrier molecules for the exploration of the immunology of *B. multivorans*, and the development of vaccines based on the O-antigen of *B. multivorans*. The results of these studies will be reported in due course.

Experimental Section

General Methods: Optical rotations were determined at 25 °C with a Rudolph Autopol I automatic polarimeter. ^{1}H and ^{13}C NMR spectra were recorded with an Agilent 600 MHz spectrometer for solutions in $CDCl_3$ or D_2O. Chemical shifts are given in ppm downfield from Me_4Si. Me_4Si was used as an internal reference for solutions in $CDCl_3$, and the DHO signal was used as the reference for solutions in D_2O. Positive-mode electrospray ionization (ESI) high-resolution mass spectra (HRMS) were recorded with a JEOL JMS-DX-303HF spectrometer. Thin-layer chromatography (TLC) was carried out on silica gel HF_{254} plates with detection by charring using H_2SO_4 (30% v/v in MeOH) or using a UV detector. Silica gel column chromatography was carried out with mixtures of ethyl acetate and petroleum ether (b.p. 60–90 °C) or toluene as the eluents. Solutions were concentrated at <60 °C under diminished pressure.

Methyl 4-*O*-Benzyl-2,3-*O*-isopropylidene-6-*O*-tosyl-α-D-mannopyranoside (10): NaH (60% in oil; 865 mg, 21.6 mmol) and BnBr (1.5 mL, 13 mmol) were added to a cooled solution of **9**[27] (4.21 g, 10.8 mmol) in dry DMF (20 mL) at 0 °C. The mixture was stirred at 0 °C for 30 min, then it was diluted with EtOAc (200 mL), and washed successively with cooled water, HCl (1 M aq.), and brine. The organic phase was dried with Na_2SO_4, and concentrated. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 2:1) to give **10** (5.07 g, 98%) as a white foamy solid. $[\alpha]_D^{25}$ = +38 (*c* = 2.7, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.77 (d, *J* = 8.4 Hz, 2 H, ArH), 7.34–7.23 (m, 7 H, ArH), 4.84 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 4.83 (s, 1 H, 1-H), 4.48 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 4.29 (dd, *J* = 10.5, 1.8 Hz, 1 H, 6-Ha), 4.25 (t, *J* = 6.0 Hz, 1 H, 3-H), 4.13 (dd, *J* = 10.5, 6.0 Hz, 1 H, 6b-H), 4.09 (d, *J* = 6.0 Hz, 1 H, 2-H), 3.74 (ddd, *J* = 10.2, 6.0, 1.8 Hz, 1 H, 5-H), 3.38 (dd, *J* = 10.2, 6.0 Hz, 1 H, 4-H), 3.31 (s, 3 H, -OC*H*$_3$), 2.42 (s, 3 H, ArC*H*$_3$), 1.48, 1.34 [2 s, 2× 3 H, C(C*H*$_3$)$_2$] ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 144.71, 137.73, 132.90, 129.74, 128.31, 127.97, 127.94, 127.76, 109.53, 98.02, 78.49, 75.59, 75.03, 72.55, 69.32, 66.55, 55.00, 27.90, 26.18, 21.64 ppm. HRMS (ESI): calcd. for $[C_{24}H_{30}O_8S + NH_4]^+$ 496.2000; found 496.1996.

Methyl 4-*O*-Benzyl-2,3-*O*-isopropylidene-α-D-rhamnopyranoside (11): A mixture of $LiAlH_4$ (1.0 g, 26.3 mmol) in THF (10 mL) was added in portions to a solution of **10** (5.0 g, 10.5 mmol) in THF (20 mL) at 0 °C. The mixture was warmed to 65 °C and stirred for 3 h, after which time TLC (petroleum ether/ethyl acetate, 4:1) indicated the disappearance of **10**. The mixture was diluted with EtOAc (150 mL), and washed with H_2SO_4 (1 M aq.; 2× 100 mL). The organic phase was dried with Na_2SO_4, and concentrated, and the residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 4:1) to give **11** (2.67 g, 83%) as a white foamy solid. $[\alpha]_D^{25}$ = +56 (*c* = 1.8, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.38–7.22 (m, 5 H, ArH), 4.88 (d, *J* = 11.6 Hz, 1 H, C*H*$_2$Ph), 4.84 (s, 1 H, 1-H), 4.62 (d, *J* = 11.6 Hz, 1 H, C*H*$_2$Ph), 4.24 (t, *J* = 6.4 Hz, 1 H, 3-H), 4.12 (d, *J* = 5.7 Hz, 1 H, 2-H), 3.65 (m, 1 H, 5-H), 3.35 (s, 3 H, -OC*H*$_3$), 3.20 (dd, *J* = 9.6, 7.2 Hz, 1 H, 4-H), 1.50, 1.36 [2 s, 2× 3 H, C(C*H*$_3$)$_2$], 1.28 (d, *J* = 6.2 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 138.33, 128.25, 127.97, 127.60, 109.16, 97.99, 81.03, 78.64, 75.98, 72.90, 64.38, 54.76, 27.98, 26.31, 17.83 ppm. HRMS (ESI): calcd. for $[C_{17}H_{24}O_5 + NH_4]^+$ 326.1962; found 326.1963.

Methyl 4-*O*-Benzyl-α-D-rhamnopyranoside (12): A solution of **11** (1.4 g, 4.54 mmol) in TFA (80% aq.; 5 mL) was stirred at room temp. for 1 h, and then the mixture was coevaporated with toluene (50 mL) twice under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 2:1) to give **12** (975 mg, 80%) as a white foamy solid. $[\alpha]_D^{25}$ = +74 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.39–7.28 (m, 5 H, ArH), 4.75 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 4.71 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 4.65 (s, 1 H, 1-H), 3.91 (br. s, 1 H, 2-H), 3.87 (m, 1 H, 3-H), 3.70 (m, 1 H, 5-H), 3.34 (s, 3 H, -OC*H*$_3$), 3.32 (t, *J* = 9.6 Hz, 1 H, 4-H), 2.26–2.21 (m, 2 H, -O*H*), 1.35 (d, *J* = 6.0 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 138.20, 128.64, 128.02, 127.93, 100.25, 81.63, 74.99, 71.41, 71.04, 66.95, 54.86, 18.00 ppm. HRMS (ESI): calcd. for $[C_{14}H_{20}O_5 + NH_4]^+$ 286.1649; found 286.1649.

Methyl 3,4-Di-*O*-Benzyl-α-D-rhamnopyranoside (13): A mixture of **12** (940 mg, 3.51 mmol) and Bu_2SnO (873 mg, 3.51 mmol) in dry toluene (15 mL) was heated at reflux for 4 h with azeotropic removal of water using Dean–Stark tube. The mixture was then cooled to 60 °C, and TBAI (1.29 g, 3.50 mmol) and BnBr (0.5 mL, 4.21 mmol) were added. The mixture was stirred at 60 °C overnight, and then it was concentrated under reduced pressure. The residue was purified by column chromatography (petroleum ether/ethyl acetate, 3:2) to give **13** (1.17 g, 93%) as a syrup. $[\alpha]_D^{25}$ = +57 (*c* = 0.5, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.40–7.25 (m, 10 H, ArH), 4.87 (d, *J* = 10.8 Hz, 1 H, C*H*$_2$Ph), 4.69 (s, 1 H, 1-H), 4.67 (s, 2 H, C*H*$_2$Ph), 4.63 (d, *J* = 10.8 Hz, 1 H, C*H*$_2$Ph), 4.01 (br. s, 1 H, 2-H), 3.81 (dd, *J* = 9.0, 3.0 Hz, 1 H, 3-H), 3.69 (m, 1 H, 5-H), 3.43 (t, *J* = 9.0 Hz, 4-H), 3.33 (s, 3 H, -OC*H*$_3$), 1.31 (d, *J* = 6.0 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 138.37, 137.88, 128.54, 128.52, 128.36, 127.92, 127.90, 127.81, 127.68, 126.96, 99.97, 80.02, 79.88, 75.32, 71.98, 68.44, 67.09, 54.73, 17.87 ppm. HRMS (ESI): calcd. for $[C_{21}H_{26}O_5 + NH_4]^+$ 376.2118; found 376.2123.

Methyl 2-*O*-Acetyl-3,4-di-*O*-benzyl-α-D-rhamnopyranoside (14): A solution of **13** (1.05 g, 2.93 mmol) in Ac_2O (5 mL) and pyridine (8 mL) was stirred at room temp. for 2 h, and then the mixture was concentrated under reduced pressure. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 2:1) to give **14** (1.13 g, 96%) as a syrup. $[\alpha]_D^{25}$ = +19 (*c* = 0.6, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.37–7.26 (m, 10 H, ArH), 5.36 (dd, *J* = 3.0, 1.2 Hz, 1 H, 2-H), 4.92 (d, *J* = 10.2 Hz, 1 H, C*H*$_2$Ph), 4.69 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 4.62 (br. s, 1 H, 1-H), 4.61 (d, *J* = 10.2 Hz, 1 H, C*H*$_2$Ph), 4.52 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 3.92 (dd, *J* = 9.6, 3.0 Hz, 1 H, 3-H), 3.73 (m, 1 H, 5-H), 3.43 (t, *J* = 9.6 Hz, 1 H, 4-H), 2.15 (s, 3 H, -COC*H*$_3$), 1.32 (d, *J* = 6.4 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 170.43, 138.45, 137.98, 128.36, 128.34, 128.03, 127.89, 127.68, 127.65, 98.64, 79.98, 77.96, 75.37, 71.68, 68.84, 67.49, 54.81, 21.13, 17.96 ppm. HRMS (ESI): calcd. for $[C_{23}H_{28}O_6 + NH_4]^+$ 418.2224; found 418.2220.

1,2-Di-*O*-acetyl-3,4-di-*O*-benzyl-D-rhamnopyranose (15): Concentrated H_2SO_4 (0.1 mL) was added to a solution of **14** (980 mg, 2.45 mmol) in Ac_2O and AcOH (1:1 v/v; 10 mL) at 0 °C, and the mixture was stirred until TLC (petroleum ether/ethyl acetate, 4:1) indicated that the reaction was complete. The solution was diluted with CH_2Cl_2 (100 mL), and the organic phase was washed successively with saturated aq. $NaHCO_3$, water, and brine. The organic phase was dried with Na_2SO_4, and concentrated. The residue was subjected to silica gel column chromatography (petroleum ether/ethyl acetate, 4:1) to give **15** (998 mg, 95%) as a white foamy solid. $[\alpha]_D^{25}$ = +24 (*c* = 0.8, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 7.36–7.26 (m, 10 H, ArH), 5.99 (s, 1 H, 1-H), 5.34 (br. s, 1 H, 2-H), 4.91 (d, *J* = 10.2 Hz, 1 H, C*H*$_2$Ph), 4.71 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 4.61 (d, *J* = 10.2 Hz, 1 H, C*H*$_2$Ph), 4.54 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 3.91 (dd, *J* = 9.6, 3.2 Hz, 1 H, 3-H), 3.79 (m, 1 H, 5-H), 3.46 (t, *J* = 9.6 Hz, 1 H, 4-H), 2.16 (s, 3 H, -COC*H*$_3$), 2.06 (s, 3 H, -COC*H*$_3$), 1.32 (d, *J* = 6.0 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 170.04, 168.53, 138.13, 137.66, 128.41, 128.06, 127.98, 127.83, 127.81, 91.07, 79.44, 77.54, 75.60, 71.87, 69.97, 67.73, 20.95, 20.89, 17.97 ppm. HRMS (ESI): calcd. for $[C_{24}H_{28}O_7 + NH_4]^+$ 446.2173; found 446.2174.

2-*O*-Acetyl-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl Trichloroacetimidate (7): Hydrazine acetate (710 mg, 7.70 mmol) was added to a solution of **15** (828 mg, 1.94 mmol) in DMF (5 mL) at 0 °C. The mixture was stirred at 0 °C for 3 h, after which time TLC (petroleum ether/ethyl acetate, 2:1) showed that the reaction was complete. The mixture was diluted with EtOAc (150 mL), and then washed with water and brine. The organic phase was dried with anhydrous Na_2SO_4, and concentrated, and the residue was purified by silica gel column chromatography (petroleum ether/ethyl acetate, 2:1).

The product was then dissolved in anhydrous CH_2Cl_2 (5 mL), The solution was cooled to 0 °C, and trichloroacetonitrile (1.0 mL, 10.0 mmol) and DBU (100 μL) were added. The mixture was stirred for 30 min, and then it was concentrated. The residue was purified by column chromatography (petroleum ether/ethyl acetate, 4:1) to give **7** (813 mg, 79% over two steps) as a white foamy solid. $[\alpha]_D^{25}$ = +31 (*c* = 0.3, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.63 (s, 1 H, N*H*), 7.40–7.26 (m, 10 H, ArH), 6.16 (s, 1 H, 1-H), 5.47 (br. s, 1 H, 2-H), 4.92 (d, *J* = 10.8 Hz, 1 H, C*H*$_2$Ph), 4.72 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 4.62 (d, *J* = 10.8 Hz, 1 H, C*H*$_2$Ph), 4.52 (d, *J* = 11.4 Hz, 1 H, C*H*$_2$Ph), 3.98 (dd, *J* = 9.6, 2.4 Hz, 1 H, 3-H), 3.93 (m, 1 H, 5-H), 3.51 (t, *J* = 9.6 Hz, 1 H, 4-H), 2.18 (s, 3 H, -COC*H*$_3$), 1.34 (d, *J* = 6.0 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 170.04, 160.08, 138.10, 137.50, 128.45, 128.43, 128.31, 128.14, 127.99, 127.92, 95.14, 90.82, 79.32, 77.15, 75.66, 72.01, 70.71, 67.56, 21.01, 17.98 ppm. $C_{24}H_{26}Cl_3NO_6$ (530.83): calcd. C 54.31, H 4.94, N 2.64; found C 54.24, H 5.11, N 2.55.

***p*-Tolyl 3-*O*-Allyl-1-thio-α-D-mannopyranoside (17):** Bu_2SnO (2.5 g, 10 mmol) was added to a solution of **16**[33] (2.86 g, 10 mmol) in dry toluene (80 mL). The mixture was heated at reflux for 6 h with azeotropic removal of water using Dean–Stark tube, and then it was cooled to 60 °C. TBAI (3.69 g, 10 mmol) and allyl bromide (1.3 mL, 15.0 mmol) were added. The mixture was stirred at 60 °C overnight, and then it was concentrated under reduced pressure. The residue was purified by flash column chromatography (ethyl acetate) to give **17** (1.80 g, 55%). $[\alpha]_D^{25}$ = +155 (*c* = 0.2, CH_3OH). ^{1}H NMR (600 MHz, CD_3OD): δ = 7.40 (d, *J* = 7.8 Hz, 2 H, ArH), 7.13 (d, *J* = 7.8 Hz, 2 H, ArH), 5.99 (m, 1 H, -OCH$_2$C*H*=CH$_2$), 5.48–5.33 (m, 2 H, 1-H and -OCH$_2$CH=C*H*$_2$), 5.20 (br. d, *J* = 10.8 Hz, 1 H, -OCH$_2$CH=C*H*$_2$), 4.18 (m, 2 H, 2-H and -OC*H*$_2$CH=CH$_2$), 4.14 (br. dd, *J* = 12.6, 6.0 Hz, 1 H, -OC*H*$_2$CH=CH$_2$), 4.05 (m, 1 H, 5-H), 3.82–3.77 (m, 2 H, 4-H and 6a-H), 3.75 (dd, *J* = 12.0, 6.0 Hz, 1 H, 6b-H), 3.52 (dd, *J* = 9.6, 3.0 Hz, 1 H, 3-H), 2.32 (s, 3 H, -SPhC*H*$_3$) ppm. ^{13}C NMR (150 MHz, CD_3OD): δ = 137.56, 135.00, 132.11, 130.57, 129.34, 116.25, 89.25, 78.86, 74.23, 70.38, 69.18, 66.19, 61.19, 19.66 ppm. HRMS (ESI): calcd. for $[C_{16}H_{22}O_5S + NH_4]^+$ 344.1526; found 344.1527.

***p*-Tolyl 2,4,6-Tri-*O*-benzoyl-3-*O*-allyl-1-thio-α-D-mannopyranoside (18):** BzCl (2.0 mL, 17.2 mmol) was added dropwise to a solution of **17** (1.5 g, 4.60 mmol) in pyridine (10 mL) at 0 °C. The mixture was stirred at room temp. for 2 h, then it was diluted with CH_2Cl_2 (150 mL), and washed with HCl (1 M aq.), and brine. The organic layer was dried with anhydrous Na_2SO_4, and concentrated. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 5:1) to give **18** (2.44 g, 83%) as a white foamy solid. $[\alpha]_D^{25}$ = +97 (*c* = 1.3, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.09 (d, *J* = 8.4 Hz, 2 H, ArH), 8.07 (d, *J* = 8.4 Hz, 2 H, ArH), 8.03 (d, *J* = 8.4 Hz, 2 H, ArH), 8.13–8.08 (m, 3 H, ArH), 7.46 (t, *J* = 8.4 Hz, 2 H, ArH), 7.41–7.36 (m, 6 H, ArH), 6.98 (d, *J* = 7.8 Hz, 2 H, ArH), 5.83 (m, 2 H, 2-H and 4-H), 5.77 (m, 1 H, -OCH$_2$C*H*=CH$_2$), 5.62 (d, *J* = 1.2 Hz, 1 H, 1-H), 5.21 (m, 1 H, -OCH$_2$CH=C*H*$_2$), 5.11 (m, 1 H, -OCH$_2$CH=C*H*$_2$), 4.85 (ddd, *J* = 9.6, 6.0, 2.4 Hz, 1 H, 5-H), 4.63 (dd, *J* = 12.0, 2.4 Hz, 1 H, 6a-H), 4.47 (dd, *J* = 12.0, 6.0 Hz, 1 H, 6b-H), 4.14 (m, 1 H, -OC*H*$_2$CH=CH$_2$), 4.12 (dd, *J* = 9.6, 3.6 Hz, 1 H, 3-H), 4.02 (m, 1 H, -OC*H*$_2$CH=CH$_2$), 2.23 (s, 3 H, -SPhC*H*$_3$) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 166.18, 165.62, 165.43, 138.30, 133.91, 133.37, 133.35, 132.96, 132.52, 129.96, 129.92, 129.87, 129.79, 129.46, 129.44, 129.01, 128.59, 128.47, 128.31, 118.15, 86.61, 74.76, 70.87, 70.63, 69.79, 68.63, 63.37, 21.12 ppm. HRMS (ESI): calcd. for $[C_{37}H_{34}O_8S + NH_4]^+$ 656.2313; found 656.2318.

***p*-Tolyl 2,4,6-Tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (8):** $PdCl_2$ (177 mg, 1.0 mmol) was added to a solution of **18** (1.28 g, 2.0 mmol) in MeOH (20 mL) at room temp. The mixture was stirred at room temp. for 3 h, after which time TLC (petroleum ether/ethyl acetate, 3:1) indicated the disappearance of **18**. The mixture was diluted with CH_2Cl_2 (50 mL), and filtered through a Celite®454 pad. The filtrate was concentrated under reduced pressure. The residue was purified by column chromatography (petroleum ether/ethyl acetate, 4:1) to give **8** (755 mg, 63%) as a white foamy solid. $[\alpha]_D^{25}$ = +145 (*c* = 1.0, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.10 (d, *J* = 8.4 Hz, 2 H, ArH), 8.04 (d, *J* = 8.4 Hz, 2 H, ArH), 8.01 (d, *J* = 8.4 Hz, 2 H, ArH), 7.64–7.53 (m, 3 H, ArH), 7.51–7.44 (m, 2 H, ArH), 7.43–7.35 (m, 6 H, ArH), 7.00 (d, *J* = 7.8 Hz, 2 H, ArH), 5.71 (t, *J* = 9.6 Hz, 1 H, 4-H), 5.69 (dd, *J* = 2.4, 1.2 Hz,

1 H, 2-H), 5.66 (s, 1 H, 1-H), 4.99 (ddd, *J* = 9.6, 5.4, 2.0 Hz, 1 H, 5-H), 4.65 (dd, *J* = 12.0, 2.0 Hz, 1 H, 6a-H), 4.52 (dd, *J* = 12.0, 5.4 Hz, 1 H, 6b-H), 4.39 (dd, *J* = 9.6, 3.0 Hz, 1 H, 3-H), 2.27 (s, 3 H, -SPhCH_3) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 166.92, 166.12, 165.76, 138.33, 133.75, 133.59, 133.07, 132.57, 129.97, 129.83, 129.75, 129.19, 128.95, 128.58, 128.36, 86.25, 74.27, 70.72, 69.80, 69.28, 63.21, 21.12 ppm. HRMS (ESI): calcd. for $[C_{34}H_{30}O_8S + H]^+$ 599.1734; found 599.1736; calcd. for $[C_{34}H_{30}O_8S + NH_4]^+$ 616.2000; found 616.2001.

***p*-Tolyl 2-*O*-Acetyl-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (19):** TMSOTf (9 μL, 0.05 mmol) was added to a solution of **8** (300 mg, 0.50 mmol) and **7** (293 mg, 0.55 mmol) in anhydrous CH_2Cl_2 (8 mL) at –78 °C under a nitrogen atmosphere. The mixture was stirred at –78 °C for 2 h, then it was neutralized with Et_3N, and then concentrated. The residue was purified by column chromatography (petroleum ether/ethyl acetate, 5:1) to give **19** (455 mg, 94%) as a white foamy solid. $[\alpha]_D^{25}$ = +27 (*c* = 0.5, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.11 (d, *J* = 8.4 Hz, 2 H, ArH), 8.07 (d, *J* = 8.4 Hz, 2 H, ArH), 8.02 (d, *J* = 8.4 Hz, 2 H, ArH), 7.61–7.54 (m, 3 H, ArH), 7.47 (t, *J* = 7.8 Hz, 2 H, ArH), 7.40–7.37 (m, 6 H, ArH), 7.27–7.23 (m, 3 H, ArH), 7.20–7.16 (m, 3 H, ArH), 7.13–7.11 (m, 2 H, ArH), 7.09–7.06 (m, 2 H, ArH), 6.99 (d, *J* = 8.0 Hz, 2 H, ArH), 5.91 (t, *J* = 9.9 Hz, 1 H, 4-H), 5.74 (dd, *J* = 3.2, 1.8 Hz, 1 H, 2-H), 5.65 (d, *J* = 1.2 Hz, 1 H, 1-H), 5.02 (dd, *J* = 3.2, 1.8 Hz, 1 H, 2′-H), 4.95 (d, *J* = 1.6 Hz, 1 H, 1′-H), 4.85 (ddd, *J* = 9.9, 5.6, 2.4 Hz, 1 H, 5-H), 4.72 (d, *J* = 11.2 Hz, 1 H, CH_2Ph), 4.62 (dd, *J* = 12.2, 2.4 Hz, 1 H, 6a-H), 4.49 (dd, *J* = 12.2, 5.6 Hz, 1 H, 6b-H), 4.44 (d, *J* = 11.2 Hz, 1 H, CH_2Ph), 4.41 (dd, *J* = 9.9, 3.2 Hz, 1 H, 3-H), 4.19 (d, *J* = 11.0 Hz, 1 H, CH_2Ph), 4.10 (d, *J* = 11.0 Hz, 1 H, CH_2Ph), 3.73 (m, 1 H, 5′-H), 3.69 (dd, *J* = 9.4, 3.2 Hz, 1 H, 3′-H), 3.27 (t, *J* = 9.4 Hz, 1 H, 4′-H), 2.27 (s, 3 H, -SPhCH_3), 1.92 (s, 3 H, -COCH_3), 1.12 (d, *J* = 6.2 Hz, 3 H, 6′-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 169.75, 166.14, 165.54, 165.44, 138.46, 138.34, 137.75, 133.61, 133.46, 132.98, 132.59, 129.96, 129.93, 129.84, 129.76, 129.25, 129.02, 128.86, 128.62, 128.60, 128.33, 128.17, 128.13, 127.95, 127.51, 127.38, 99.48 (C-1′), 86.13 (C-1), 79.36 (C-4′), 77.33 (C-3′), 76.19 (C-3), 74.54 (*C*H_2Ph), 73.08 (C-2), 71.43 (*C*H_2Ph), 69.65 (C-5), 68.93 (C-5′), 68.68 (C-2′), 68.63 (C-4), 63.16 (C-6), 21.11 (-SPh*C*H_3), 20.77 (-CO*C*H_3), 17.69 (C-6′) ppm. HRMS (ESI): calcd. for $[C_{56}H_{54}O_{13}S + NH_4]^+$ 984.3623; found 984.3639.

***p*-Tolyl 3,4-Di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (20):** Acetyl chloride (1.0 mL) was slowly added to a solution of **19** (427 mg, 0.442 mmol) in MeOH and CH_2Cl_2 (1:1 v/v; 20 mL) at 0 °C. The mixture was stirred at room temp. overnight, and then it was neutralized with saturated aq. $NaHCO_3$, and extracted with CH_2Cl_2 (2× 100 mL). The combined organic phases were dried with anhydrous Na_2SO_4, and concentrated. The residue was purified by column chromatography (toluene/ethyl acetate, 10:1) to give **20** (368 mg, 90%) as a white foamy solid. $[\alpha]_D^{25}$ = +14 (*c* = 0.2, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.10 (d, *J* = 8.4 Hz, 2 H, ArH), 8.08 (d, *J* = 8.4 Hz, 2 H, ArH), 8.02 (d, *J* = 8.4 Hz, 2 H, ArH), 7.62–7.54 (m, 3 H, ArH), 7.48 (t, *J* = 7.8 Hz, 2 H, ArH), 7.43–7.37 (m, 6 H, ArH), 7.28–7.24 (m, 3 H, ArH), 7.22–7.20 (m, 3 H, ArH), 7.16 (d, *J* = 7.2 Hz, 2 H, ArH), 7.13–7.11 (m, 2 H, ArH), 7.00 (d, *J* = 7.8 Hz, 2 H, ArH), 5.91 (t, *J* = 9.8 Hz, 1 H, 4-H), 5.74 (br. s, 1 H, 2-H), 5.65 (br. s, 1 H, 1-H), 5.00 (d, *J* = 1.6 Hz, 1 H, 1′-H), 4.86 (ddd, *J* = 9.8, 6.0, 2.0 Hz, 1 H, 5-H), 4.71 (d, *J* = 11.3 Hz, 1 H, CH_2Ph), 4.59 (dd, *J* = 12.2, 2.0 Hz, 1 H, 6a-H), 4.50 (d, *J* = 11.3 Hz, 1 H, CH_2Ph), 4.49 (dd, *J* = 12.2, 6.0 Hz, 1 H, 6b-H), 4.43 (dd, *J* = 9.8, 3.0 Hz, 1 H, 3-H), 4.38 (d, *J* = 11.3 Hz, 1 H, CH_2Ph), 4.28 (d, *J* = 11.3 Hz, 1 H, CH_2Ph), 3.74 (m, 1 H, 5′-H), 3.72 (br. s, 1 H, 2′-H), 3.62 (dd, *J* = 9.2, 3.0 Hz, 1 H, 3′-H), 3.32 (t, *J* = 9.2 Hz, 1 H, 4′-H), 2.27 (s, 3 H, -SPhCH_3), 1.16 (d, *J* = 6.2 Hz, 3 H, 6′-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 166.16, 165.56, 165.41, 138.38, 138.33, 137.67, 133.71, 133.45, 133.01, 132.60, 129.97, 129.86, 129.81, 129.75, 129.36, 129.03, 128.88, 128.72, 128.59, 128.38, 128.33, 128.20, 127.81, 127.73, 127.60, 127.47, 101.12 (C-1′), 86.17 (C-1), 79.36 (C-3′), 79.25 (C-4′), 75.66 (C-3), 74.59 (*C*H_2Ph), 73.36 (C-2), 71.88 (*C*H_2Ph), 69.68 (C-5), 68.84 (C-4), 68.56 (C-5′), 68.46 (C-2′), 63.20 (C-6), 21.12 (-SPh*C*H_3), 17.65 (C-6′) ppm. HRMS (ESI): calcd. for $[C_{54}H_{52}O_{12}S + NH_4]^+$ 942.3518; found 942.3534.

***p*-Tolyl 2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (4):** TMSOTf (25 μL, 0.135 mmol) was added to a solution of **20** (358 mg, 0.386 mmol) and **6**[25] (860 mg, 1.35 mmol) in anhydrous CH_2Cl_2 (10 mL) (7 μL, 0.038 mmol) at –78 °C under a nitrogen atmosphere. The mixture was stirred for 2 h, then it was neutralized with Et_3N, and then concentrated. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 3:1) to give **4** (492 mg, 91%) as a white foamy solid. $[\alpha]_D^{25}$ = +47 (*c* = 0.5, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.08 (br. d, *J* = 5.5 Hz, 4 H, ArH), 8.02 (d, *J* = 7.6 Hz, 2 H, ArH), 7.60–7.54 (m, 2 H, ArH), 7.48 (t, *J* = 7.1 Hz, 1 H, ArH), 7.43–7.20 (m, 25 H, ArH), 7.19–7.12 (m, 6 H, ArH), 7.11–7.08 (m, 2 H, ArH), 6.98 (d, *J* = 7.6 Hz, 2 H, ArH), 5.87 (t, *J* = 9.6 Hz, 1 H, 4-H), 5.74 (br. s, 1 H, 2-H), 5.64 (s, 1 H, 1-H), 5.37 (br. s, 1 H, 2′′-H), 5.09 (s, 1 H, 1′-H), 4.81 (d, *J* = 10.8 Hz, 1 H, CH_2Ph), 4.80 (m, 1 H, 5-H), 4.73–4.67 (m, 3 H, CH_2Ph), 4.67 (s, 1 H, 1′′-H), 4.57 (br. d, *J* = 11.9 Hz, 1 H, 6a-H), 4.52–4.43 (m, 4 H, 6b-H and CH_2Ph), 4.41 (d, *J* = 10.8 Hz, 1 H, CH_2Ph), 4.37 (br. d, *J* = 8.5 Hz, 1 H, 3-H), 4.32 (d, *J* = 11.6 Hz, 1 H, CH_2Ph), 4.16 (d, *J* = 11.6 Hz, 1 H, CH_2Ph), 3.88 (br. d, *J* = 7.2 Hz, 1 H, 3′′-H), 3.78 (t, *J* = 9.5 Hz, 1 H, 4′′-H), 3.71 (m, 1 H, 5′′-H), 3.68–3.62 (m, 3 H, 2′-H, 3′-H, and 5′-H), 3.55 (dd, *J* = 10.8, 3.6 Hz, 1 H, 6a′′-H), 3.38 (br. d, *J* = 10.8 Hz, 1 H, 6b′′-H), 3.28 (t, *J* = 9.4 Hz, 1 H, 4′-H), 2.26 (s, 3 H, -SPhCH_3), 2.08 (s, 3 H, -COCH_3), 1.07 (d, *J* = 6.0 Hz, 3 H, 6′-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 169.96, 166.18, 165.59, 165.46, 138.52, 138.35, 138.27, 138.18, 138.13, 137.86, 133.66, 133.47, 133.01, 132.50, 129.95, 129.91, 129.84, 129.75, 129.31, 129.06, 128.98, 128.77, 128.62, 128.35, 128.29, 128.19, 128.18, 128.13, 127.89, 127.72, 127.66, 127.62, 127.37, 100.58 (C-1′), 99.47 (C-1′′), 86.09 (C-1), 79.08 (C-4′), 79.00 (C-3′), 77.69 (C-3′′), 76.08 (C-3), 75.33 (C-2′), 75.07 (*C*H_2Ph), 74.32 (*C*H_2Ph), 74.10 (C-4′′), 73.37 (*C*H_2Ph), 73.26 (C-2), 71.79 (*C*H_2Ph), 71.73 (C-5′′), 71.63 (*C*H_2Ph), 69.72 (C-5), 69.12 (C-5′), 68.64 (C-4), 68.52 (2 C, C-2′′ and C-6′′), 63.23 (C-6), 21.12 (-SPh*C*H_3), 21.09 (-CO*C*H_3), 17.74 (C-6′) ppm. HRMS (ESI): calcd. for $[C_{83}H_{82}O_{18}S + NH_4]^+$ 1416.5560; found 1416.5563.

3-Azidopropyl 2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (21): NIS (146 mg, 0.652 mmol) and TMSOTf (6 μL, 0.033 mmol) were added to a solution of **4** (456 mg, 0.326 mmol) and **5**[24] (165 mg, 1.63 mmol) in anhydrous CH_2Cl_2 (10 mL) at –15 °C under a nitrogen atmosphere. The mixture was slowly heated to 40 °C, and stirred for 4 h, after which time TLC indicated the complete disappearance of **4**. The mixture was then neutralized with Et_3N, and concentrated. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 2:1) to give **21** (355 mg, 79%) as a white foamy solid. $[\alpha]_D^{25}$ = +11 (*c* = 1.7, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.08 (d, *J* = 8.1 Hz, 2 H, ArH), 8.02 (d, *J* = 8.1 Hz, 4 H, ArH), 7.58 (t, *J* = 8.4 Hz, 1 H, ArH), 7.54 (t, *J* = 8.4 Hz, 1 H, ArH), 7.46

(t, J = 8.4 Hz, 1 H, ArH), 7.43–7.19 (m, 22 H, ArH), 7.18–7.14 (m, 3 H, ArH), 7.13–7.06 (m, 6 H, ArH), 5.84 (t, J = 9.9 Hz, 1 H, 4-H), 5.48 (br. s, 1 H, 2-H), 5.36 (br. s, 1 H, 2′′-H), 5.06 (s, 1 H, 1′-H), 5.02 (s, 1 H, 1-H), 4.79 (d, J = 11.2 Hz, 1 H, CH_2Ph), 4.70 (d, J = 11.2 Hz, 1 H, CH_2Ph), 4.68 (s, 1 H, 1′′-H), 4.67 (d, J = 11.2 Hz, 1 H, CH_2Ph), 4.63 (d, J = 12.4 Hz, 1 H, CH_2Ph), 4.60 (dd, J = 12.2, 2.3 Hz, 1 H, 6a-H), 4.46 (d, J = 11.2 Hz, 2 H, CH_2Ph), 4.44–4.34 (m, 4 H, 3-H, 6b-H, and CH_2Ph), 4.30 (d, J = 11.6 Hz, 1 H, CH_2Ph), 4.19 (m, 1 H, 5-H), 4.15 (d, J = 11.6 Hz, 1 H, CH_2Ph), 3.86 (dd, J = 9.6, 3.2 Hz, 1 H, 3′′-H), 3.82 (m, 1 H, -OCH_2-), 3.76 (t, J = 9.6 Hz, 1 H, 4′′-H), 3.70–3.60 (m, 4 H, 2′-H, 3′-H, 5′-H, and 5′′-H), 3.55 (m, 1 H, -OCH_2-), 3.52 (dd, J = 10.5, 4.2 Hz, 1 H, 6a′′-H), 3.36 (t, J = 6.5 Hz, 2 H, -CH_2N$_3$), 3.32 (br. d, J = 10.5 Hz, 1 H, 6b′′-H), 3.25 (t, J = 9.7 Hz, 1 H, 4′-H), 2.08 (s, 3 H, -COCH_3), 1.84 (m, 2 H, -OCH$_2$CH_2CH$_2$N$_3$), 1.04 (d, J = 6.2 Hz, 3 H, 6′-H) ppm. ^{13}C NMR (150 MHz, CDCl$_3$): δ = 169.92, 166.16, 165.72, 165.39, 138.56, 138.33, 138.21, 138.14, 137.84, 133.58, 133.42, 133.03, 129.84, 129.66, 129.34, 129.15, 128.73, 128.59, 128.39, 128.34, 128.28, 128.17, 128.09, 127.87, 127.71, 127.67, 127.61, 127.58, 127.34, 127.32, 127.29, 100.55 (C-1′), 99.29 (C-1′′), 97.35 (C-1), 79.08 (C-4′), 79.05 (C-3′), 77.66 (C-3′′), 75.71 (C-3), 75.07 (2 C, C-2′ and CH_2Ph), 74.23 (CH_2Ph), 74.06 (C-4′′), 73.14 (CH_2Ph), 71.78 (C-2), 71.73 (CH_2Ph), 71.69 (C-5′′), 71.55 (CH_2Ph), 68.97 (2 C, C-5 and C-5′), 68.45 (C-2′′), 68.42 (C-6′′), 68.33 (C-4), 65.10 (-OCH_2-), 63.08 (C-6), 48.20 (-CH_2N$_3$), 28.65 (-OCH$_2$CH_2CH$_2$N$_3$), 21.07 (-COCH_3), 17.74 (C-6′) ppm. HRMS (ESI): calcd. for [C$_{79}$H$_{81}$N$_3$O$_{19}$ + NH$_4$]$^+$ 1393.5803; found 1393.5803.

3-Aminopropyl α-D-Mannopyranosyl-(1→2)-α-D-rhamnopyranosyl-(1→3)-α-D-mannopyranoside (1): Compound **21** (40 mg, 0.029 mmol) was dissolved in MeOH (5 mL), and NaOMe (1 M in MeOH) was added dropwise until the pH reached 10. The mixture was stirred at room temp. for 8 h, and then it was neutralized with Amberlite IR 120 (H$^+$). The solution was filtered and concentrated. The residue was briefly purified by column chromatography (CH$_2$Cl$_2$/MeOH, 20:1).

The product was dissolved in a mixture of AcOH and H$_2$O (1:9 v/v; 5 mL), and then Pd/C (10%; 10 mg) was added. The suspension was stirred under a hydrogen atmosphere at room temp. overnight. The solid materials were filtered off, and the filtrate was concentrated. The residue was purified by size-exclusion chromatography on a Bio-Gel P-2 column with distilled water as the eluent. Product-containing fractions were then lyophilized to give **1** (12.4 mg, 78% over two steps) as a white foamy solid. ^{1}H NMR (600 MHz, D$_2$O): δ = 5.09 (s, 1 H, 1′-H), 4.88 (d, J = 1.2 Hz, 1 H, 1-H), 4.67 (d, J = 1.2 Hz, 1 H, 1′′-H), 3.94 (dd, J = 3.0, 1.6 Hz, 1 H, 2′-H), 3.91 (dd, J = 3.2, 1.8 Hz, 1 H, 2-H), 3.86 (dd, J = 3.0, 1.5 Hz, 1 H, 2′′-H), 3.78 (dd, J = 9.8, 3.2 Hz, 1 H, 3′-H), 3.72 (dd, J = 12.0, 1.5 Hz, 1 H, 6a-H), 3.70–3.63 (m, 5 H, 3-H, 3′′-H, 5′-H, 6a′′-H, and -OCH_2-), 3.63–3.55 (m, 3 H, 4′′-H, 6b-H, and 6b′′-H), 3.53–3.50 (m, 2 H, 4-H and 5-H), 3.49–3.40 (m, 2 H, 5′′-H and -OCH_2-), 3.33 (t, J = 9.7 Hz, 1 H, 4′-H), 2.97 (m, 2 H, -CH_2NH$_2$), 1.83 (m, 2 H, -OCH$_2$CH_2CH$_2$NH$_2$), 1.13 (d, J = 6.2 Hz, 3 H, 6′-H) ppm. ^{13}C NMR (150 MHz, D$_2$O): δ = 102.33 (C-1), 100.84 (C-1′), 99.53 (C-1′′), 78.62 (C-3), 78.36 (C-2′), 73.19 (C-5), 72.86 (C-5′′), 71.97 (C-4′), 70.21 (C-3′′), 69.81 (C-2), 69.76 (C-3′), 69.65 (C-2′′), 69.10 (C-5′), 66.50 (C-4), 65.89 (C-4′′), 64.77 (-OCH_2-), 60.80 (C-6′′), 60.73 (C-6), 37.36 (-CH_2NH$_2$), 26.57 (-OCH$_2$CH_2CH$_2$NH$_2$), 16.54 (C-6′) ppm. HRMS (ESI): calcd. for [C$_{21}$H$_{39}$NO$_{15}$ + H]$^+$ 546.2392; found 546.2388.

3-Azidopropyl 3,4,6-Tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (22): Acetyl chloride (1.0 mL) was added to a solution of **21** (300 mg, 0.22 mmol) in MeOH and CH$_2$Cl$_2$ (1:1 v/v; 20 mL) at 0 °C. The solution was stirred at room temp. overnight, and then it was neutralized with saturated aq. NaHCO$_3$. The mixture was extracted with CH$_2$Cl$_2$ (2 × 100 mL). The organic phase was dried with anhydrous Na$_2$SO$_4$, and concentrated. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 2:1) to give **22** (232 mg, 80%) as a white foamy solid. $[\alpha]_D^{25}$ = +8 (c = 0.8, CHCl$_3$). ^{1}H NMR (600 MHz, CDCl$_3$): δ = 8.11–8.02 (m, 6 H, ArH), 7.58 (t, J = 7.2 Hz, 1 H, ArH), 7.54 (t, J = 7.2 Hz, 1 H, ArH), 7.50 (t, J = 7.2 Hz, 1 H, ArH), 7.44–7.20 (m, 22 H, ArH), 7.19–7.15 (m, 3 H, ArH), 7.14–7.11 (m, 2 H, ArH), 7.10–7.02 (m, 4 H, ArH), 5.84 (t, J = 10.0 Hz, 1 H, 4-H), 5.49 (br. s, 1 H, 2-H), 5.13 (s, 1 H, 1′-H), 5.02 (s, 1 H, 1-H), 4.76 (d, J = 10.7 Hz, 1 H, CH_2Ph), 4.70 (br. s, 1 H, 1′′-H), 4.68–4.62 (m, 4 H, CH_2Ph), 4.60 (dd, J = 12.2, 2.0 Hz, 1 H, 6a-H), 4.47 (d, J = 12.5 Hz, 1 H, CH_2Ph), 4.45–4.35 (m, 4 H, 3-H, 6b-H, and CH_2Ph), 4.23 (d, J = 11.5 Hz, 1 H, CH_2Ph), 4.19 (m, 1 H, 5-H), 4.10 (d, J = 11.5 Hz, 1 H, CH_2Ph), 3.94 (br. s, 1 H, 2′′-H), 3.81 (m, 1 H, -OCH_2-), 3.79–3.71 (m, 3 H, 3′′-H, 4′′-H, and 5′′-H), 3.67–3.62 (m, 2 H, 2′-H and 3′-H), 3.61 (m, 1 H, 5′-H), 3.58–3.49 (m, 2 H, -OCH_2- and 6a′′-H), 3.42 (br. d, J = 10.8 Hz, 1 H, 6b′′-H), 3.33 (t, J = 6.5 Hz, 2 H, -CH_2N$_3$), 3.20 (t, J = 9.6 Hz, 1 H, 4′-H), 1.83 (m, 2 H, -OCH$_2$CH_2CH$_2$N$_3$), 1.04 (d, J = 6.2 Hz, 3 H, 6′-H) ppm. ^{13}C NMR (150 MHz, CDCl$_3$): δ = 166.15, 165.74, 165.53, 138.64, 138.20, 138.08, 137.85, 133.66, 133.38, 133.01, 129.85, 129.83, 129.66, 129.35, 129.20, 128.76, 128.58, 128.47, 128.38, 128.33, 128.22, 128.07, 127.93, 127.87, 127.74, 127.68, 127.59, 127.48, 127.33, 127.25, 100.99 (C-1′′), 100.76 (C-1′), 97.35 (C-1), 79.56 (C-3′′), 79.44 (C-4′), 78.95 (C-3′), 76.20 (C-3), 75.46 (C-2′), 75.05 (CH_2Ph), 74.18 (C-4′′), 74.08 (CH_2Ph), 73.11 (CH_2Ph), 72.01 (CH_2Ph), 71.81 (C-2), 71.70 (CH_2Ph), 71.36 (C-5′′), 68.96 (C-5), 68.89 (C-5′), 68.60 (C-6′′), 68.33 (C-2′′), 68.26 (C-4), 65.12 (-OCH_2-), 63.11 (C-6), 48.17 (-CH_2N$_3$), 28.64 (-OCH$_2$CH_2CH$_2$N$_3$), 17.74 (C-6′) ppm. HRMS (ESI): calcd. for [C$_{77}$H$_{79}$N$_3$O$_{18}$ + NH$_4$]$^+$ 1351.5693; found 1351.5719.

3-Azidopropyl 2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (23): NIS (100 mg, 0.45 mmol) and TMSOTf (4.2 μL, 0.023 mmol) were added to a solution of **22** (214 mg, 0.16 mmol) and **4** (312 mg, 0.22 mmol) in dry CH$_2$Cl$_2$ (8 mL) at –15 °C under a nitrogen atmosphere. The mixture was warmed slowly to room temp., and stirred for 30 h, after which time TLC indicated the disappearance of **4**. The mixture was then neutralized with Et$_3$N, and concentrated. The residue was purified by column chromatography (petroleum ether/ethyl acetate, 3:1) to give **23** (310 mg, 74%) as a white foamy solid. $[\alpha]_D^{25}$ = +10 (c = 0.2, CHCl$_3$). ^{1}H NMR (600 MHz, CDCl$_3$): δ = 8.16–8.02 (m, 8 H, ArH), 7.99 (d, J = 7.4 Hz, 2 H, ArH), 7.86 (d, J = 7.4 Hz, 2 H, ArH), 7.61 (t, J = 7.4 Hz, 1 H, ArH), 7.58 (t, J = 7.4 Hz, 1 H, ArH), 7.54 (t, J = 7.4 Hz, 1 H, ArH), 7.52 (t, J = 7.4 Hz, 1 H, ArH), 7.43–7.07 (m, 59 H, ArH), 6.98 (d, J = 7.5 Hz, 2 H, ArH), 6.89 (t, J = 7.6 Hz, 2 H, ArH), 6.64 (t, J = 7.5 Hz, 1 H, ArH), 5.89 (t, J = 9.9 Hz, 1 H, 4′′′-H), 5.84 (t, J = 9.9 Hz, 1 H, 4-H), 5.59 (br. s, 1 H, 2′′′-H), 5.49 (br. s, 1 H, 2-H), 5.41 (br. s, 1 H, 2′′′′′-H), 5.06 (s, 1 H, 1′-H), 5.03 (br. s, 2 H, 1-H and 1′′-H), 4.98 (s, 2 H, 1′′′-H and 1′′′′-H), 4.90 (s, 1 H, 1′′′′′-H), 4.81 (br. d, J = 10.8 Hz, 1 H, CH_2Ph), 4.78 (d, J = 11.4 Hz, 2 H, CH_2Ph), 4.68 (d, J = 11.4 Hz, 1 H, CH_2Ph), 4.66 (d, J = 11.4 Hz, 1 H, CH_2Ph), 4.63 (br. s, 2 H, CH_2Ph), 4.62–4.58 (m, 2 H, 6a-H and CH_2Ph), 4.57–4.52 (m, 2 H, 3′′′-H and CH_2Ph), 4.49 (d, J =

12.6 Hz, 1 H, CH_2Ph), 4.46–4.38 (m, 7 H, 3-H, 6b-H, and CH_2Ph), 4.32 (d, J = 10.2 Hz, 1 H, CH_2Ph), 4.31 (d, J = 10.8 Hz, 1 H, CH_2Ph), 4.25–4.14 (m, 4 H, 5-H, 5′′′-H, 6a′′′-H, and CH_2Ph), 4.12 (d, J = 12.2 Hz, 1 H, CH_2Ph), 4.07 (d, J = 11.2 Hz, 1 H, CH_2Ph), 4.00 (br. d, J = 11.0 Hz, 1 H, 6b′′′-H), 3.93 (br. s, 1 H, 2′-H), 3.91 (m, 1 H, 3′′-H), 3.90–3.81 (m, 5 H, 4′′-H, 3′′′′′-H, 4′′′′′-H, 5′′′′-H, and -OCH_2-), 3.80 (br. s, 1 H, 2′′′′-H), 3.72 (dd, J = 9.6, 2.4 Hz, 1 H, 3′′′′-H), 3.70 (br. s, 1 H, 2′′-H), 3.64 (m, 1 H, 5′-H), 3.61 (dd, J = 9.6, 2.4 Hz, 2 H, 3′-H and 5′′-H), 3.56 (m, 1 H, -OCH_2-), 3.43 (dd, J = 10.7, 4.2 Hz, 1 H, 6a′′′′′-H), 3.40–3.32 (m, 4 H, 4′′′′-H, 5′′′′′-H, and -CH_2N$_3$), 3.23 (br. d, J = 10.7 Hz, 1 H, 6b′′′′′-H), 3.20–3.13 (m, 2 H, 4′-H and 6a′′-H), 2.86 (br. d, J = 10.6 Hz, 1 H, 6b′′-H), 2.03 (s, 3 H, -COCH_3), 1.85 (m, 2 H, -OCH$_2$CH_2CH$_2$N$_3$), 1.10 (d, J = 6.1 Hz, 3 H, 6′′′′-H), 1.07 (d, J = 6.1 Hz, 3 H, 6′-H) ppm. ^{13}C NMR (150 MHz, CDCl$_3$): δ = 169.93, 166.15, 165.94, 165.67, 165.42, 165.22, 165.08, 138.70, 138.60, 138.31, 138.23, 138.12, 137.88, 137.79, 133.57, 133.49, 133.40, 133.30, 133.01, 132.85, 130.08, 129.88, 129.83, 129.79, 129.67, 129.66, 129.61, 129.37, 129.09, 129.02, 128.72, 128.68, 128.59, 128.57, 128.45, 128.42, 128.38, 128.35, 128.33, 128.29, 128.21, 128.20, 128.15, 128.13, 128.07, 127.87, 127.85, 127.78, 127.67, 127.62, 127.55, 127.48, 127.34, 127.26, 127.24, 127.12, 125.29, 100.53 (C-1′′), 99.90 (2 C, C-1′ and C-1′′′′), 98.86 (2 C, C-1′′′ and C-1′′′′′), 97.39 (C-1), 79.62, 79.55, 79.23, 78.94, 78.42, 77.65, 76.81, 75.18, 74.99, 74.92, 74.34, 74.29, 74.28, 74.08, 73.64, 73.14, 73.09, 72.62, 72.19, 72.01, 71.96, 71.83 (2 C), 71.79 (2 C), 71.68 (2 C), 69.26, 69.10, 69.04 (2 C), 68.63, 68.50, 68.47, 68.32 (C-6′′′′′), 67.69 (C-6′′), 65.08 (-OCH_2-), 63.13 (C-6), 62.31 (C-6′′′), 48.19 (-CH_2N$_3$), 28.68 (-OCH$_2$CH_2CH$_2$N$_3$), 21.10 (-COCH_3), 17.76 (C-6′), 17.72 (C-6′′′′) ppm. HRMS (ESI): calcd. for [C$_{153}$H$_{153}$N$_3$O$_{36}$ + 2NH$_4$]$^{2+}$ 1322.0455; found 1322.0473.

3-Aminopropyl α-D-Mannopyranosyl-(1→2)-α-D-rhamnopyranosyl-(1→3)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-rhamnopyranosyl-(1→3)-α-D-mannopyranoside (2): Compound **23** (45 mg, 0.017 mmol) was dissolved in MeOH (5 mL), and NaOMe (1 M in MeOH) was added dropwise until the pH reached 10. The mixture was stirred at room temp. for 24 h, and then it was neutralized with Amberlite IR 120 (H$^+$). The solution was filtered and concentrated. The residue was purified by flash column chromatography (CH$_2$Cl$_2$/MeOH, 25:1).

The product was dissolved in a mixture of AcOH and H$_2$O (1:9 v/v; 5 mL), and Pd/C (10%; 15 mg) was added. The suspension was stirred under a hydrogen atmosphere at room temp. overnight. The solid materials were filtered off, and the solution was concentrated. The residue was purified by size-exclusion chromatography on a Bio-Gel P-2 column with distilled water as the eluent. Product-containing fractions were lyophilized to give **2** (11.4 mg, 65% over two steps) as a white solid. ^{1}H NMR (600 MHz, D$_2$O): δ = 5.12 (s, 1 H, 1-H), 5.10 (s, 1 H, 1-H), 5.07 (s, 1 H, 1-H), 4.87 (s, 1 H, 1-H), 4.85 (s, 1 H, 1-H), 4.67 (s, 1 H, 1-H), 3.96 (br. s, 1 H, 2-H), 3.94 (br. s, 1 H, 2-H), 3.93 (br. s, 1 H, 2-H), 3.91 (br. s, 2 H, 2× 2-H), 3.85 (br. s, 1 H, 2-H), 3.80–3.74 (m, 3 H, 3× 3-H), 3.74–3.63 (m, 10 H, 3× 3-H, 2× 5-H, 4× 6a-H, and -OCH_2-), 3.62–3.53 (m, 8 H, 4-H, 3× 5-H, and 4× 6b-H), 3.52–3.40 (m, 5 H, 3× 4-H, 5-H, and -OCH_2-), 3.32 (t, J = 9.6 Hz, 2 H, 2× 4-H), 2.97 (m, 2 H, -CH_2NH$_2$), 1.83 (m, 2 H, -OCH$_2$CH_2CH$_2$NH$_2$), 1.14 (br. d, J = 6.0 Hz, 3 H, 6-H), 1.13 (br. d, J = 5.4 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, D$_2$O): δ = 102.31 (C-1), 101.88 (C-1), 100.79 (C-1), 100.76 (C-1), 100.62 (C-1), 99.50 (C-1), 78.64, 78.58, 78.49, 78.42, 78.34, 78.31, 73.22, 73.16, 72.81, 71.95 (2 C), 70.18, 69.83, 69.80, 69.71 (2 C), 69.63, 69.60 (2 C), 69.09 (2 C), 66.68, 66.50, 65.85 (2 C), 64.7 (-OCH_2-), 60.77 (4 C, 4× C-6), 37.33 (-CH_2NH$_2$), 26.54 (-OCH$_2$CH_2CH$_2$NH$_2$), 16.52 (2 C, 2× C-6) ppm. HRMS (ESI): calcd. for [C$_{39}$H$_{69}$NO$_{29}$ + H]$^+$ 1016.4028; found 1016.4045.

3-Azidopropyl 3,4,6-Tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (24): Acetyl chloride (0.5 mL) was added to a solution of **23** (246 mg, 0.094 mmol) in MeOH and CH$_2$Cl$_2$ (1:1 v/v; 10 mL) at 0 °C. The mixture was stirred at room temp. for 36 h, then it was neutralized with saturated aq. NaHCO$_3$, and extracted with CH$_2$Cl$_2$ (2× 60 mL). The organic phase was dried with anhydrous Na$_2$SO$_4$, and concentrated. The residue was purified by flash column chromatography (petroleum ether/ethyl acetate, 2:1) to give **24** (206 mg, 85%) as a white foamy solid. $[a]_D^{25}$ = +19 (c = 0.3, CHCl$_3$). ^{1}H NMR (600 MHz, CDCl$_3$): δ = 8.13–8.02 (m, 8 H, ArH), 7.99 (d, J = 7.8 Hz, 2 H, ArH), 7.87 (d, J = 8.4 Hz, 2 H, ArH), 7.60 (t, J = 7.2 Hz, 1 H, ArH), 7.57 (t, J = 7.8 Hz, 1 H, ArH), 7.54 (t, J = 7.2 Hz, 1 H, ArH), 7.49 (t, J = 7.2 Hz, 1 H, ArH), 7.43–7.07 (m, 59 H, ArH), 6.97 (d, J = 7.8 Hz, 2 H, ArH), 6.88 (t, J = 7.5 Hz, 2 H, ArH), 6.64 (t, J = 7.5 Hz, 1 H, ArH), 5.88 (t, J = 9.6 Hz, 1 H, 4′′′-H), 5.84 (t, J = 9.9 Hz, 1 H, 4-H), 5.58 (br. s, 1 H, 2′′′-H), 5.48 (br. s, 1 H, 2-H), 5.06 (s, 1 H, 1′-H), 5.02 (br. s, 3 H, 1-H, 1′′-H, and 1′′′′-H), 4.99 (s, 1 H, 1′′′-H), 4.91 (s, 1 H, 1′′′′′-H), 4.81 (br. d, J = 9.6 Hz, 1 H, CH_2Ph), 4.74 (d, J = 10.8 Hz, 1 H, CH_2Ph), 4.70 (d, J = 11.4 Hz, 1 H, CH_2Ph), 4.68 (d, J = 12.6 Hz, 1 H, CH_2Ph), 4.65–4.56 (m, 6 H, 6a-H and CH_2Ph), 4.53 (dd, J = 9.7, 2.6 Hz, 1 H, 3′′′-H), 4.49 (d, J = 12.6 Hz, 1 H, CH_2Ph), 4.45 (d, J = 11.4 Hz, 1 H, CH_2Ph), 4.45–4.37 (m, 5 H, 3-H, 6b-H, and CH_2Ph), 4.35 (d, J = 10.8 Hz, 1 H, CH_2Ph), 4.33 (d, J = 12.0 Hz, 1 H, CH_2Ph), 4.27 (d, J = 11.4 Hz, 1 H, CH_2Ph), 4.22 (m, 1 H, 5′′′-H), 4.21–4.12 (m, 4 H, 5-H, 6a′′′-H, and CH_2Ph), 4.05 (d, J = 11.8 Hz, 1 H, CH_2Ph), 4.01 (br. d, J = 12.0 Hz, 1 H, 6b′′′-H), 3.93 (br. s, 2 H, 2′-H and 2′′′′′-H), 3.91–3.81 (m, 4 H, 3′′-H, 4′′-H, 4′′′′′-H, and -OCH_2-), 3.80–3.67 (m, 5 H, 2′′-H, 2′′′′-H, 3′′′′-H, 3′′′′′-H, 5′′′-H, and 5′′′′-H), 3.67–3.52 (m, 4 H, 3′-H, 5′-H, 5′′-H, and -OCH_2-), 3.46–3.38 (m, 2 H, 5′′′′′-H and 6a′′′′′-H), 3.35 (t, J = 6.5 Hz, 2 H, -CH_2N$_3$), 3.26 (t, J = 9.6 Hz, 1 H, 4′′′′-H), 3.22 (br. d, J = 10.8 Hz, 1 H, 6b′′′′′-H), 3.20–3.13 (m, 2 H, 4′-H and 6a′′-H), 2.94 (br. d, J = 10.8 Hz, 1 H, 6b′′-H), 1.85 (m, 2 H, -OCH$_2$CH_2CH$_2$N$_3$), 1.10 (d, J = 6.0 Hz, 3 H, 6′′′′-H), 1.07 (d, J = 6.0 Hz, 3 H, 6′-H) ppm. ^{13}C NMR (150 MHz, CDCl$_3$): δ = 166.14, 165.94, 165.66, 165.42, 165.23, 165.15, 138.69, 138.60, 138.32, 138.28, 138.24, 138.07, 137.96, 137.77, 133.57, 133.51, 133.39, 133.27, 133.00, 132.84, 130.08, 129.86, 129.83, 129.78, 129.65, 129.37, 129.08, 129.02, 128.72, 128.68, 128.58, 128.56, 128.45, 128.43, 128.40, 128.37, 128.34, 128.28, 128.23, 128.22, 128.19, 128.13, 128.10, 128.06, 127.88, 127.81, 127.77, 127.73, 127.64, 127.56, 127.53, 127.48, 127.45, 127.34, 127.29, 127.25, 127.22, 125.28, 100.50 (2 C, C-1′′ and C-1′′′′′), 100.04 (C-1′′′′), 99.85 (C-1′), 98.84 (C-1′′′), 97.39 (C-1), 79.60, 79.46, 79.42, 79.37, 79.22, 78.39, 76.19, 75.16, 74.93, 74.87, 74.48, 74.35, 74.28, 74.15, 73.77, 73.15 (2 C), 73.08 (2 C), 72.17, 72.03, 71.95 (3 C), 71.82, 71.78, 71.47, 69.19, 69.09, 69.04 (2 C), 69.00, 68.56, 68.50 (2 C), 68.36, 67.81, 65.08, 63.12, 62.34, 48.19 (-CH_2N$_3$), 28.67 (-OCH$_2$CH_2CH$_2$N$_3$), 17.75 (2 C, C-6′ and C-6′′′′) ppm. HRMS (ESI): calcd. for [C$_{151}$H$_{151}$N$_3$O$_{35}$ + 2NH$_4$]$^{2+}$ 1301.0402; found 1301.0423.

3-Azidopropyl 2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-

α-D-mannopyranosyl-(1→2)-3,4-di-*O*-benzyl-α-D-rhamnopyranosyl-(1→3)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (25): NIS (70 mg, 0.312 mmol) and TMSOTf (3.0 μL, 0.017 mmol) were added to a solution of **24** (200 mg, 0.078 mmol) and **4** (218 mg, 0.156 mmol) in dry CH_2Cl_2 (8 mL) at –15 °C under a nitrogen atmosphere. The mixture was stirred for 5 h, after which time TLC indicated the disappearance of **24**. The mixture was then neutralized with Et_3N, and concentrated. The residue was purified by column chromatography (petroleum ether/ethyl acetate, 3:1) to give **25** (245 mg, 82%) as a white foamy solid. $[a]_D^{25}$ = +9 (*c* = 0.2, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$): δ = 8.19–7.95 (m, 14 H, ArH), 7.80 (d, *J* = 8.4 Hz, 2 H, ArH), 7.77 (d, *J* = 7.8 Hz, 2 H, ArH), 7.63 (t, *J* = 7.5 Hz, 1 H, ArH), 7.59 (t, *J* = 7.5 Hz, 2 H, ArH), 7.55 (t, *J* = 7.5 Hz, 2 H, ArH), 7.49 (t, *J* = 7.2 Hz, 1 H, ArH), 7.43–7.07 (m, 84 H, ArH), 7.06–7.00 (m, 4 H, ArH), 6.99 (d, *J* = 7.8 Hz, 2 H, ArH), 6.90 (t, *J* = 7.5 Hz, 2 H, ArH), 6.85 (t, *J* = 7.5 Hz, 2 H, ArH), 6.66 (t, *J* = 7.2 Hz, 1 H, ArH), 6.56 (t, *J* = 7.2 Hz, 1 H, ArH), 5.89 (t, *J* = 9.6 Hz, 1 H, 4-H), 5.87–5.82 (m, 2 H, 2× 4-H), 5.58 (s, 1 H, 2-H), 5.57 (s, 1 H, 2-H), 5.50 (s, 1 H, 2-H), 5.41 (s, 1 H, 2-H), 5.27 (s, 1 H, 1-H), 5.06 (br. s, 2 H, 2× 1-H), 5.04 (s, 1 H, 1-H), 4.98 (s, 1 H, 1-H), 4.96 (s, 1 H, 1-H), 4.94 (s, 1 H, 1-H), 4.90 (s, 1 H, 1-H), 4.88 (s, 1 H, 1-H), 4.87–4.72 (m, 4 H, CH_2Ph), 4.72–4.37 (m, 23 H, 2× 3-H, 6-H, and CH_2Ph), 4.36–4.26 (m, 3 H, 5-H and CH_2Ph), 4.25–4.13 (m, 8 H, 2× 5-H, 2× 6-H, and CH_2Ph), 4.12–3.98 (m, 7 H, 2× 2-H, 3-H, 2× 5-H, and 2× 6-H), 3.89–3.76 (m, 8 H, 2× 2-H, 3× 3-H, 2× 5-H, and -OCH_2-), 3.74–3.69 (m, 2 H, 2-H and 5-H), 3.68–3.54 (m, 5 H, 3× 3-H, 5-H, and -OCH_2-), 3.46 (dd, *J* = 10.6, 4.0 Hz, 1 H, 6-H), 3.41–3.31 (m, 4 H, 2× 4-H and -CH_2N$_3$), 3.27 (br. d, *J* = 10.6 Hz, 1 H, 6-H), 3.23 (t, *J* = 9.6 Hz, 2 H, 2× 4-H), 3.19 (t, *J* = 9.6 Hz, 2 H, 2× 4-H), 3.15 (br. d, *J* = 10.8 Hz, 1 H, 6-H), 3.02 (br. d, *J* = 11.2 Hz, 1 H, 6-H), 2.83 (br. d, *J* = 10.8 Hz, 1 H, 6-H), 2.65 (br. d, *J* = 11.2 Hz, 1 H, 6-H), 2.03 (s, 3 H, -COCH_3), 1.86 (m, 2 H, -OCH$_2$CH_2CH$_2$N$_3$), 1.16 (d, *J* = 6.0 Hz, 3 H, 6-H), 1.10 (d, *J* = 6.0 Hz, 3 H, 6-H), 1.09 (d, *J* = 6.0 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, $CDCl_3$): δ = 169.92, 166.16, 165.95, 165.92, 165.68, 165.46, 165.26, 165.15, 165.11, 165.00, 138.74, 138.64, 138.61, 138.39, 138.34, 138.31, 138.23, 138.22, 138.15, 137.90, 137.81, 137.74, 133.59, 133.47, 133.41, 133.29, 133.02, 132.83, 130.15, 130.10, 129.91, 129.84, 129.80, 129.67, 129.64, 129.59, 129.53, 129.38, 129.11, 129.00, 128.88, 128.69, 128.65, 128.60, 128.57, 128.46, 128.43, 128.39, 128.36, 128.34, 128.32, 128.31, 128.29, 128.24, 128.20, 128.17, 128.15, 128.12, 128.10, 128.08, 128.02, 127.86, 127.81, 127.74, 127.72, 127.68, 127.66, 127.61, 127.60, 127.55, 127.50, 127.43, 127.40, 127.34, 127.29, 127.26, 127.23, 127.13, 100.58 (C-1), 99.95 (C-1), 99.78 (2 C, 2× C-1), 99.08 (2 C, 2× C-1), 98.90 (C-1), 98.86 (C-1), 97.41 (C-1), 79.76, 79.66, 79.54, 79.51, 79.24, 78.99, 78.22, 77.67, 77.37, 76.96, 75.25, 75.03, 75.00, 74.95, 74.43, 74.37, 74.31, 74.24 (2 C), 73.97, 73.90, 73.64, 73.12 (3 C), 73.07, 72.62, 72.56, 72.19, 72.05 (2 C), 72.01, 71.97, 71.79 (5 C), 71.69, 71.08, 69.47, 69.25, 69.18, 69.11, 69.06 (2 C), 68.96, 68.65, 68.57, 68.51, 68.36, 67.68, 67.59, 65.10, 63.15, 62.59, 62.28, 48.20 (-CH_2N$_3$), 28.69 (-OCH$_2$CH_2CH$_2$N$_3$), 21.10 (-COCH_3), 17.76 (C-6), 17.74 (C-6), 17.69 (C-6) ppm. HRMS (ESI): calcd. for $[C_{227}H_{225}N_3O_{53} + 2NH_4]^{2+}$ 1938.2840; found 1938.2813.

3-Aminopropyl α-D-Mannopyranosyl-(1→2)-α-D-rhamnopyranosyl-(1→3)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-rhamnopyranosyl-(1→3)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-rhamnopyranosyl-(1→3)-α-D-mannopyranoside (3): Compound **25** (76 mg, 0.02 mmol) was dissolved in MeOH (8 mL), and NaOMe (1 M in MeOH) was added dropwise until the pH reached 10. The mixture was stirred at room temp. for 10 h, then it was neutralized with Amberlite IR 120 (H^+). The solution was filtered and concentrated. The residue was purified by flash column chromatography (CH_2Cl_2/MeOH, 25:1).

The product was dissolved in a mixture of AcOH and H_2O (1:9 v/v; 4 mL), and Pd/C (10%; 12 mg) was added. The suspension was stirred under a hydrogen atmosphere at room temp. for 36 h. The solid materials were filtered off, and the solution was concentrated. The residue was purified by size-exclusion chromatography on a Bio-Gel P-2 column with distilled water as the eluent. Product-containing fractions were lyophilized to give **3** (18.1 mg, 61% over two steps) as a white solid. ^{1}H NMR (600 MHz, D_2O): δ = 5.13 (s, 2 H, 2× 1-H), 5.10 (br. s, 2 H, 2× 1-H), 5.08 (s, 1 H, 1-H), 4.88 (s, 1 H, 1-H), 4.86 (s, 2 H, 2× 1-H), 4.67 (s, 1 H, 1-H), 3.98 (br. s, 2 H, 2× 2-H), 3.95 (br. s, 2 H, 2× 2-H), 3.93 (br. s, 1 H, 2-H), 3.91 (br. s, 3 H, 3× 2-H), 3.86 (br. s, 1 H, 2-H), 3.80–3.75 (m, 4 H, 4× 3-H), 3.74–3.40 (m, 35 H, 5× 3-H, 7× 4-H, 9× 5-H, 12× 6-H, and -OCH_2-), 3.32 (t, *J* = 9.7 Hz, 2 H, 2× 4-H), 2.96 (m, 2 H, -CH_2NH$_2$), 1.83 (m, 2 H, -OCH$_2$CH_2CH$_2$NH$_2$), 1.14 (br. d, *J* = 6.0 Hz, 6 H, 2× 6-H), 1.13 (br. d, *J* = 5.4 Hz, 3 H, 6-H) ppm. ^{13}C NMR (150 MHz, D_2O): δ = 102.32 (C-1), 101.89 (2 C, 2× C-1), 100.81 (C-1), 100.77 (2 C, 2× C-1), 100.62 (2 C, 2× C-1), 99.52 (C-1), 78.65 (2 C), 78.59, 78.56, 78.51, 78.43, 78.38 (2 C), 73.24 (3 C), 73.17, 72.84, 71.99 (3 C), 70.2, 69.86, 69.83, 69.74 (3 C), 69.65 (3 C), 69.40 (2 C), 69.12 (3 C), 66.75, 66.72, 66.53, 65.87 (3 C), 64.76 (-OCH_2-), 60.81 (6 C, 6× C-6), 37.36 (-CH_2NH$_2$), 26.57 (-OCH$_2$CH_2CH$_2$NH$_2$), 16.54 (3 C, 3× C-6) ppm. HRMS (ESI): calcd. for $[C_{57}H_{99}NO_{43} + H]^+$ 1486.5664; found 1486.5684.

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