Tetrahedron 64 (2008) 10558–10572

Contents lists available at ScienceDirect

Tetrahedron

journal homepage: www.elsevier.com/locate/tet

Synthesis of branched tri- to pentasaccharides representative of fragments of *Shigella flexneri* serotypes 3a and/or X O-antigens

Julien Boutet [a,b], Catherine Guerreiro [a], Laurence A. Mulard [a,*]

[a] *Institut Pasteur, Unité de Chimie des Biomolécules (CNRS URA 2128), 28 rue du Dr Roux, F-75015 Paris, France*
[b] *Université Paris Descartes, 12 rue de l'Ecole de Médecine, F-75006 Paris, France*

ARTICLE INFO

Article history:
Received 24 June 2008
Received in revised form 26 August 2008
Accepted 27 August 2008
Available online 3 September 2008

Keywords:
Oligosaccharide
Glycosylation
N-Trichloroacetyl
Shigella

ABSTRACT

Fragments of the {2)-[α-D-Glc*p*-(1→3)]-α-L-Rha*p*-(1→2)-α-L-Rha*p*-(1→3)-[Ac→2]-α-L-Rha*p*-(1→3)-β-D-Glc*p*NAc-(1→}$_n$ (**(E)AB$_{Ac}$CD**)$_n$ polymer were synthesized. **D(E)A**, **CD(E)A**, **$_{Ac}$CD(E)A** were obtained according to a linear strategy, whereas **BCD(E)A** and **B$_{Ac}$CD(E)A** were derived from the condensation of appropriate **BC** and **D(E)A** building blocks. Oligosaccharides were synthesized as their propyl glycoside, relying on (i) the efficient trichloroacetimidate chemistry, (ii) a common **EA** allyl glycoside, and (iii) a 2-trichloroacetamido-D-glucopyranose precursor to residue **D**. Final Pd/C-mediated deprotection, run under a high pressure of hydrogen, ensured *O*-acetyl stability. All targets are parts of the O-antigen of *Shigella flexneri* 3a, a prevalent serotype. Non-*O*-acetylated oligosaccharides are shared by the *S. flexneri* serotype X O-antigen.

1. Introduction

Shigellosis, or bacillary dysentery, is an invasive infection of the human colon which in its most classical expression is characterized by a triad of fever, intestinal cramps and bloody diarrhea.[1] This highly contagious infection, associated with increased antibiotic-resistance,[1,2] is endemic worldwide. In the absence of a vaccine,[3] shigellosis remains a major health concern especially in the pediatric population living in the most impoverished areas.[2–4] *Shigella* is divided into 4 different species. *Shigella sonnei* (1 serotype) and *Shigella flexneri* account for the endemic disease. The latter which, by far, prevails in developing countries and in children below five years of age,[2,4] is divided into 15 serotypes. Importantly, a wide range of *S. flexneri* serotypes, whose geographical distribution is somewhat heterogeneous, are isolated from patients, emphasizing the need for a multivalent vaccine providing broad serotype coverage.[2,4,3] Serotypes are defined on the basis of the carbohydrate repeating unit of the *S. flexneri* O-antigen (O-Ag), that is, the polysaccharide part of the bacterial lipopolysaccharide (LPS), the major surface antigen, and well-known virulence factor.[5] Interestingly in the case of *S. flexneri*, all serotypes but one share a linear backbone, defined by a tetrasaccharide composed of 3 α-linked L-rhamnosyl residues (**A**, **B**, **C**) and a 2-acetamido-2-deoxy-β-D-glucopyranosyl residue (**D**). Tetrasaccharide **ABCD** (**I**) is the basic repeating unit of serotype Y. Additional serotype-specificity is associated to the presence of branched α-D-glucopyranosyl (**E**) and *O*-acetyl (*O*-Ac) decorations (Fig. 1).[5] Interestingly, it was recently demonstrated in the case of *S. flexneri* serotype 1a, 2a, and 5a, two of which are well studied in the laboratory,[6–9] that LPS glucosylation promotes both bacterial invasion and survival from the intense inflammatory response associated with host innate immunity.[10] Clearly, glucosylation affects *S. flexneri* 5a O-Ag conformation, resulting in shortened length, crucially impacting on the type III secretion system exposure at the cell surface, and consequently on bacterial virulence.[10] On the other hand, clinical *Shigella* infection protects against subsequent exposure to homologous serotypes, pointing to the O-Ag as the major target of the host adaptive immunity.[11,12] The key role played by *S. flexneri* O-Ags in bacterial virulence, resistance to innate immunity, added to the high resemblance amongst known *S. flexneri* O-Ag repeating units, a number of which are simple regioisomers, associated to the high burden of shigellosis and broad heterogeneous distribution of *S. flexneri* isolates encouraged us to investigate additional serotype-specific glucosylation patterns. Herein, focus is on *S. flexneri* 3a, one of the most prevalent *Shigella* serotypes. Interestingly, it was suggested that a bivalent *S. flexneri* 2a/*S. flexneri* 3a vaccine might confer protection against other serotypes.[13] Taking advantage of our experience on *S. flexneri* 2a and *S. flexneri* 5a, we reasoned that probing the role of O-Ag structure on bacterial properties might be best performed by use of well-defined synthetic fragments of the O-Ag. In this context, the following reports on the synthesis of fragments of *S. flexneri* serotype X and 3a O-Ags, which are defined by the branched

* Corresponding author. Tel.: +33 1 40 61 38 20; fax: +33 1 45 68 84 04.
E-mail address: laurence.mulard@pasteur.fr (L.A. Mulard).

0040-4020/$ – see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tet.2008.08.080

A B C D
2)-α-L-Rha*p*-(1–>2)-α-L-Rha*p*-(1–>3)-α-L-Rha*p*-(1–>3)-β-D-Glc*p*NAc-(1–> **(I)**

E A B C D
2)-[α-D-Glc*p*-(1–>3)]-α-L-Rha*p*-(1–>2)-α-L-Rha*p*-(1–>3)-α-L-Rha*p*-(1–>3)-β-D-Glc*p*NAc-(1–> **(II)**

E A B $_{Ac}$C D
2)-[α-D-Glc*p*-(1–>3)]-α-L-Rha*p*-(1–>2)-α-L-Rha*p*-(1–>3)-[2-OAc]-α-L-Rha*p*-(1–>3)-β-D-Glc*p*NAc-(1–> **(III)**

Figure 1. Repeating units of the O-Ags of *S. flexneri* serotypes Y (**I**), X (**II**), and 3a (**III**).

pentasaccharides **(E)ABCD** (**II**) and **(E)AB$_{Ac}$CD** (**III**),[5] respectively (Fig. 1). Noteworthy, *S. flexneri* X O-Ag is the non-*O*-acetylated form of *S. flexneri* 3a O-Ag.

2. Results and discussion

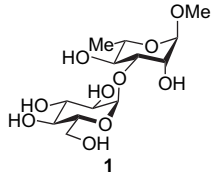
Following extensive synthetic work and investigation on *S. flexneri* Y O-Ag reported by others,[14,15] we focused on O-Ag fragments bearing serotype-specific substitutions.

Di- to pentasaccharides **3** (**EA**), **4** (**D(E)A**), **5** (**$_{Ac}$CD(E)A**), **6** (**CD(E)A**), **7** (**B$_{Ac}$CD(E)A**), **8** (**BCD(E)A**), all bearing rhamnoside **A** at their reducing end were synthesized as their propyl glycosides. Indeed, blocking the reducing end of the oligosaccharide targets in a form mimicking the natural linkages found in the O-Ag was thought important. Besides as a general rule, based on our previous experience in the *S. flexneri* 2a and 5a series,[16,8] all glycosylation steps relied on the highly efficient trichloroacetimidate (TCA) chemistry.[17] Since this mode of activation requires temporary masking of the anomeric hydroxyl, all fully protected intermediates were isolated as their allyl glycoside. This protecting pattern was selected for three reasons: (i) it is introduced in one high-yielding Fisher glycosylation step on commercially available L-rhamnose, (ii) it is fully orthogonal to most other conventional protecting groups used in glycochemistry, in particular *O*-acetyl, which was thought to be an essential parameter in the *S. flexneri* 3a series, and (iii) it is smoothly converted into propyl upon concomitant Pd/C-mediated benzyl hydrogenolysis. In addition, in order to ascertain the possible interference of the propyl aglycon with antibody binding, the methyl glycoside **2** (**D(E)A**) was synthesized in complement to disaccharide **1** (**EA**), previously isolated in the course of our study on *S. flexneri* 5a (Fig. 2).

2.1. Synthesis of trisaccharide 2 (Scheme 1)

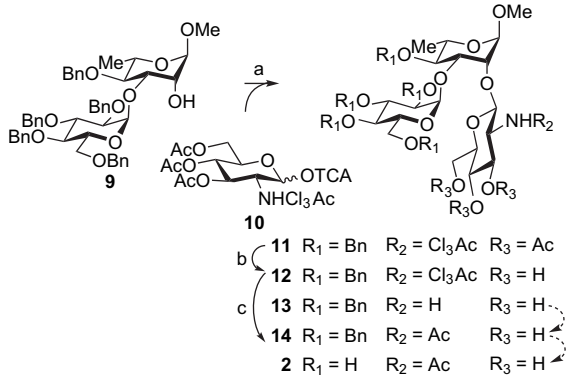
The synthetic strategy to methyl glycoside **2** derived from that developed early on when studying other *S. flexneri* serotypes. It relied on the condensation of the known disaccharide acceptor **9**[16] and the known trichloroacetimidate donor **10**,[18] bearing a *N*-trichloroacetyl protecting group, which was previously found efficient in terms of accessibility, condensation yield, and deprotection.

The latter was prepared from D-glucosamine hydrochloride according to the alternative protocol we recently disclosed (four steps, 76% overall yield).[19] The TMSOTf-promoted condensation



1

Figure 2. Structure of disaccharide **1**.

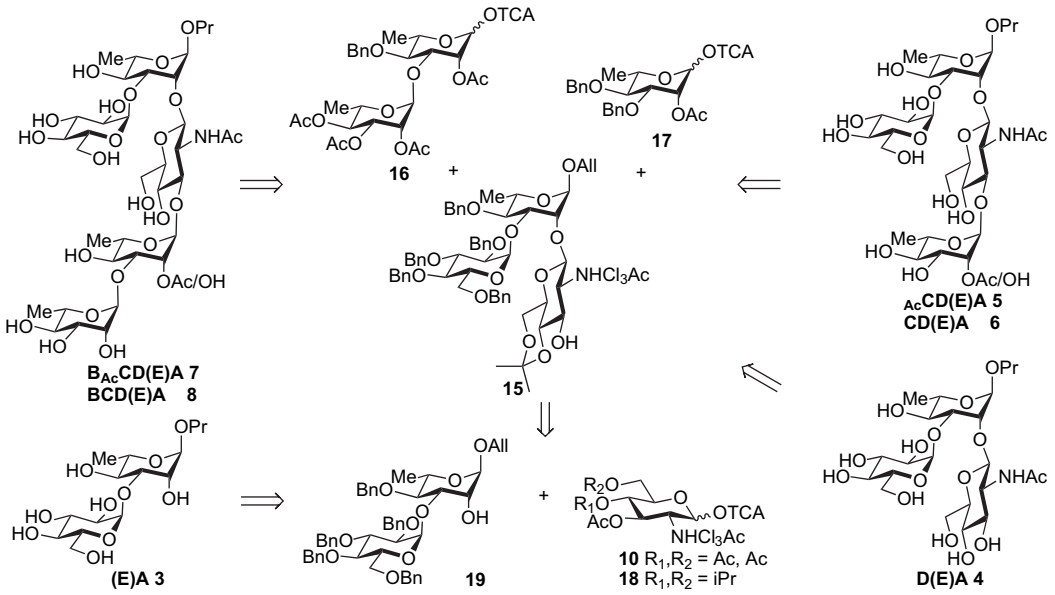


Scheme 1. Synthesis of the methyl glycoside **4**: (a) cat. TMSOTf, 4 Å MS, CH_2Cl_2, −30 °C→rt, 91%; (b) MeONa, CH_2Cl_2/MeOH, 89%; (c) (i) Pd/C, H_2, HCl, EtOH; (ii) Pd/C, H_2, Et_3N, EtOH, 53%.

between **9** and **10** was run in CH_2Cl_2 to give the fully protected trisaccharide **11** (91%). NMR analysis ($^3J_{1,2}$ (H-1$_D$)=8.9 Hz) ascertained the β-stereoselectivity of the coupling. Subsequent transesterification using MeONa in CH_2Cl_2/MeOH resulted in two products, one of which was the target triol **12** (89%). The aminotriol **13** issued from concomitant N-deprotection was clearly identified as a more polar side-product reacting with ninhydrin (ESI-MS: $C_{54}H_{65}NO_{14}$ 952.1084, found *m*/*z* 952.4432 $[M+H]^+$). Although opening an alternate route to target **2** via acetamide **14**, the trichloroacetamide to amine conversion was not investigated further at this stage. Alternatively, triol **12** was submitted to benzyl hydrogenolysis, followed by Pd/C-mediated hydrodechlorination under slightly basic medium,[9] as planned, to give **2** in 53% yield over two steps following HPLC purification. In fact, the present strategy is an alternative to the existing ones.[20,21] Both the glycosylation chemistry and glucosamine N-protection pattern we have selected differ from those previously reported. Interestingly, both orders of glycosylation at O-2 and O-3 of rhamnoside **A** were investigated successfully, even though the late 3-*O*-α-D-glucosylation suffered from poor α/β stereoselectivity yielding a mixture of trisaccharides, which could be separated only in their free form.[21] For that reason, we chose to introduce the α-D-glucosyl residue first. Interestingly, the yield of acceptor **9** is identical to that previously reported,[20] but the subsequent steps involving the glucosamine residue offer additional perspectives.

2.2. Retrosynthetic analysis of propyl glycosides 3, 4, 5, and 6 (Scheme 2)

Since targets **3**, **4**, **5**, **6**, and **8** are simply fragments of target **7**, the retrosynthetic analysis privileging a convergent approach focused on pentasaccharide **7**. More readily available intermediates, not necessarily compatible with chain elongation, were used to access shorter targets whenever relevant. Thus, tri- and tetrasaccharides, **4** and **5**, **6**, respectively, derived from the sequential introduction of each residue, whereas the synthesis of pentasaccharides **7** and **8**



Scheme 2. Retrosynthetic analysis of propyl glycosides **3**, **4**, **5**, **6**, **7**, and **8**.

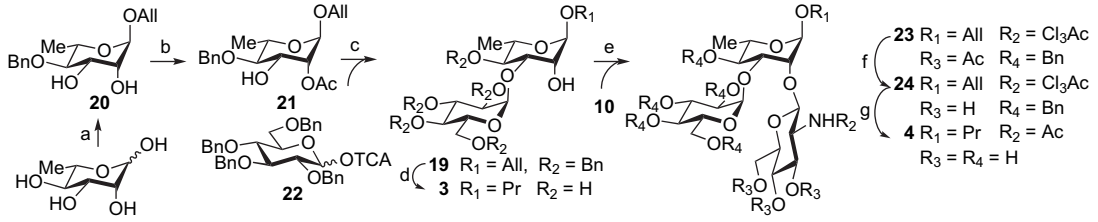
was through a convergent approach. Analogously to **9** for the synthesis of **2**, disaccharide **19**,[22] benzylated at all positions but OH-2_A, served as key precursor to the **EA** moiety involved in all targets. Relying on our recent study on precursors to 2-*N*-acetyl-3-*O*-glycosylated-β-D-glucopyranosyl residues, trichloroacetimidate donors **10** and **18**,[19] both *N*-trichloroacetylated, served as precursors to residue **D**. Trichloroacetimidate **17**,[23] featuring benzyl groups at position 3 and 4 and the critical serotype 3a-specific 2-*O*-acetyl moiety, which could serve advantageously for anchimeric assistance, was an ideal precursor to residue **C** involved in targets **5** and **6**. Finally, in the absence of any need for chain extension of the target pentasaccharides **7** and **8**, the tetra-*O*-acetyl rhamnobiose **16** was selected as an appropriate precursor to the **BC** fragment.

2.3. Synthesis of disaccharide 3 (Scheme 3)

Disaccharide **19** was previously used successfully in the course of our study on *S. flexneri* 5a oligosaccharides.[22] It was synthesized accordingly. Briefly, crystalline trichloroacetimidate **22**, easily obtained in one step from commercially available 2,3,4,6-tetra-*O*-benzyl-D-glucopyranose (76%),[24,25] was condensed with the crude allyl α-L-rhamnoside acceptor **21**[26] prepared from diol **20**[27,28] by conventional regioselective ring-opening of the intermediate orthoester into the kinetically favored axial acetate. The resulting 85:15 mixture of α- and β-condensation products was best separated after transesterification. Under the best conditions used (TMSOTf, toluene/CH_2Cl_2), alcohol **19** was isolated in 58% yield from diol **20**, a result which fully supports that previously described when running the condensation in a mixture of Et_2O and CH_2Cl_2.[22] The yield of **19** reached 61% when working on larger amounts, such as 8 g of key diol **20**, but could not be increased any further in contrast to that described by others.[29] Lastly, conventional Pd/C-mediated hydrogenolysis of **19** gave target **3** (83%). Interestingly, taking advantage of its crystalline form, diol **20** was made readily available in four steps involving one single crystallization. Overall, the 78% isolated yield obtained when starting from 20 g of L-rhamnose compares favorably with the previously reported 46% obtained following a closely related procedure.[28] The improvement mostly derived from the efficiency of the allylation process. Indeed, relying on the in situ generation of hydrogen chloride by action of allyl alcohol on acetyl chloride,[30] the allyl L-rhamnopyranoside was isolated in 98% yield as a clean 9:1 α/β mixture, following column chromatography.

2.4. Synthesis of trisaccharide 4 (Scheme 3)

The strategy to **4** followed that developed to obtain analogue **2**. Indeed, TMSOTf-promoted condensation of disaccharide acceptor **19** and tri-*O*-acetyl donor **10** provided intermediate **23**[19] in an excellent 92% yield. Subsequent transesterification using catalytic MeONa in MeOH was carefully controlled to avoid trichloroacetyl migration, and consequently unwanted N-deprotection. The resulting triol **24** (94%) was next submitted to conventional hydrogenolysis and subsequent Pd/C-mediated 2_D-trichloroacetamide reduction into the target acetamide **4** (69%) under slightly basic conditions.



Scheme 3. Synthesis of the propyl glycosides **3** and **4**: (a) (i) AllOH, AcCl; (ii) $Me_2C(OMe)_2$, APTS, acetone; (iii) NaH, BnBr, DMF; (iv) 80% aq AcOH, 60 °C, 78%; (b) (i) $MeC(OMe)_3$, APTS, CH_3CN; (ii) 80% aq AcOH; (c) (i) cat. TMSOTf, −78 °C→rt, toluene/CH_2Cl_2; (ii) MeONa, MeOH, 50 °C, 61%; (d) Pd/C, H_2, AcOH, EtOH, 83%; (e) cat. TMSOTf, 4 Å MS, −78 °C→rt, CH_2Cl_2, 92%; (f) MeONa, MeOH, rt, 94%; (g) (i) Pd/C, H_2, HCl, EtOH; (ii) Pd/C, H_2, Et_3N, EtOH, 69%.

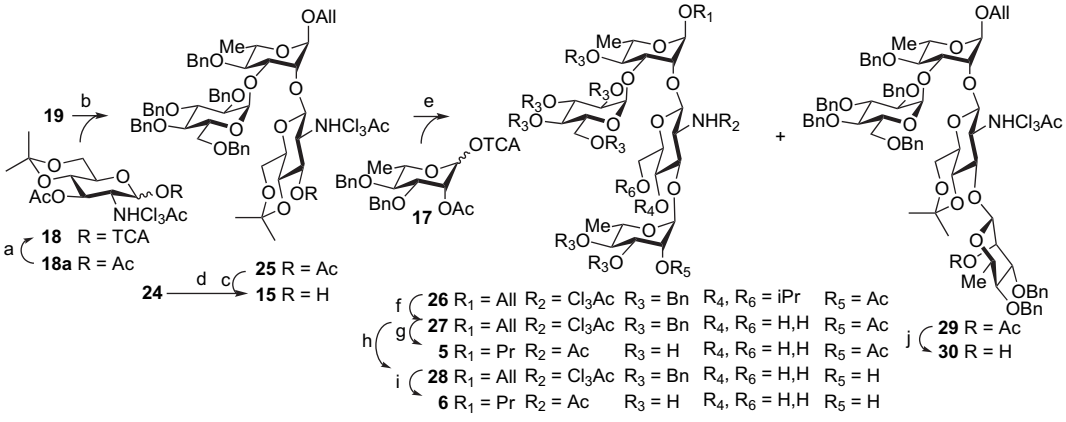
2.5. Synthesis of tetrasaccharides 5 and 6 (Scheme 4)

The simplest version involved regioselective acetalation of the available triol **24** into the corresponding 4,6-*O*-isopropylidene derivative **15** by use of 2-methoxypropene and CSA. However, considering the yield of the acetalation step (76%), we reasoned that the regioselective 4,6-O-protection could be introduced at an early stage. To our utmost satisfaction, coupling of acceptor **19** with the recently disclosed 4,6-*O*-isopropylidene glucosamine donor[19] **18**, prepared from diacetate[19] **18a** (80%), provided the pre-equipped trisaccharide **25**[19] in high yield (90%). Selective removal of the isolated acetate in **25** providing **15** (84%) was best performed using 0.2 equiv of methanolic sodium methoxide. Interestingly, trisaccharide **15**, having a free hydroxyl at position 3_D, proved to be rather sensitive to slightly acidic media resulting in partial loss of the isopropylidene acetal, as found out during NMR analysis. Clearly, ^{1}H NMR investigation suggested the in situ formation of an equilibrium between acceptor **15** and the resulting triol **24**, coexisting in a 65:35 ratio. Interestingly, identical treatment did not affect the fully protected precursor **25**. Running the two routes to **15** on a 5 g scale allowed their comparison. Both provided **15** in comparable overall yields starting from **19** (86% over three steps and 87% over two steps using donor **10** and donor **18**, respectively).

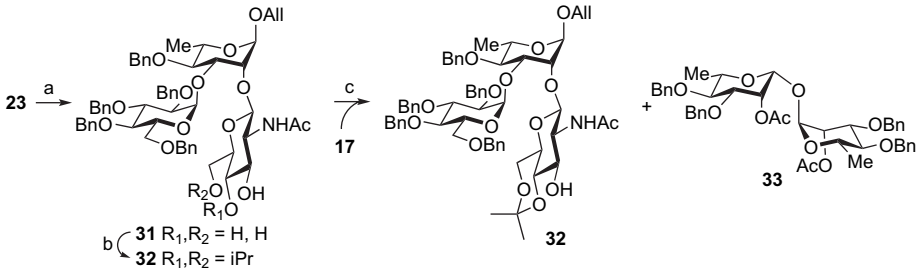
Condensation of trisaccharide **15** and the readily available rhamnosyl trichloroacetimidate **17** required optimization. Running the condensation in CH_2Cl_2 allowed the isolation of three products, among which the fully protected α-linked tetrasaccharide **26** (40%, $^1J_{C,H}$ (C-1_C)=169.1 Hz) and the corresponding diol **27** (22%, $^1J_{C,H}$ (C-1_C)=169.8 Hz) due to isopropylidene loss post condensation. Formation of **27** was ascertained from HMBC-NMR analysis, and confirmed following 50% aq TFA-mediated acetal removal of **26** (88%), which provided a diol whose spectral characteristics were identical to that of the above-mentioned **27**. Most interestingly, transesterification of the second side-product, migrating closely to the expected **26**, gave tetrasaccharide **30** having a β-**CD** interglycosidic linkage ($^1J_{C,H}$ (C-1_C)=156.6 Hz). Thus, formation of the fully protected β-**C**-linked isomer **29** occurred upon condensation of **15** and **17** in CH_2Cl_2 despite the presence of the acetate group at C-2_C thought to ensure α-selectivity. The lack of anchimeric assistance from 2-*O*-acetyl groups is not without precedents. Clearly addressed in various reports,[31–36] it may have several origins whether electronic, steric, or simply reaction conditions.[37,38] We reasoned that the solvent could play a critical role on the condensation outcome. Alternatives were thus investigated. Contrary to previous successful uses of Et_2O as solvent in glycosylation reactions involving **17** as donor,[39] formation of the expected tetrasaccharide **26** was not observed when reacting **15** and **17** in this solvent in the presence of a catalytic amount of TMSOTf. However, to our satisfaction, the target tetrasaccharide **26** and diol **27** were isolated in 58% and 21% yield, respectively, in the absence of any observed **29**, when the condensation between **15** and **17** was run in toluene (not described). Interestingly, our findings on the input of this solvent on the stereochemical outcome of the condensation support those reported for a closely related mannosyl trichloroacetimidate donor.[36] Besides, none of the regioisomers of **27** was isolated, ensuring that the isopropylidene hydrolysis occurred post coupling. Limiting any exaggerated loss of the acetal protecting group was the next step. This was best achieved by maintaining the reaction temperature at −78 °C to give **26** and **27** in 72% and 5% yield, respectively.

Considering the basic/acidic conditions involved, we reasoned that the two-step allyl reduction/hydrogenolysis-hydrodechlorination process used to convert triol **24** into target **4** was not appropriate to ensure the transformation of **27** into mono-*O*-acetylated **5**. Thus, in order to limit the risk of deacetylation at 2_C, Pd/C-mediated benzyl removal, allyl reduction, and concomitant trichloroacetamide conversion into acetamide were run in the absence of Et_3N at 45 bar under a hydrogen atmosphere. Completion of the hydrodechlorination step required 10 days, a duration which was demonstrated to be necessary at the pentasaccharide level (see below, synthesis of **7**). The mono-*O*-acetylated tetrasaccharide **5** was isolated as a mixture whereby the 2_C- and 3_C-*O*-acetyl isomers (76%) coexisted in a 70:30 equilibrium, based on NMR data. This result was anticipated, although exceptions do exist.[40] Alternatively, treatment of diol **27** in refluxing methanolic sodium methoxide gave triol **28** (85%), which was converted to target **6** (71%) as described for the preparation of **5**.

Taking advantage of the various ways allowing trichloroacetamide to acetamide conversion, the *N*-acetyl route was considered as a possible alternative to get **6**, possibly facilitating the final deprotection steps. For that reason, trichloroacetamide **23** was fully deacylated and converted to the acetamidotriol **31** (90%). Thus, taking into account our observations on the input of CH_2Cl_2 on the outcome of the deacylation process (see above, synthesis of **2**), the combination of reaction duration, amount of methanolic sodium methoxide, and CH_2Cl_2 volume providing the highest yielding transformation was investigated. Our findings outlined on this example the crucial importance of the CH_2Cl_2/0.5 M methanolic MeONa ratio, which was set to 8:1. Subsequent 4,6-O-isopropylidenation gave the acetamido acceptor **32** (85%). However, the latter reacted poorly when treated with donor **17** under the successful conditions set up for the trichloroacetamide



Scheme 4. Synthesis of tetrasaccharides **5** and **6**: (a) (i) ethylenediamine/AcOH, THF; (ii) CCl_3CN, DBU, −5 °C, DCE (80%); (b) cat. TMSOTf, 4 Å MS, −78 °C→rt, CH_2Cl_2, 90%; (c) MeONa, MeOH, rt, 84%; (d) H_2C=C(OMe)Me, CSA, DMF, 76%; (e) cat. TMSOTf, 4 Å MS, toluene, −78 °C→rt, 72%; (f) 50% aq TFA, CH_2Cl_2, 0 °C, 88%; (g) Pd/C, H_2, 45 bar, EtOH, 76%; (h) MeONa, MeOH, 50 °C, 85%; (i) Pd/C, H_2, 45 bar, EtOH, 71%; (j) MeONa, MeOH.



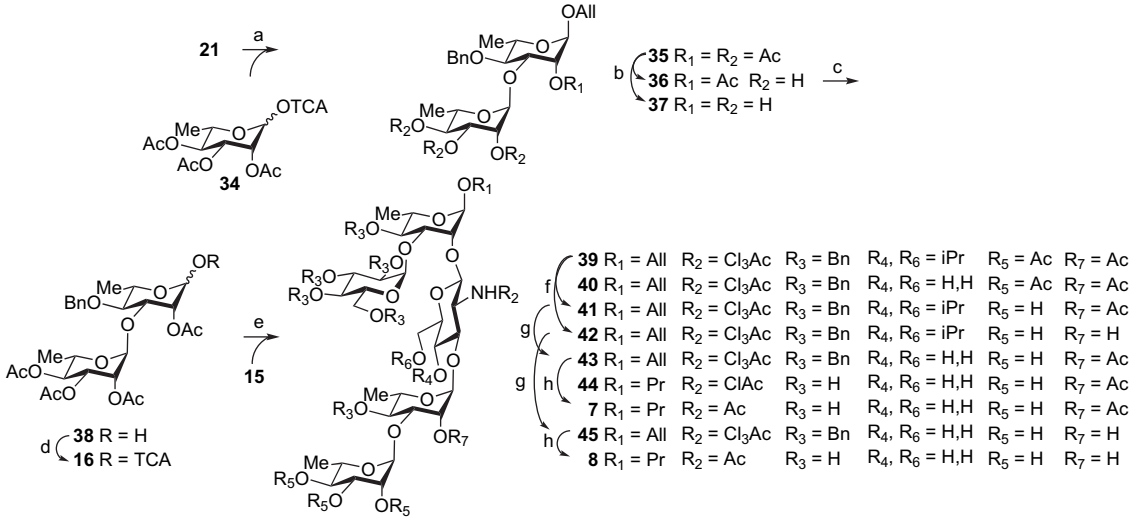
Scheme 5. Synthesis and attempted condensation of acceptor **32**: (a) MeONa, CH_2Cl_2/MeOH, 90%; (b) $H_2C{=}C(OMe)Me$, CSA, DMF, 85%; (c) cat. TMSOTf, 4 Å MS, −78 °C→rt, CH_2Cl_2.

analogue **15**. Interestingly, in addition to unreacted **32** (46%) and hydrolyzed donor, disaccharide **33** (22%) resulting from the donor autocondensation was isolated among other products (Scheme 5, not described). The (β1→α1)-linkage in **33** was ascertained based on the $^1J_{C,H}$ coupling constants and HMBC NMR analysis ($^1J_{C,H}$ (C-1_C)=159.1 Hz, $^1J_{C,H}$ (C-$1_{C'}$)=170.0 Hz). We have previously reported the successful condensation of 4-*O*-benzyl-2,3-di-*O*-acetyl-L-rhamnosyl trichloroacetimidate and allyl (2-acetamido-2-deoxy-4,6-*O*-isopropylidene-β-D-glucopyranosyl)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranoside,[22] and at this point we have no clear explanation for the strong difference observed in the behavior of acceptors **15** and **32**. This route was not investigated any further.

2.6. Synthesis of pentasaccharides 7 and 8 (Scheme 6)

Looking for the simplest precursor to residue **B**, we reasoned that in the absence of any requirement for chain elongation at this residue, we could take advantage of the known resistance of isolated 2-*O*-acetyl groups to Zemplén deacetylation conditions,[41] and therefore consider a regioselective transesterification step in the final deprotection process. Accordingly, the readily accessible triacetate **34**[42] was selected as an ideal rhamnosyl donor. TMSOTf-mediated condensation of **34** with allyl glycoside **21** gave rhamnobioside **35** (95%).

Preliminary investigation of various conditions allowing the regioselective transesterification of **35** (Table 1, not described) supported the use of the latter as precursor to residue **B**. Indeed, based on ^{1}H NMR estimation of the **36**/**37** ratio, triol **36** (δ=2.15 ppm) was obtained as a 7:3 mixture with tetraol **37** (δ=5.90 ppm) upon treatment of **35** in methanolic K_2CO_3. Consequently, **35** was deallylated according to the cationic iridium based two-step process:[46] (i) isomerization of the allyl group under catalysis with 1,5-cyclooctadienebis(methyldiphenyl-phosphine)iridium hexafluorophosphate complex, and (ii) subsequent hydrolysis of the resulting prop-1-enyl ether.[47] The resulting hemiacetal **38** (91%) was readily converted into trichloroacetimidate **16** (89%) by reaction with trichloroacetonitrile in the presence of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU). Analogously to our observations at the tetrasaccharide level, TMSOTf-mediated condensation of trisaccharide **15** and donor **16**, run at −78 °C in toluene, gave the fully protected **39** ($^1J_{C,H}$ (C-1_C)=170.5 Hz) and diol **40** in a 9:1 ratio (87%), illustrating once more the high efficiency of the coupling conditions despite the sensitivity of the 4_D,6_D-*O*-isopropylidene to the acidic medium. As above, HMBC NMR analysis of **40** ensured that the condensation had taken place at OH-3_D, an observation also confirmed upon subsequent re-acetalation. As expected, treatment of **39** with K_2CO_3 in methanol provided triol **41** (85%) and tetraol **42** (7%). The improved 9:1 triol/tetraol ratio obtained at the pentasaccharide stage, in comparison to the 7:3 ratio seen at the disaccharide level, most probably reflects the increased steric hindrance at 2_C in **39** versus **35**. Acidic hydrolysis of **41** gave pentaol **43** (95%), which was subsequently converted to 2_C-*O*-acetylated pentasaccharide **7** (75%) upon treatment with Pd/C under 45 bar of hydrogen for 10 days. Although somewhat unusual, this duration was required for completion of the trichloroacetamide transformation. Indeed, NMR and mass spectrometry follow-up of the later indicated a two-step kinetics. Total conversion into the corresponding chloroacetamide **44** (ESI-MS MW=940.3429, found *m*/*z* 940.3425, δ_{CH_2Cl}=4.10 ppm) was observed after 2 days. The



Scheme 6. Synthesis of pentasaccharides **7** and **8**: (a) cat. TMSOTf, 4 Å MS, −78 °C→rt, CH_2Cl_2, 95%; (b) K_2CO_3, MeOH; (c) (i) cat. $[Ir(COD)\{PCH_3(C_6H_5)_2\}_2]^+PF_6^-$, THF, rt; (ii) I_2, THF/H_2O, rt, 91%; (d) CCl_3CN, DBU, DCE, −5 °C, 15 min, 89%; (e) cat. TMSOTf, 4 Å MS, −78 °C, toluene, 15 min, 87%; (f) K_2CO_3, MeOH, 25 min, 85% **41**, 7% **42**; (g) 50% aq TFA, CH_2Cl_2, 0 °C, 95%; (h) Pd/C, H_2, 45 bar, EtOH, 75% **7**, 71% **8**.

Table 1
Regioselective de-O-acetylation of **35** into **36**

Entry	Conditions	Temperature/time	Ratio **36**/**37**
1[41]	NaOMe/MeOH 0.2 equiv	rt[a]/2 h 30 min	60:40
2	NaOMe/MeOH 0.2 equiv	0 °C/2 days	n.d.[b]
3[43]	NEt_3/MeOH/H_2O 3.8 equiv	0 °C/2 days	55:45
4[44]	K_2CO_3/MeOH 1 equiv	rt/15 min	70:30
5	K_2CO_3/MeOH 1 equiv	0 °C/1 h 30 min	65:35
6[45]	HBF_4/Et_2O/MeOH 6.4 equiv	rt/7 days	n.d.

[a] rt: room temperature.
[b] n.d.: not determined.

conversion of the later into target **7** was much slower. Interestingly, the successful Pd/C-mediated trichloroacetamide to acetamide conversion under medium pressure of hydrogen was reported previously.[48] Finally, tetraol **42** was treated analogously to **43** to give first the hexaol intermediate **45** (95%) and then target **8** (71%).

3. Conclusion

The high yielding synthesis of seven di- to pentasaccharide fragments of *S. flexneri* 3a O-Ag, all bearing residue **A** at their reducing end and sharing the α-D-glucosyl-(1→3)-α-L-rhamnosyl (**EA**) serotype-specific branching pattern is disclosed. The efficiency of the strategy relied on the combined use of (i) the trichloroacetimidate chemistry and its compatibility with the 4,6-*O*-isopropylidene moiety provided that glycosylation reactions are run at −78 °C to minimize acetal hydrolysis, (ii) toluene as solvent for the glycosylation reactions, (iii) the allyl aglycone as temporary/permanent anomeric protection, and (iv) the trichloroacetyl moiety as the N-protecting pattern of the glucosamine residue **D**, and its convenient conversion to the *N*-acetyl group under Pd-mediated neutral hydrodechlorination conditions run at 45 bar of hydrogen. These oligosaccharides represent the first set of tools required to investigate the fine specificity of *S. flexneri* 3a O-Ag recognition by protective antibodies.

4. Experimental

4.1. General methods

TLC was performed on precoated slides of silica gel 60 F_{254} (Merck). Detection was effected when applicable, with UV light and/or by charring in orcinol (35 mM) in 4 N aq sulfuric acid and ethanol (95:5). Preparative chromatography was performed by elution from columns of silica gel 60 (particle size 0.040–0.063 mm). NMR spectra were recorded at 30 °C for solutions in $CDCl_3$ or D_2O (400 MHz for ^1H, 100 MHz for ^{13}C). Residual $CHCl_3$ (7.28 ppm for ^1H and 77.0 ppm for ^{13}C), and HOD (4.79 ppm) were used as internal references for solutions in $CDCl_3$ and D_2O, respectively. Proton-signal assignments were made by first-order analysis of the spectra, as well as analysis of 2D ^1H–^1H correlation maps (COSY). Of the two magnetically non-equivalent geminal protons at C-6, the one resonating at lower field is denoted H-6a and the one at higher field is denoted H-6b. The ^{13}C NMR assignments were supported by 2D ^{13}C–^1H correlations maps (HMBC and HSQC). Interchangeable assignments are marked with an asterisk in the listing of signal assignments. Sugar residues are serially lettered according to the lettering of the repeating unit of the *S. flexneri* 3a O-SP and identified by a subscript in the listing of signal assignments. Additional abbreviation in the listing of signal assignments includes NTCA, which stands for trichloroacetamide whereas in the schemes OTCA stands for trichloroacetimidate. Electrospray Ionization-Time of flight (ESI-TOF) mass spectra were recorded in the positive-ion mode using a 1:1 acetonitrile (CH_3CN)/water containing 0.1% formic acid ESI-TOF spectrometer-solution. Melting points were determined in capillary tubes with an electrothermal apparatus and are uncorrected. Anhydrous dichloromethane (CH_2Cl_2) and 1,2-dichloroethane (DCE) sold on molecular sieves were used as such. Powder molecular sieves (4 Å) were activated before use by heating at 250 °C under vacuum. Additional solvents commonly cited in the text are abbreviated as Chex (Cyclohexane) and Tol (Toluene).

4.2. Methyl (3,4,6-tri-*O*-acetyl-2-deoxy-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (11)

TMSOTf (14 μL, 81 μmol) was added to a solution of disaccharide **9** (321 mg, 406 μmol) and trichloroacetimidate **10** (314 mg, 487 μmol) in CH_2Cl_2 (2.2 mL) containing 4 Å molecular sieves (400 mg), stirred at −30 °C. The reaction mixture allowed to come back to rt, at which time TLC (Chex/EtOAc, 7:3) showed the complete disappearance of acceptor **9**. Et_3N (500 μL) was added. The mixture was filtered and concentrated to dryness. Chromatography of the residue (Chex/EtOAc, 9:1) gave the condensation product **11** (450 mg, 91%). Trisaccharide **11** had R_f=0.35 (Chex/EtOAc, 7:3); ^1H NMR ($CDCl_3$): δ 7.41–7.04 (m, 26H, NH_{NTCA}, CH_{Ph}), 5.16 (br s, 3H, H-1_E, 2H_{Bn}), 5.05 (s, 2H, H_{Bn}), 5.02 (pt, 1H, $J_{3,4}$=9.7 Hz, H-4_D), 4.81 (dd, 1H, $J_{2,3}$=9.5 Hz, H-3_D), 4.79 (d, 1H, $J_{1,2}$=8.9 Hz, H-1_D), 4.76 (d, 1H, J=11.0 Hz, H_{Bn}), 4.69 ($d_{overlapped}$, 1H, H-1_A), 4.68 ($d_{overlapped}$, 1H, H_{Bn}), 4.55 (d, 2H, J=11.6 Hz, H_{Bn}), 4.45 (d, 1H, J=11.0 Hz, H_{Bn}), 4.29 (d, 1H, J=11.9 Hz, H_{Bn}), 4.20 (m, 1H, H-2_D), 4.15–4.03 (m, 5H, H-3_A, H-3_E, H-5_E, H-6a$_D$, H-6b$_D$), 3.96 (dd, 1H, H-2_A), 3.90 (dd, 1H, $J_{1,2}$=3.6 Hz, $J_{2,3}$=9.7 Hz, H-2_E), 3.77 (dd, 1H, $J_{4,5}$=10.0 Hz, H-4_E), 3.68 (dq, 1H, $J_{4,5}$=9.4 Hz, H-5_A), 3.44 (pt, 1H, $J_{3,4}$=9.5 Hz, H-4_A), 3.38 (m, 2H, H-6a$_E$, H-6b$_E$), 3.36 (s, 3H, OMe), 2.93 (m, 1H, $J_{5,6a}$=2.7 Hz, $J_{5,6b}$=4.2 Hz, H-5_D), 2.12, 2.03, 2.02 (3s, 9H, H_{Ac}), 1.41 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$); ^{13}C NMR ($CDCl_3$): δ 171.0, 179.5 (3C, C_{Ac}), 162.4 (C_{NTCA}), 139.0–127.7 (C_{Ph}), 101.3 (C-1_D), 100.2 (C-1_A), 95.0 (C-1_E), 93.1 (CCl_3), 83.8 (C-3_E), 80.1 (C-4_A), 79.4 (C-2_E), 79.0 (C-4_E), 76.4, 75.6, 75.3 (3C, C_{Bn}), 75.0 (C-3_A), 74.8 (C-2_A), 74.3, 73.8 (2C, C_{Bn}), 73.6 (C-3_D), 72.0 (C-5_D), 70.2 (C-5_E), 68.4, 68.3 (2C, C-5_A, C-4_D), 68.2 (C-6_E), 62.0 (C-6_D), 56.0 (C-2_D), 54.9 (OMe), 21.1, 21.0 (3C, C_{Ac}), 18.3 (C-6_A).

4.3. Methyl (2-deoxy-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (12)

A 0.5 M methanolic solution of sodium methoxide (900 μL) was added to a solution of **11** (358 mg, 292 μmol) in MeOH/CH_2Cl_2 (2:3, 6.5 mL). The mixture was stirred at rt over 48 h. TLC showed the complete disappearance of starting **11** (Chex/EtOAc, 7:3) and the presence of one major more polar product (CH_2Cl_2/MeOH, 19:1), together with a minor one, which reacted when charring with ninhydrin. Neutralization with Dowex X8-200 ion exchange resin (H^+) was followed by filtration and concentration of the filtrate. Column chromatography of the residue (CH_2Cl_2/MeOH, 19:1→9:1) gave **12** (188 mg, 89%). Trichloroacetamide **12** had R_f=0.34 (CH_2Cl_2/MeOH, 19:1); ^1H NMR ($CDCl_3$): δ 7.45–7.06 (m, 26H, NH_{NTCA}, CH_{Ph}), 5.10 (d, 1H, $J_{1,2}$=3.6 Hz, H-1_E), 5.08 (d, 1H, J=11.2 Hz, H_{Bn}), 5.03 (d, 1H, H_{Bn}), 5.00 (d, 1H, J=12.2 Hz, H_{Bn}), 4.89 (d, 1H, H_{Bn}), 4.78 (d, 1H, J=11.2 Hz, H_{Bn}), 4.77 (br s, 1H, H-1_A), 4.73 (d, 1H, J=10.2 Hz, H_{Bn}), 4.68 (d, 1H, $J_{1,2}$=8.2 Hz, H-1_D), 4.57 (d, 1H, J=12.0 Hz, H_{Bn}), 4.55 (d, 1H, J=10.4 Hz, H_{Bn}), 4.47 (d, 1H, J=11.1 Hz, H_{Bn}), 4.31 (d, 1H, J=12.0 Hz, H_{Bn}), 4.14–4.07 (m, 3H, H-3_A, H-3_E, H-5_E), 4.03 (dd, 1H, H-2_A), 3.88–3.74 (m, 5H, H-2_D, H-6a$_D$, H-6b$_D$, H-2_E, H-4_E), 3.68 (dq, 1H, $J_{4,5}$=9.4 Hz, H-5_A), 3.56 (pt, 1H, H-4_D), 3.56 (pt, 1H, $J_{3,4}$=9.6 Hz,

H-4$_A$), 3.43 (m, 2H, H-6a$_E$, H-6b$_E$), 3.35 (s, 3H, OMe), 3.02 (m, 1H, $J_{5,6a}$=3.1 Hz, $J_{5,6b}$=3.4 Hz, $J_{4,5}$=9.5 Hz, H-5$_D$), 2.65 (m, 1H, H-3$_D$), 1.41 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$); ^{13}C NMR ($CDCl_3$): δ 164.1 (C$_{NTCA}$), 138.9–127.7 (C$_{Ph}$), 101.3 (C-1$_D$), 100.4 (C-1$_A$), 94.9 (C-1$_E$), 93.0 (CCl_3), 83.6 (C-3$_E$), 80.2 (C-4$_A$), 79.4, 79.0 (2C, C-2$_E$, C-4$_E$), 76.5 (C$_{Bn}$), 73.6 (C-3$_D$), 75.7 (2C, C-5$_D$, C$_{Bn}$), 75.3 (2C, C$_{Bn}$), 74.8 (C-3$_A$), 74.2 (C-2$_A$), 73.8 (C$_{Bn}$), 71.3 (C-4$_D$), 70.2 (C-5$_E$), 68.5 (C-5$_A$), 68.3 (C-6$_E$), 62.2 (C-6$_D$), 58.5 (C-2$_D$), 55.0 (OMe), 18.3 (C-6$_A$); HRMS (ESI$^+$) for $C_{56}H_{64}Cl_3NO_{18}$ ([M+H]$^+$, 1096.3419) found *m*/*z* 1270.3423 ([M+NH$_4$]$^+$, 1115.3674) found *m*/*z* 1115.3638.

The side-product, identified as **13**, had R_f=0.2 (CH_2Cl_2/MeOH, 19:1), HRMS (ESI$^+$) for $C_{54}H_{65}NO_{14}$ ([M+H]$^+$, 952.4483) found *m*/*z* 952.4432.

4.4. Methyl (2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→2)-[α-D-glucopyranosyl-(1→3)]-α-L-rhamnopyranoside (2)

A solution of **12** (114 mg, 104 μmol), in 95% EtOH (10 mL) containing 1 M HCl (80 μL) was hydrogenated in the presence of Pd/C (80 mg) for 2 h at rt, at which time TLC (*i*-PrOH/NH_3/H_2O, 4:1:2) showed the complete disappearance of the triol. The mixture was filtered and concentrated. A solution of the residue in 95% EtOH (10 mL) and Et_3N (80 μL) was hydrogenated in the presence of Pd/C catalyst (80 mg) for 2 h at rt. The mixture was filtered and concentrated. RP-HPLC purification of the residue (Kromasil 5 μm C18 100 Å 10×250 mm column, 215 nm, 0–20% linear gradient over 20 min of CH_3CN in 0.01 M aq TFA at 1 mL/min flow rate) provided **2** as a freeze-dried powder (30 mg, 53%). ^{1}H NMR (D_2O): δ 8.09 (d, 1H, $J_{2,NH}$=9.7 Hz, NH), 5.10 (d, 1H, $J_{1,2}$=3.1 Hz, H-1$_E$), 4.80 (br s$_{overlapped}$, 1H, H-1$_A$), 4.79 (d$_{overlapped}$, 1H, $J_{1,2}$=7.7 Hz, H-1$_D$), 4.23 (br s, 1H, H-2$_A$), 4.00 (m, 1H, H-5$_E$), 3.88 (br d, 1H, $J_{6a,6b}$=12.4 Hz, H-6a$_E$), 3.83 (pt, 1H, H-3$_A$), 3.80 (pt, 1H, H-3$_E$), 3.78–3.61 (m, 7H, H-2$_D$, H-6a$_D$, H-6b$_D$, H-2$_E$, H-6b$_E$, H-5$_A$), 3.46 (pt, 1H, $J_{3,4}$=$J_{4,5}$=9.5 Hz, H-4$_E$), 3.40–3.36 (m, 3H, H-3$_D$, H-4$_D$, H-5$_D$), 3.35 (s, 3H, OMe), 3.32 (pt, 1H, $J_{3,4}$=$J_{4,5}$=9.6 Hz, H-4$_A$), 2.07 (s, 3H, H$_{Ac}$), 1.26 (d, 3H, $J_{5,6}$=6.0 Hz, H-6$_A$); ^{13}C NMR (D_2O): δ 174.5 (C$_{Ac}$), 101.9 (C-1$_D$), 99.9 (C-1$_A$), 94.7 (C-1$_E$), 76.0 (C-4$_D$), 74.3 (C-3$_D$), 74.0 (2C, C-2$_A$, C-3$_A$), 73.1 (C-3$_E$), 71.5 (C-5$_E$), 71.3 (C-2$_E$), 70.9 (C-4$_A$), 69.8 (C-5$_D$), 69.4 (C-4$_E$), 68.8 (C-5$_A$), 60.7 (C-6$_D$), 60.3 (C-6$_E$), 55.7 (C-2$_D$), 54.8 (OMe), 22.7 (C$_{Ac}$), 16.8 (C-6$_A$). HRMS (ESI$^+$) for $C_{21}H_{37}NO_{15}$ ([M+H]$^+$, 544.2241) found *m*/*z* 544.2259.

4.5. Propyl α-D-glucopyranosyl-(1→3)-α-L-rhamnopyranoside (3)

The benzylated disaccharide **19** (500 mg, 0.61 mmol) was dissolved in a 9:1 EtOH/acetic acid mixture (24 mL), treated with 10% Pd/C catalyst (420 mg), and the suspension was stirred at rt for 1 night under a hydrogen atmosphere. At this time, TLC (*i*-PrOH/H_2O/NH_3, 4:1:0.5) showed that **19** had been transformed into a major polar product. The suspension was filtered on a bed of Celite and the filtrate was concentrated. Reverse phase chromatography (H_2O/CH_3CN, 100:0→70:30) of the residue, followed by freeze-drying, gave target **3** (187 mg, 83%) as a white foam. Disaccharide **3** had R_f=0.6 (*i*-PrOH/H_2O/NH_3, 7:1:2); δ ^{1}H NMR (D_2O): δ 5.03 (d, 1H, $J_{1,2}$=3.8 Hz, H-1$_E$), 4.81 (d, 1H, $J_{1,2}$=1.6 Hz, H-1$_A$), 4.10 (dd, 1H, $J_{2,3}$=2.2 Hz, H-2$_A$), 3.92 (m, 1H, H-5$_E$), 3.80–3.70 (m, 5H, H-3$_A$, H-3$_E$, H-6a$_E$, H-6b$_E$, H-5$_A$), 3.62 (m, 1H, H$_{Pr}$), 3.56–3.45 (m, 3H, H-2$_E$, H-4$_A$, H$_{Pr}$), 3.42 (pt, 1H, $J_{3,4}$=9.3 Hz, H-4$_E$), 1.63 (m, 2H, CH_2), 1.27 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$), 0.88 (t, 3H, J=7.4 Hz, CH_3); ^{13}C NMR (D_2O): δ 99.6 (C-1$_A$, $^1J_{CH}$=170.2 Hz), 95.9 (C-1$_E$, $^1J_{CH}$=172.7 Hz), 76.1 (C-3$_A$), 73.3 (C-3$_E$), 72.1 (C-5$_E$), 71.8 (C-2$_E$), 70.7 (C-4$_A$), 70.0 (C$_{Pr}$), 69.8 (C-4$_E$), 69.0 (C-5$_A$), 67.3 (C-2$_A$), 60.7 (C-6$_E$), 22.4 (CH_2), 17.1 (C-6$_A$), 10.3 (CH_3); HRMS (ESI$^+$) for $C_{15}H_{28}NO_{10}$ ([M+Na]$^+$, 391.1580) found *m*/*z* 391.1556.

4.6. Allyl (3,4,6-tri-*O*-acetyl-2-deoxy-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (23)

TMSOTf (40 μL, 230 μmol, 0.2 equiv) was added to a solution of disaccharide **19**[22] (0.92 g, 1.13 mmol) and trichloroacetimidate **10**[18] (0.8 g, 1.35 mmol, 1.2 equiv) in CH_2Cl_2 (24 mL) containing 4 Å molecular sieves (1 g), stirred at −78 °C. The reaction mixture was stirred for 3 h. TLC (Chex/EtOAc, 7:3) showed the complete disappearance of acceptor **19**.[22] Et_3N (1 mL) was added. The mixture was filtered and concentrated to dryness. Chromatography of the residue (Chex/EtOAc, 8:2→7:3) gave the condensation product **23** (1.3 g, 92%) as a white foam. Trisaccharide **23** had R_f=0.2 (Chex/EtOAc, 7:3); ^{1}H NMR ($CDCl_3$): δ 7.40–7.03 (m, 26H, NH$_{NTCA}$, CH$_{Ph}$), 5.88 (m, 1H, CH=), 5.29 (m, 1H, J_{trans}=17.2 Hz, =CH$_2$), 5.20 (m, 1H, J_{cis}=10.4 Hz, =CH$_2$), 5.22–5.16 (m, 3H, H-1$_E$, 2H$_{Bn}$), 5.06 (s, 2H, H$_{Bn}$), 5.01 (pt, 1H, $J_{3,4}$=9.7 Hz, H-4$_D$), 4.85 (d, 1H, $J_{1,2}$=1.5 Hz, H-1$_A$), 4.86–4.75 (m, 3H, H-1$_D$, H-3$_D$, H$_{Bn}$), 4.72 (d, 1H, J=10.1 Hz, H$_{Bn}$), 4.55 (m, 2H, H$_{Bn}$), 4.45 (d, 1H, J=10.9 Hz, H$_{Bn}$), 4.30 (d, 1H, J=12.0 Hz, H$_{Bn}$), 4.25–4.12 (m, 4H, H-2$_D$, H-3$_A$, H-3$_E$, H$_{All}$), 4.07–3.99 (m, 3H, H-6a$_D$, H-6b$_D$, H-5$_E$), 3.98–3.90 (m, 2H, H-2$_A$, H$_{All}$), 3.91 (dd, 1H, $J_{1,2}$=3.6 Hz, H-2$_E$), 3.80 (pt, 1H, $J_{3,4}$=9.2 Hz, H-4$_E$), 3.71 (m, 1H, H-5$_A$), 3.45 (pt, 1H, $J_{3,4}$=9.8 Hz, H-4$_A$), 3.37 (m, 2H, H-6a$_E$, H-6b$_E$), 2.94 (m, 1H, H-5$_D$), 2.12, 2.02 (2s, 9H, H$_{Ac}$), 1.40 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$); ^{13}C NMR ($CDCl_3$): δ 170.6, 170.5, 169.1 (3C, C$_{Ac}$), 161.9 (C$_{NTCA}$), 138.5–137.6 (C$_{Ph}$), 133.7 (CH=), 128.9–127.2 (CH$_{Ph}$), 117.2 (=CH$_2$), 100.8 (C-1$_D$, $^1J_{CH}$=161.0 Hz), 98.1 (C-1$_A$, $^1J_{CH}$=172.2 Hz), 94.5 (C-1$_E$, $^1J_{CH}$=165.5 Hz), 92.7 (CCl_3), 83.4 (C-3$_E$), 79.6 (C-4$_A$), 78.9 (C-2$_E$), 78.5 (C-4$_E$), 76.0, 75.1, 74.8 (3C, C$_{Bn}$), 74.6 (C-3$_A$), 74.4 (C-2$_A$), 73.9, 73.3 (2C, C$_{Bn}$), 73.1 (C-3$_D$), 71.6 (C-5$_D$), 69.8 (C-5$_E$), 68.1 (C-5$_A$), 67.9 (C$_{All}$), 67.8 (C-4$_D$), 67.7 (C-6$_E$), 61.6 (C-6$_D$), 55.5 (C-2$_D$), 20.7, 20.6, 20.5 (3C, C$_{Ac}$), 17.8 (C-6$_A$); HRMS (ESI$^+$) for $C_{64}H_{72}Cl_3NO_{18}$ ([M+Na]$^+$, 1270.3713) found *m*/*z* 1270.3662, ([M+NH$_4$]$^+$, 1265.4159) found *m*/*z* 1265.4180.

4.7. Allyl (2-deoxy-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (24)

Methanolic MeONa (0.5 M, 0.16 mL, 0.08 mmol, 0.2 equiv) was added to a solution of **23** (0.5 g, 0.4 mmol) in MeOH (3 mL), and the mixture was stirred for 30 min. TLC (CH_2Cl_2/MeOH, 9.5:0.5) showed the complete disappearance of the triacetate and the presence of a single more polar product. The mixture was neutralized by addition of Dowex X8-200 ion exchange resin (H^+) and filtered. Evaporation of the filtrate gave a syrup, which was chromatographed (CH_2Cl_2/MeOH, 99:1→96:4) to give compound **24** (0.42 g, 94%) as a white foam. Triol **24** had R_f=0.3 (CH_2Cl_2/MeOH, 7:3); ^{1}H NMR ($CDCl_3$): δ 7.38–7.06 (m, 26H, NH, CH$_{Ph}$), 5.88 (m, 1H, CH=), 5.29 (m, 1H, J_{trans}=17.2 Hz, =CH$_2$), 5.20 (m, 1H, J_{cis}=10.4 Hz, =CH$_2$), 5.10 (d, 1H, $J_{1,2}$=3.7 Hz, H-1$_E$), 5.07 (m, 3H, J=10.0 Hz, H$_{Bn}$), 4.90–4.87 (m, 2H, H-1$_A$, H$_{Bn}$), 4.79–4.70 (m, 2H, J=11.0 Hz, H$_{Bn}$), 4.62 (d, 1H, $J_{1,2}$=8.3 Hz, H-1$_D$), 4.61–4.46 (m, 3H, J=11.0 Hz, H$_{Bn}$), 4.30 (d, 1H, J=12.0 Hz, H$_{Bn}$), 4.17–4.09 (m, 4H, H-3$_A$, H-5$_E$, H$_{All}$, H-3$_E$), 4.01 (m, 2H, H-2$_A$, H$_{All}$), 3.84–3.78 (m, 5H, H-2$_E$, H-4$_E$, H-2$_D$, H-6a$_D$, H-6b$_D$), 3.63 (m, 1H, H-5$_A$), 3.51 (pt, H, $J_{3,4}$=9.2 Hz, H-4$_D$), 3.44 (m, 3H, H-4$_A$, H-6a$_E$, H-6b$_E$), 3.01 (m, 2H, H-5$_D$, OH), 2.57 (pt, 1H, $J_{2,3}$=9.6 Hz, H-3$_D$), 2.56 (br s, 1H, OH), 1.40 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$); ^{13}C NMR ($CDCl_3$): δ 164.4 (C$_{NTCA}$), 138.9–137.8 (C$_{Ph}$), 129.5 (CH=), 129.1–127.7 (CH$_{Ph}$), 117.7 (=CH$_2$), 101.3 (C-1$_D$, $^1J_{CH}$=160.3 Hz), 98.6 (C-1$_A$, $^1J_{CH}$=171.6 Hz), 94.8 (C-1$_E$, $^1J_{CH}$=166.4 Hz), 92.9 (CCl_3), 83.6 (C-3$_E$), 80.2 (C-4$_A$), 79.5, 79.0 (2C, C-2$_E$, C-4$_E$), 76.6 (C$_{Bn}$), 76.0 (C-3$_D$), 75.6 (C$_{Bn}$), 75.5 (C-5$_D$), 75.4, 75.3 (2C, C$_{Bn}$), 74.8 (C-3$_A$), 74.6 (C-2$_A$), 73.8 (C$_{Bn}$), 71.6 (C-4$_D$), 70.3 (C-5$_E$), 68.7 (C-5$_A$), 68.3 (C$_{All}$), 66.2 (C-

6_E), 62.4 (C-6_D), 58.6 (C-2_D), 18.3 (C-6_A); HRMS (ESI^+) for $C_{58}H_{66}Cl_3NO_{15}$ ($[M+Na]^+$, 1144.3396) found *m*/*z* 1144.3389, ($[M+NH_4]^+$, 1139.3842) found *m*/*z* 1139.3890.

4.8. Propyl (2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→2)-[α-D-glucopyranosyl-(1→3)]-α-L-rhamnopyranoside (4)

The benzylated trisaccharide **24** (412 mg, 0.36 mmol) was dissolved in 95% EtOH (30 mL) containing 1 M aq HCl (200 μL), treated with 10% Pd/C catalyst (280 mg), and the suspension was stirred at rt for 1 night under a hydrogen atmosphere. At this time, TLC (*i*-PrOH/H_2O/NH_3, 4:1:0.5) showed that **24** had been transformed into a major polar product. The suspension was filtered on a bed of Celite and the filtrate was concentrated. A solution of the residue in EtOH (30 mL) and Et_3N (153 μL, 1.1 mmol, 3 equiv) was treated with 10% Pd/C catalyst (280 mg), and the suspension was stirred at rt for 1 night under a hydrogen atmosphere. TLC (*i*-PrOH/H_2O/NH_3, 4:1:0.5) showed that the intermediate trichloroacetamide had been transformed into a major polar product. The suspension was filtered on a bed of Celite and the filtrate was concentrated. Reverse phase chromatography (H_2O/CH_3CN, 100:0→70:30) of the residue, followed by freeze-drying, gave target **4** (144 mg, 69%) as a white foam. Trisaccharide **4** had R_f=0.45 (*i*-PrOH/H_2O/NH_3, 7:1:2); δ ^{1}H NMR (D_2O): δ 5.10 (d, 1H, $J_{1,2}$=3.7 Hz, H-1_E), 4.89 (d, 1H, $J_{1,2}$=1.8 Hz, H-1_A), 4.79 (d, 1H, $J_{1,2}$=8.5 Hz, H-1_D), 4.23 (dd, 1H, $J_{2,3}$=2.3 Hz, H-2_A), 4.01 (m, 1H, H-5_E), 3.89–3.86 (m, 2H, H-3_A, H-$6a_D$), 3.80 (pt, 1H, $J_{3,4}$=9.7 Hz, H-3_E), 3.78–3.64 (m, 6H, H-$6b_D$, H-$6a_E$, H-$6b_E$, H-2_D, H-2_E, H-5_A), 3.60 (m, 1H, H_{Pr}), 3.50–3.44 (m, 2H, H-4_E, H_{Pr}), 3.42–3.38 (m, 3H, H-5_D, H-3_D, H-4_D), 3.32–3.34 (pt, 1H, $J_{3,4}$=9.7 Hz, H-4_A), 2.10 (s, 3H, H_{Ac}), 1.57 (m, 2H, CH_2), 1.24 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_A), 0.87 (t, 3H, *J*=7.4 Hz, CH_3); ^{13}C NMR (D_2O): δ 174.8 (C_{NAc}), 102.3 (C-1_D, $^1J_{CH}$=163.4 Hz), 99.6 (C-1_A, $^1J_{CH}$=171.3 Hz), 95.1 (C-1_E, $^1J_{CH}$=169.5 Hz), 76.3 (C-4_D), 74.6 (2C, C-2_A, C-3_D), 74.5 (C-3_A), 73.5 (C-3_E), 71.8 (C-5_E), 71.7 (C-2_E), 71.3 (C-4_A), 70.2 (C5-$_D$), 70.0 (C_{Pr}), 69.8 (C-4_E), 69.3 (C-5_A), 61.0 (C-6_D), 60.7 (C-6_E), 56.0 (C-2_D), 23.0 (C_{NAc}), 22.4 (CH_2), 17.1 (C-6_A), 10.3 (CH_3); HRMS (ESI^+) for $C_{23}H_{41}NO_{15}$ ($[M+Na]^+$, 594.2374) found *m*/*z* 594.2379.

4.9. 1,3-Di-*O*-acetyl-2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-α/β-D-glucopyranose (18a)

Methanolic NaOMe (25%, 16.1 mL, 58.1 mmol, 2.5 equiv) was slowly added to a solution of D-glucosamine hydrochloride (5.0 g, 23.2 mmol) in methanol (100 mL) stirred at 0 °C. After 10 min, trichloroacetic anhydride (6.4 mL, 34.9 mmol, 1.5 equiv) was added dropwise. The mixture was stirred at this temperature for 1 h, when TLC (*i*-PrOH/H_2O/NH_3, 4:1:0.5) showed the complete disappearance of the starting material and the presence of a single less polar product. The mixture was carefully neutralized by addition of Dowex X8-200 ion exchange resin (H^+) and filtered. Evaporation of the filtrate gave crude 2-deoxy-2-trichloroacetamido-D-glucopyranose[18] as a foam. The trichloroacetamide, isolated as a 60:40 α/β mixture, had R_f=0.6 (*i*-PrOH/H_2O/NH_3, 4:1:0.5); ^{1}H NMR (DMSO-d_6): δ 8.59 (d, 1H, $J_{NH,2}$=8.5 Hz, $NH_{NTCA\beta}$), 8.13 (br s, 1H, $NH_{NTCA\alpha}$), 5.06 (d, 1H, $J_{1,2}$=3.5 Hz, H-1_α), 4.99 (br s, 1H, OH-4_α), 4.95 (br s, 1H, OH-4_β), 4.90 (br s, 1H, OH-2_α), 4.82 (br s, 1H, OH-3_α), 4.65 (d, 1H, $J_{1,2}$=7.6 Hz, H-1_β), 4.50 (br s, 1H, OH-6_β), 4.43 (br s, 1H, OH-6_α), 3.73 (m, 1H, H-3_α), 3.68 (m, 1H, H-$6a_\beta$), 3.64 (m, 1H, H-6a), 3.61 (m, 1H, H-5_α), 3.56 (m, 1H, H-2_α), 3.53 (m, 1H, H-$6b_\alpha$), 3.50 (m, 1H, H-5_β), 3.46 (m, 1H, H-$6b_\beta$), 3.41 (m, 1H, H-2_β), 3.18 (m, 2H, H-3, H-4_β), 3.16 (pt, 1H, $J_{3,4}$=8.6 Hz, H-4_α); ^{13}C NMR (DMSO-d_6): δ 162.3 ($C_{NTCA\alpha}$), 162.1 ($C_{NTCA\beta}$), 95.4 (C-1_β, $^1J_{CH}$=157.0 Hz), 94.3 ($CCl_{3\beta}$), 93.5 ($CCl_{3\alpha}$), 90.5 (C-1_α, $^1J_{CH}$=167.4 Hz), 77.7 (C-4_β), 74.2 (C-5_β), 73.1 (C-5_α), 72.0 (C-3_β), 71.6 (C-4_α), 70.7 (C-3_α), 62.0 (C-6_β), 61.8 (C-6_α), 59.9 (C-2_β), 57.8 (C-2_α).

Camphorsulfonic acid (CSA, 24 g, 103 mmol) was added to a suspension of the crude trichloroacetamide (54 mmol) in a mixture of DMF (185 mL) and 2-methoxypropene (10.3 mL, 108 mmol, 2 equiv), and the suspension was stirred at rt. After 2 h, the formed methanol was evaporated under reduced pressure, and more 2-methoxypropene (2 mL, 21.6 mmol, 0.4 equiv) was added. After 1 h, TLC (DCM/MeOH, 8:2 and Chex/EtOAc, 1:1) showed the presence of a less polar product. Et_3N (2 mL) was added and volatiles were evaporated to give the corresponding 2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-α/β-D-glucopyranose as a crude yellow foam (30 g). The α anomer had R_f=0.3 (Chex/EtOAc, 1:1); ^{1}H NMR (DMSO-d_6): δ 8.37 (d, 1H, $J_{NH,2}$=7.8 Hz, NH_{NTCA}), 6.88 (d, 1H, $J_{1,2}$=3.9 Hz, H-1), 5.0 (m, 2H, OH), 3.77 (m, 1H, H-3), 3.71–3.65 (m, 4H, H-2, H-5, H-6a, H-6b), 3.50 (m, 1H, H-4), 1.44 (s, 3H, $H_{i\text{-}Pr}$), 1.25 (s, 3H, $H_{i\text{-}Pr}$); ^{13}C NMR (DMSO-d_6): δ 162.4 (C_{NTCA}), 99.9 ($C_{i\text{-}Pr}$), 93.3 (CCl_3), 91.2 (C-1, $^1J_{CH}$=168.2 Hz), 75.0 (C-4), 67.5 (C-3), 63.9 (C-5), 62.3 (C-6), 58.0 (C-2), 29.8 ($C_{i\text{-}Pr}$), 21.6 ($C_{i\text{-}Pr}$); HRMS (ESI^+) for $C_{11}H_{16}NO_6Cl_3$ ($[M+Na]^+$, 385.9941) found *m*/*z* 385.9962.

Acetic anhydride (100 mL) was added dropwise to a solution of the crude 4,6-*O*-isopropylidene acetal (30.0 g, from 54 mmol of D-glucosamine) in anhydrous pyridine (100 mL) stirred at 0 °C. After overnight stirring at rt, TLC (Chex/EtOAc, 1:1) showed the presence of two less polar products. Volatiles were eliminated by repeated coevaporation with toluene under reduced pressure. The residue was purified by column chromatography (Chex/EtOAc, 8:2→7.5:2.5) to give a 1:1 inseparable mixture of α/β anomers **18a** (17.0 g, 70%) as a white solid. The α anomer had R_f=0.7 (Chex/EtOAc, 1:1); ^{1}H NMR ($CDCl_3$): δ 7.01 (d, 1H, $J_{NH,2}$=8.4 Hz, NH), 6.23 (d, 1H, $J_{1,2}$=3.9 Hz, H-1), 5.30 (pt, 1H, $J_{2,3}$=$J_{3,4}$=9.5 Hz, H-3), 4.28 (ddd, 1H, H-2), 3.93–3.83 (m, 2H, H-4, H-6a), 3.79–3.74 (m, 2H, H-5, H-6b), 2.16, 2.09 (2s, 6H, H_{Ac}), 1.51 (s, 3H, $H_{i\text{-}Pr}$), 1.39 (s, 3H, $H_{i\text{-}Pr}$); ^{13}C NMR ($CDCl_3$): δ 172.2, 169.4 (2C, C_{Ac}), 162.4 (C_{NTCA}), 100.4 ($C_{i\text{-}Pr}$), 92.2 (CCl_3), 90.5 (C-1, $^1J_{CH}$=178.6 Hz), 71.8 (C-4), 70.0 (C-3), 66.4 (C-5), 62.2 (C-6), 53.8 (C-2), 29.2 ($C_{i\text{-}Pr}$), 21.2, 21.1 (2C, C_{Ac}), 19.4 ($C_{i\text{-}Pr}$). The β anomer had R_f=0.75 (Chex/EtOAc, 1:1); mp=207 °C (Chex/EtOAc); ^{1}H NMR ($CDCl_3$): δ 7.03 (d, 1H, $J_{NH,2}$=9.7 Hz, NH_{NTCA}), 5.78 (d, 1H, $J_{1,2}$=8.7 Hz, H-1), 5.24 (pt, 1H, $J_{2,3}$=$J_{3,4}$=9.6 Hz, H-3), 4.25 (m, 1H, H-2), 4.01 (m, 1H, H-6a), 3.88–3.83 (m, 2H, H-4, H-6b), 3.55 (m, 1H, H-5), 2.11 (s, 3H, H_{Ac}), 2.09 (s, 3H, H_{Ac}), 1.52 (s, 3H, $H_{i\text{-}Pr}$), 1.45 (s, 3H, $H_{i\text{-}Pr}$); ^{13}C NMR ($CDCl_3$) δ 171.8, 169.5 (2C, C_{Ac}), 162.8 (C_{NTCA}), 100.5 ($C_{i\text{-}Pr}$), 93.2 (C-1), 92.2 (CCl_3), 71.6 (C-4), 71.3 (C-3), 69.1 (C-5), 62.1 (C-6), 55.9 (C-2), 30.1 ($C_{i\text{-}Pr}$), 21.2, 21.1 (2C, C_{Ac}), 19.3 ($C_{i\text{-}Pr}$); HRMS (ESI^+) for $C_{15}H_{20}NO_8Cl_3$ ($[M+Na]^+$, 470.0152) found *m*/*z* 470.0123.

4.10. 3-*O*-Acetyl-2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-α/β-D-glucopyranosyl trichloroacetimidate (18)

Glacial acetic acid (840 μL, 14.5 mmol, 1.4 equiv) was added dropwise to a solution of ethylenediamine (920 μL, 12.5 mmol, 1.2 equiv) in THF (200 mL), resulting in the immediate formation of a precipitate, which remained until aqueous work-up. Diacetate **18a** (4.65 g, 10.4 mmol) was added and the mixture was stirred at rt for 24 h. TLC (CH_2Cl_2/MeOH, 95:5 and Chex/EtOAc, 1:1) showed the complete disappearance of the starting materials and the presence of a more polar product. The reaction mixture was diluted with water and EtOAc, then washed with saturated aq $NaHCO_3$, saturated aq NaCl, and finally water. The organic layer was dried on Na_2SO_4, filtered, and concentrated under reduced pressure. Crude 3-*O*-acetyl-2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-α/β-D-glucopyranose was directly engaged in the next step without purification (4.2 g). Relying on an analytical sample, the α anomer had R_f=0.5 (Chex/EtOAc, 1:1); ^{1}H NMR ($CDCl_3$): δ 7.11 (d, 1H, $J_{NH,2}$=8.9 Hz, NH_{NTCA}), 5.37–5.34 (m, 2H, H-1, H-3), 4.20 (ddd, 1H, $J_{1,2}$=3.7 Hz, $J_{2,3}$=9.5 Hz, $J_{2,OH}$=1.8 Hz, H-2), 4.02 (ddd, 1H, H-5), 3.91

(dd, 1H, $J_{5,6a}$=5.2 Hz, $J_{6a,6b}$=10.6 Hz, H-6a), 3.86–3.77 (m, 2H, $J_{3,4}$=10.6 Hz, H-4, H-6b), 2.09 (s, 3H, H_{Ac}), 1.53 (s, 3H, $H_{i\text{-}Pr}$), 1.45 (s, 3H, $H_{i\text{-}Pr}$); ^{13}C NMR ($CDCl_3$): δ 171.8 (C_{Ac}), 162.5 (C_{NTCA}), 100.4 ($C_{i\text{-}Pr}$), 92.4 (CCl_3), 92.1 (C-1, $^1J_{CH}$=173.5 Hz), 72.0 (C-4), 70.2 (C-3), 64.3 (C-5), 62.6 (C-6), 55.3 (C-2), 29.3 ($C_{i\text{-}Pr}$), 21.3 (C_{Ac}), 19.4 ($C_{i\text{-}Pr}$); HRMS (ESI$^+$) for $C_{13}H_{18}Cl_3NO_7$ ([M+Na]$^+$, 428.0047) found *m/z* 428.0048.

The crude hemiacetal (4.2 g, 10.4 mmol) was dissolved in DCE (30 mL), placed under argon, and cooled at −5 °C. Trichloroacetonitrile (4.5 mL, 44.6 mmol, 4.3 equiv) and then DBU (434 μL, 2.9 mmol, 0.28 equiv) were added. The mixture was stirred at −5 °C for 10 min. TLC (Chex/EtOAc, 7:3) showed the complete disappearance of the hemiacetal and the presence of a single less polar product. Direct chromatography (Chex/EtOAc, 7:3) gave donor **18** (4.6 g, 80%) as a white foam. The α anomer had R_f=0.5 (Chex/EtOAc, 7:3); ^{1}H NMR ($CDCl_3$): δ 8.78 (s, 1H, =NH), 7.10 (d, 1H, $J_{NH,2}$=8.5 Hz, NH_{NTCA}), 6.45 (d, 1H, $J_{1,2}$=3.7 Hz, H-1), 5.40 (pt, 1H, $J_{2,3}$=9.2 Hz, H-3), 4.39 (m, 1H, H-2), 3.98–3.91 (m, 3H, H-4, H-5, H-6a), 3.81 (m, 1H, H-6b), 2.11 (s, 3H, H_{Ac}), 1.54 (s, 3H, $H_{i\text{-}Pr}$), 1.43 (s, 3H, $H_{i\text{-}Pr}$); ^{13}C NMR ($CDCl_3$): δ 171.9 (C_{Ac}), 162.5 (C_{NTCA}), 160.7 (C=NH), 100.5 ($C_{i\text{-}Pr}$), 94.7 (C-1, $^1J_{CH}$=180.1 Hz), 92.2, 91.0 (2C, $2CCl_3$), 71.4 (C-4), 69.9 (C-3), 67.0 (C-5), 62.3 (C-6), 55.0 (C-2), 29.3 ($C_{i\text{-}Pr}$), 21.2 (C_{Ac}), 19.4 ($C_{i\text{-}Pr}$).

4.11. Allyl (3-*O*-acetyl-2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (25)

TMSOTf (59 μL, 330 μmol, 0.3 equiv) was added to a solution of disaccharide **19**[22] (0.90 g, 1.1 mmol) and donor **18** (0.85 g, 1.5 mmol, 1.4 equiv) in CH_2Cl_2 (10 mL) containing 4 Å MS (0.9 g), stirred at −78 °C. The reaction mixture was stirred for 3 h. TLC (Chex/EtOAc, 7:3) showed the complete disappearance of acceptor **19**.[22] Et_3N (1 mL) was added. The mixture was filtered and concentrated to dryness. Chromatography of the residue (Chex/EtOAc, 8:2→7:3) gave the glycosylation product **25** (1.2 g, 90%) as a white foam. Trisaccharide **25** had R_f=0.35 (Chex/EtOAc, 7:3); ^{1}H NMR ($CDCl_3$): δ 7.42–7.04 (m, 26H, NH_{NTCA}, CH_{Ph}), 5.89 (m, 1H, CH=), 5.28 (m, 1H, J_{trans}=17.2 Hz, =CH_2), 5.19 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.13–5.10 (m, 3H, $J_{1,2}$=3.3 Hz, $2H_{Bn}$, $H\text{-}1_E$), 5.04 (d, 2H, H_{Bn}), 4.79–4.74 (m, 3H, $H\text{-}3_D$, $H\text{-}1_A$, H_{Bn}), 4.71 (m, 2H, $H\text{-}1_D$, H_{Bn}), 4.58–4.51 (m, 2H, H_{Bn}), 4.45 (d, 1H, *J*=10.9 Hz, H_{Bn}), 4.29 (d, 1H, *J*=12.0 Hz, H_{Bn}), 4.18–4.10 (m, 4H, $H\text{-}3_A$, $H\text{-}3_E$, H_{All}, $H\text{-}2_D$), 4.07 (m, 1H, $H\text{-}5_E$), 3.97 (br s, 1H, $H\text{-}2_A$), 3.94 (m, 1H, H_{All}), 3.91–3.83 (m, 2H, $H\text{-}2_E$, $H\text{-}6a_D$), 3.78 (pt, 1H, $J_{3,4}$=9.4 Hz, $H\text{-}4_E$), 3.75–3.64 (m, 3H, $H\text{-}6b_D$, $H\text{-}5_A$, $H\text{-}4_D$), 3.43 (pt, 1H, $J_{3,4}$=9.6 Hz, $H\text{-}4_A$), 3.41 (m, 2H, $H\text{-}6a_E$, $H\text{-}6b_E$), 2.71 (m, 1H, $H\text{-}5_D$), 2.07 (s, 3H, H_{Ac}), 1.45 (s, 3H, $H_{i\text{-}Pr}$), 1.40 (s, 3H, $H_{i\text{-}Pr}$), 1.39 (d, 3H, $J_{5,6}$=6.2 Hz, $H\text{-}6_A$); ^{13}C NMR ($CDCl_3$): δ 171.2 (C_{Ac}), 162.5 (C_{NTCA}), 138.8–137.8 (C_{Ph}), 134.1 (CH=), 129.5–127.7 (CH_{Ph}), 117.6 (=CH_2), 101.8 ($C\text{-}1_D$, $^1J_{CH}$=164.4 Hz), 100.1 ($C_{i\text{-}Pr}$), 98.7 ($C\text{-}1_A$, $^1J_{CH}$=173.7 Hz), 94.9 ($C\text{-}1_E$, $^1J_{CH}$=168.6 Hz), 93.1 (CCl_3), 83.8 ($C\text{-}3_E$), 80.1 ($C\text{-}4_A$), 78.9 (2C, $C\text{-}2_E$, $C\text{-}4_E$), 76.5, 75.5, 75.3 (3C, C_{Bn}), 74.7 ($C\text{-}3_A$), 74.6 ($C\text{-}2_A$), 74.4, 73.8 (2C, C_{Bn}), 72.8 ($C\text{-}3_D$), 71.5 ($C\text{-}4_D$), 70.1 ($C\text{-}5_E$), 68.6 ($C\text{-}5_A$), 68.2 (2C, C_{All}, $C\text{-}6_E$), 67.6 ($C\text{-}5_D$), 62.4 ($C\text{-}6_D$), 56.8 ($C\text{-}2_D$), 29.4 ($C_{i\text{-}Pr}$), 21.3 (C_{Ac}), 19.3 ($C_{i\text{-}Pr}$), 18.3 ($C\text{-}6_A$); HRMS (ESI$^+$) for $C_{63}H_{72}Cl_3NO_{16}$ ([M+Na]$^+$, 1226.3814) found *m/z* 1226.3860, ([M+NH_4]$^+$, 1221.4260) found *m/z* 1221.4227, ([M+K]$^+$, 1242.3553) found *m/z* 1242.3586.

4.12. Allyl (2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (15)

Route a. CSA (10 mg, 23 μmol, 0.1 equiv) was added to a suspension of triol **24** (0.5 g, 0.45 mmol) in a mixture of DMF (3 mL) and 2-methoxypropene (85 μL, 0.89 mmol, 2 equiv). After stirring for 2 h at rt, TLC (Chex/EtOAc, 1:1 and CH_2Cl_2/MeOH, 9.6:0.4) showed the complete disappearance of the starting material and the presence of a less polar product. Et_3N (0.2 mL) was added and the reaction mixture was concentrated to dryness. Chromatography of the residue (Chex/EtOAc, 9:1→1:1) gave **15** (0.39 g, 76%) as a white foam.

Alternatively, starting from acceptor **19**[22] (1.5 g, 1.83 mmol) and donor **10**[18] (1.31 g, 2.19 mmol), the condensation, transesterification, and acetalation steps were run without any intermediate purification. Column chromatography (Chex/EtOAc, 9:1→1:1) of the residue gave the expected **15** (1.8 g, 86%) over three steps.

Route b. 0.5 M MeONa (108 μL, 54 μmol, 0.2 equiv) was added to a solution of compound **25** (328 mg, 0.27 mmol) in MeOH (5 mL), and the mixture was stirred for 4 h. TLC (Chex/EtOAc, 1:1 and Chex/EtOAc, 7:3) showed the complete disappearance of the starting material and the presence of a single more polar product. The mixture was neutralized by addition of Dowex X8-200 ion exchange resin (H^+) and filtered. Evaporation of the filtrate gave a syrup, which was chromatographed (Chex/EtOAc+NEt_3, 7:3→6:4) to give **15** (241 mg, 76%) as a white foam.

Alternatively, starting from acceptor **19**[22] (3.65 g, 4.5 mmol) and donor **18** (3.5 g, 6.3 mmol), the condensation and transesterification steps were run without any intermediate purification. Column chromatography (Chex/EtOAc, 9:1→1:1) of the residue gave the expected **15** (4.5 g, 87%) over two steps. Acceptor **15** had R_f=0.45 (Chex/EtOAc, 6:4); ^{1}H NMR ($CDCl_3$): δ 7.42–7.08 (m, 26H, NH, CH_{Ph}), 5.89 (m, 1H, CH=), 5.29 (m, 1H, J_{trans}=15.6 Hz, =CH_2), 5.21 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.10 (d, 1H, $J_{1,2}$=3.6 Hz, $H\text{-}1_E$), 5.15–4.91 (m, 3H, H_{Bn}), 4.90 (d, 1H, *J*=12.1 Hz, H_{Bn}), 4.82–4.79 (m, 2H, $H\text{-}1_A$, H_{Bn}), 4.74 (d, 1H, *J*=10.0 Hz, H_{Bn}), 4.62–4.49 (m, 4H, H_{Bn}, $H\text{-}1_D$, $2H_{Bn}$), 4.34 (d, 1H, *J*=10.9 Hz, H_{Bn}), 4.18–4.11 (m, 4H, $H\text{-}3_A$, $H\text{-}5_E$, H_{All}, $H\text{-}3_E$), 4.02 (br s, 1H, $H\text{-}2_A$), 4.01 (m, 1H, H_{All}), 3.91–3.82 (m, 4H, $H\text{-}2_E$, $H\text{-}4_E$, $H\text{-}2_D$, $H\text{-}6a_D$), 3.76–3.71 (m, 2H, $H\text{-}6b_D$, $H\text{-}5_A$), 3.51–3.42 (m, 4H, $H\text{-}4_A$, $H\text{-}6a_E$, $H\text{-}6b_E$, $H\text{-}4_D$), 2.84 (m, 2H, $H\text{-}5_D$, OH), 2.48 (pt, 1H, $J_{2,3}$=9.4 Hz, $H\text{-}3_D$), 1.51 (s, 3H, $H_{i\text{-}Pr}$), 1.50 (s, 3H, $H_{i\text{-}Pr}$), 1.40 (d, 3H, $J_{5,6}$=6.2 Hz, $H\text{-}6_A$); ^{13}C NMR ($CDCl_3$): δ 164.1 (C_{NTCA}), 138.8–137.8 (C_{Ph}), 134.2 (CH=), 129.3–127.7 (CH_{Ph}), 117.6 (=CH_2), 101.5 ($C\text{-}1_D$, $^1J_{CH}$=163.6 Hz), 100.1 ($C_{i\text{-}Pr}$), 98.7 ($C\text{-}1_A$, $^1J_{CH}$=174.0 Hz), 94.5 ($C\text{-}1_E$, $^1J_{CH}$=167.5 Hz), 92.9 (CCl_3), 83.6 ($C\text{-}3_E$), 80.2 ($C\text{-}4_A$), 80.1 ($C\text{-}2_E$), 79.1 ($C\text{-}4_E$), 76.6, 75.8, 75.7, 75.3 (4C, C_{Bn}), 74.7 ($C\text{-}3_A$), 74.4 ($C\text{-}4_D$), 74.0 ($C\text{-}2_A$), 73.8 (C_{Bn}), 73.4 ($C\text{-}3_D$), 70.2 ($C\text{-}5_E$), 68.7 ($C\text{-}5_A$), 68.2 (2C, C_{All}, $C\text{-}6_E$), 67.4 ($C\text{-}5_D$), 62.3 ($C\text{-}6_D$), 59.1 ($C\text{-}2_D$), 27.3 ($C_{i\text{-}Pr}$), 19.3 ($C_{i\text{-}Pr}$), 18.3 ($C\text{-}6_A$); HRMS (ESI$^+$) for $C_{61}H_{70}Cl_3NO_{15}$ ([M+Na]$^+$, 1184.3709) found *m/z* 1184.3669, ([M+NH_4]$^+$, 1179.4155) found *m/z* 1179.4165.

4.13. Allyl (2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (26)

TMSOTf (24 μL, 131 μmol, 0.3 equiv) was added to a solution of **15** (0.51 g, 0.44 mmol) and trichloroacetimidate **17**[39] (0.35 g, 0.66 mmol, 1.5 equiv) in toluene (11 mL) containing 4 Å MS (0.9 g), stirred at −78 °C. The reaction mixture was stirred for 30 min at −78 °C. TLC (Chex/EtOAc, 7.5:2.5 and Chex/EtOAc, 6:4) showed the complete disappearance of the starting materials and the presence of a major more polar product. Et_3N (1 mL) was added and the mixture was filtered, and concentrated to dryness. Chromatography of the residue (Chex/EtOAc, 6.5:3.5→1:1) gave firstly fully protected **26** (480 mg, 72%) as a white foam and next, diol **27** (33 mg, 5%). The former, **26**, had R_f=0.7 (Chex/EtOAc, 6:4);

^{1}H NMR ($CDCl_3$): δ 7.45–7.10 (m, 35H, CH_{Ph}), 6.98 (d, 1H, $J_{NH,2}$=8.6 Hz, NH), 5.92 (m, 1H, CH=), 5.37 (m, 1H, H-2$_C$), 5.29 (m, 1H, J_{trans}=16.9 Hz, =CH_2), 5.21 (m, 1H, J_{cis}=10.6 Hz, =CH_2), 5.17 (d, 1H, $J_{1,2}$=3.6 Hz, H-1$_E$), 5.05–4.90 (m, 3H, H_{Bn}), 4.83–4.69 (m, 6H, H-1$_C$, 2H_{Bn}, H-1$_A$, 2H_{Bn}), 4.64–4.50 (m, 7H, 3H_{Bn}, H-1$_D$, 3H_{Bn}), 4.34 (d, 1H, J=12.0 Hz, H_{Bn}), 4.17–4.14 (m, 3H, H-3$_E$, H_{All}, H-3$_A$), 4.12–4.03 (m, 3H, H-5$_E$, H-5$_C$, H-2$_D$), 4.00 (br s, 1H, H-2$_A$), 3.99–3.89 (m, 2H, H_{All}, H-3$_C$), 3.90–3.86 (m, 2H, H-2$_E$, H-6a$_D$), 3.84 (pt, 1H, $J_{3,4}$=9.8 Hz, H-4$_E$), 3.74–3.69 (m, 2H, H-6b$_D$, H-5$_A$), 3.50 (pt, 1H, $J_{3,4}$=9.4 Hz, H-4$_D$), 3.49–3.41 (m, 3H, H-4$_A$, H-6a$_E$, H-6b$_E$), 3.40 (pt, 1H, $J_{3,4}$=9.5 Hz, H-4$_C$), 2.84–2.76 (m, 2H, H-5$_D$, H-3$_D$), 2.16 (s, 3H, H_{Ac}), 1.51 (s, 3H, H$_{i\text{-}Pr}$), 1.50 (s, 3H, H$_{i\text{-}Pr}$), 1.41 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$), 1.41 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_C$); ^{13}C NMR ($CDCl_3$): δ 170.1 (C_{Ac}), 162.2 (C_{NTCA}), 139.0–137.8 (C_{Ph}), 134.3 (CH=), 129.8–127.7 (CH_{Ph}), 117.5 (=CH_2), 101.7 (C-1$_D$, $^1J_{CH}$=161.0 Hz), 99.9 (C$_{i\text{-}Pr}$), 98.9 (C-1$_C$, $^1J_{CH}$=169.1 Hz), 98.8 (C-1$_A$, $^1J_{CH}$=171.2 Hz), 94.6 (C-1$_E$, $^1J_{CH}$=167.6 Hz), 93.5 (CCl_3), 83.5 (C-3$_E$), 80.6 (C-2$_E$), 80.2 (C-4$_C$), 80.1 (C-4$_A$), 79.1 (C-4$_E$), 79.0 (C-3$_D$), 78.5 (C-3$_C$), 76.5, 75.7, 75.6, 75.3, 75.2 (5C, C_{Bn}), 74.8 (C-3$_A$), 74.1 (C-2$_A$), 73.8 (C_{Bn}), 73.0 (C-4$_D$), 72.2 (C_{Bn}), 70.3 (C-5$_E$), 69.7 (C-2$_C$), 68.7 (C-5$_A$), 68.3 (C-6$_E$), 68.3 (C-5$_C$), 68.2 (C_{All}), 67.4 (C-5$_D$), 62.5 (C-6$_D$), 57.8 (C-2$_D$), 29.5 (C$_{i\text{-}Pr}$), 21.5 (C_{Ac}), 19.3 (C$_{i\text{-}Pr}$), 18.4, 18.3 (C-6$_A$, C-6$_C$); HRMS (ESI$^+$) for $C_{83}H_{94}Cl_3NO_{20}$ ([M+Na]$^+$, 1552.5332) found m/z 1552.5293, ([M+NH_4]$^+$, 1547.5779) found m/z 1547.5818, ([M+K]$^+$, 1568.5072) found m/z 1568.5120.

4.14. Allyl (2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-deoxy-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (27)

Aq TFA (50%, 1.6 mL) was added, at 0 °C, to a solution of tetrasaccharide **26** (79 mg, 52 μmol) in CH_2Cl_2 (4 mL), and the biphasic mixture was stirred vigorously at rt for 1 h. TLC (Chex/EtOAc, 6:4) showed the complete disappearance of the starting material and the presence of a major more polar product. Repeated coevaporation with toluene and chromatography of the residue (Chex/EtOAc, 7:3→6:4) provided diol **27** (68 mg, 88%) as a white foam. Compound **27** had R_f=0.3 (Chex/EtOAc, 6:4); ^{1}H NMR ($CDCl_3$): δ 7.40–7.07 (m, 35H, CH_{Ph}), 6.99 (d, 1H, $J_{NH,2}$=8.3 Hz, NH), 5.91 (m, 1H, CH=), 5.31 (m, 1H, H-2$_C$), 5.29 (m, 1H, J_{trans}=16.9 Hz, =CH_2), 5.25–5.23 (m, 2H, =CH_2, H-1$_E$), 5.12 (m, 2H, H_{Bn}), 5.08 (d, 1H, J=12.6 Hz, H_{Bn}), 4.99–4.91 (m, 2H, H_{Bn}), 4.85 (d, 1H, $J_{1,2}$=1.5 Hz, H-1$_A$), 4.82 (d, 1H, J=11.1 Hz, H_{Bn}), 4.73 (d, 1H, J=10.1 Hz, H_{Bn}), 4.67 (d, 1H, J=11.4 Hz, H_{Bn}), 4.62–4.51 (m, 6H, 2H_{Bn}, H-1$_D$, 3H_{Bn}), 4.49 (d, 1H, $J_{1,2}$=1.8 Hz, H-1$_C$), 4.35 (d, 1H, J=11.9 Hz, H_{Bn}), 4.22–4.13 (m, 5H, OH-4$_D$, H-3$_A$, H-3$_E$, H_{All}, H-5$_E$), 4.04–4.01 (m, 3H, H_{All}, H-2$_A$, H-3$_C$), 3.98 (m, 1H, H-2$_D$), 3.96 (m, 1H, H-5$_C$), 3.87–3.82 (m, 3H, H-6a$_D$, H-2$_E$, H-4$_E$), 3.80–3.70 (m, 2H, H-6b$_D$, H-5$_A$), 3.52–3.49 (m, 3H, H-4$_A$, H-6a$_E$, H-6b$_E$), 3.46 (pt, 1H, $J_{3,4}$=9.4 Hz, H-4$_C$), 3.39 (pt, 1H, $J_{3,4}$=9.4 Hz, H-4$_D$), 3.09 (m, 1H, H-5$_D$), 2.09 (m, 4H, H_{Ac}, H-3$_D$), 1.41 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$), 1.34 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_C$); ^{13}C NMR ($CDCl_3$): δ 170.5 (C_{Ac}), 162.3 (C_{NTCA}), 138.8–137.8 (C_{Ph}), 134.3 (CH=), 129.7–127.8 (CH_{Ph}), 117.8 (=CH_2), 101.4 (C-1$_D$, $^1J_{CH}$=158.6 Hz), 99.5 (C-1$_C$, $^1J_{CH}$=169.8 Hz), 98.6 (C-1$_A$, $^1J_{CH}$=174.0 Hz), 94.3 (C-1$_E$, $^1J_{CH}$=169.3 Hz), 93.7 (CCl_3), 87.3 (C-3$_D$), 83.4 (C-3$_E$), 81.0 (C-2$_E$), 80.2 (C-4$_A$), 79.6 (C-4$_C$), 79.2 (C-4$_E$), 77.5 (C-3$_C$), 76.6, 75.7, 75.6, 75.5, 75.3 (5C, C_{Bn}), 75.2 (C-5$_D$), 74.6 (C-3$_A$), 74.3 (C-2$_A$), 73.8, 72.2 (2C, C_{Bn}), 71.2 (C-4$_D$), 70.3 (C-5$_E$), 69.8 (C-5$_C$), 69.4 (C-2$_C$), 68.8 (C-5$_A$), 68.3 (C-6$_E$), 68.1 (C_{All}), 63.3 (C-6$_D$), 55.6 (C-2$_D$), 21.4 (C_{Ac}), 18.4 (C-6$_A$), 18.2 (C-6$_C$); HRMS (ESI$^+$) for $C_{80}H_{90}Cl_3NO_{20}$ ([M+Na]$^+$, 1512.5019) found m/z 1512.4950, ([M+NH_4]$^+$, 1507.5465) found m/z 1507.5507.

4.15. Allyl (3,4-di-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-deoxy-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (28)

MeONa (0.5 M, 102 μL, 50.8 μmol, 1.1 equiv) was added to a solution of compound **27** (69 mg, 46.2 μmol) in MeOH (3 mL), and the mixture was stirred for 2 h at 50 °C. TLC (Chex/EtOAc, 6:4) showed the complete disappearance of the starting material and the presence of a single more polar product. The mixture was neutralized by addition of Dowex X8-200 ion exchange resin (H^+) and filtered. Evaporation of the filtrate gave a syrup, which was chromatographed (Chex/EtOAc, 6:4→1:1) to give **28** (57 mg, 85%) as a white foam. Triol **28** had R_f=0.2 (Chex/EtOAc, 6:4); ^{1}H NMR ($CDCl_3$): δ 7.41–7.07 (m, 35H, CH_{Ph}), 6.93 (d, 1H, $J_{NH,2}$=7.7 Hz, NH), 5.89 (m, 1H, CH=), 5.29 (m, 1H, J_{trans}=17.2 Hz, =CH_2), 5.23 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.21 (d, 1H, $J_{1,2}$=3.7 Hz, H-1$_E$), 5.13–4.88 (m, 5H, H_{Bn}), 4.84 (d, 1H, $J_{1,2}$=1.7 Hz, H-1$_A$), 4.79 (d, 1H, J=11.0 Hz, H_{Bn}), 4.73–4.67 (m, 3H, H_{Bn}), 4.62 (m, 1H, H_{Bn}), 4.58 (d, 1H, $J_{1,2}$=8.5 Hz, H-1$_D$), 4.58 (m, 1H, H_{Bn}), 4.55 (m, 1H, H-1$_C$), 4.51 (d, 2H, J=11.0 Hz, H_{Bn}), 4.34 (d, 1H, J=12.0 Hz, H_{Bn}), 4.19–4.11 (m, 4H, H-3$_A$, H_{All}, H-3$_E$, H-5$_E$), 4.03–4.00 (m, 3H, H-2$_A$, H-2$_C$, H_{All}), 3.96 (m, 1H, H-2$_D$), 3.93–3.87 (m, 3H, H-5$_C$, H-3$_C$, H-6a$_D$), 3.85 (m, 1H, H-2$_E$), 3.83 (m, 1H, H-4$_E$), 3.77 (m, 1H, H-6b$_D$), 3.73 (m, 1H, H-5$_A$), 3.50–3.44 (m, 4H, H-4$_C$, H-6a$_E$, H-6b$_E$, H-4$_A$), 3.38 (pt, 1H, $J_{3,4}$=8.9 Hz, H-4$_D$), 3.08 (m, 1H, H-5$_D$), 2.30 (m, 1H, $J_{3,4}$=8.8 Hz, H-3$_D$), 1.40 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$), 1.32 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_C$); ^{13}C NMR ($CDCl_3$): δ 162.0 (C_{NTCA}), 138.7–138.2 (C_{Ph}), 134.3 (CH=), 129.7–127.6 (CH_{Ph}), 117.8 (=CH_2), 101.4 (C-1$_D$, $^1J_{CH}$=161.7 Hz), 101.0 (C-1$_C$, $^1J_{CH}$=168.3 Hz), 98.6 (C-1$_A$, $^1J_{CH}$=168.3 Hz), 94.3 (C-1$_E$, $^1J_{CH}$=17.6 Hz), 93.7 (CCl_3), 87.1 (C-3$_D$), 83.5 (C-3$_E$), 80.8 (C-2$_E$), 80.2 (C-4$_A$), 79.5 (C-4$_C$), 79.4 (C-3$_C$), 79.3 (C-4$_E$), 76.6, 75.7, 75.6, 75.5, 75.3 (5C, C_{Bn}), 75.3 (C-5$_D$), 74.5 (2C, C-2$_A$, C-3$_A$), 73.8, 72.2 (2C, C_{Bn}), 71.1 (C-4$_D$), 70.3 (C-5$_E$), 69.5 (C-5$_C$), 68.9 (C-2$_C$), 68.8 (C-5$_A$), 68.4 (C-6$_E$), 68.1 (C_{All}), 63.3 (C-6$_D$), 55.9 (C-2$_D$), 21.4 (C_{Ac}), 18.3, 18.2 (2C, C-6$_A$, C-6$_C$); HRMS (ESI$^+$) for $C_{78}H_{88}Cl_3NO_{19}$ ([M+Na]$^+$, 1470.4913) found m/z 1470.5050, ([M+NH_4]$^+$, 1465.5360) found m/z 1465.5448, ([M+K]$^+$, 1486.4653) found m/z 1486.4777.

4.16. Allyl (3,4-di-*O*-benzyl-β-L-rhamnopyranosyl)-(1→3)-(2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (29)

TMSOTf (25 μL, 140 μmol, 0.5 equiv) was added to a solution of **15** (0.3 g, 0.26 mmol) and trichloroacetimidate **17**[39] (0.19 g, 0.36 mmol, 1.4 equiv) in CH_2Cl_2 (4 mL) containing 4 Å MS (0.4 g), stirred at −78 °C. The reaction mixture was stirred for 30 min, while slowly coming back to rt. TLC (Chex/EtOAc, 7:3) showed the complete disappearance of the starting materials and the presence of several products. Et_3N (1 mL) was added and the mixture was filtered and concentrated to dryness. Chromatography of the residue (Chex/EtOAc, 6.5:3.5→1:1) gave first fully protected **26** (170 mg, 40%) as a white foam, then, the side-product **29** (80 mg, 20%), which had R_f=0.65 (Chex/EtOAc, 6:4) and finally diol **27** (85 mg, 22%). MeONa (0.5 M, 0.8 mL, 0.4 mmol) was added to a solution of **29** (25 mg) in MeOH (1 mL). After stirring for 4 h at rt, TLC (Chex/EtOAc, 6:4) showed the presence of a single more polar product. The mixture was neutralized by addition of Dowex X8-200 ion exchange resin (H^+) and filtered. Evaporation of the filtrate gave a syrup, which was chromatographed (Chex/EtOAc, 8:2→6:4) to give trichloroacetamide **30** (8 mg) as a white foam. Tetrasaccharide **30** had R_f=0.5 (Chex/EtOAc, 6:4); ^{1}H NMR ($CDCl_3$): δ 7.40–7.03 (m, 35H, CH_{Ph}), 5.88 (m, 1H, CH=), 5.26 (m, 1H, J_{trans}=17.2 Hz, =CH_2), 5.18 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.10–5.05 (m, 3H, H_{Bn}, H-1$_E$, H_{Bn}),

5.00–4.92 (m, 3H, H_{Bn}), 4.86 (d, 1H, J=12.1 Hz, H_{Bn}), 4.76 (m, 1H, $J_{1,2}$=1.5 Hz, H-1_A), 4.75–4.69 (m, 4H, H_{Bn}, H-1_D, 2H_{Bn}), 4.66–4.50 (m, 4H, 3H_{Bn}, H-1_C), 4.45 (d, 1H, J=10.9 Hz, H_{Bn}), 4.30 (d, 1H, J=11.9 Hz, H_{Bn}), 4.17–4.02 (m, 6H, H-3_E, H-3_A, H_{All}, H-5_E, H-2_C, H-2_D), 3.99 (m, 1H, H-2_A), 3.91 (m, 1H, H_{All}), 3.85–3.68 (m, 5H, H-6a$_D$, H-2_E, H-4_E, H-6b$_D$, H-5_A), 3.62 (pt, 1H, $J_{3,4}$=9.4 Hz, H-4_D), 3.52–3.39 (m, 6H, H-4_C, H-3_D, H-4_A, H-3_C, H-6a$_E$, H-6b$_E$), 3.24 (m, 1H, H-5_C), 2.72 (m, 1H, H-5_D), 1.45 (s, 6H, $H_{i\text{-}Pr}$), 1.40 (d, 3H, $J_{5,6}$=6.3 Hz, H-6_A), 1.18 (d, 3H, $J_{5,6}$=6.3 Hz, H-6_C); ^{13}C NMR ($CDCl_3$): δ 163.2 (C_{NTCA}), 138.8–137.8 (C_{Ph}), 134.2 (CH=), 129.5–127.6 (CH_{Ph}), 117.6 (=CH_2), 101.8 (C-1_D, $^1J_{CH}$=160.3 Hz), 99.8 ($C_{i\text{-}Pr}$), 99.1 (C-1_C, $^1J_{CH}$=156.6 Hz), 98.7 (C-1_A, $^1J_{CH}$=172.7 Hz), 95.0 (C-1_E, $^1J_{CH}$=166.1 Hz), 93.4 (CCl_3), 83.8 (C-3_E), 81.7 (C-3_C), 80.1 (C-4_A), 79.7 (C-4_C), 79.1 (C-4_E), 78.5 (C-2_E), 77.1 (C-3_D), 76.5, 75.8, 75.5, 75.1 (4C, C_{Bn}), 75.1 (C-3_A), 74.6 (C-4_D), 74.4 (C-2_A), 74.3, 73.8 (2C, C_{Bn}), 71.7 (C-5_C), 71.1 (C_{Bn}), 70.7 (C-5_E), 68.7 (C-5_A), 68.2 (C-2_C), 68.2, 68.1 (2C, C-6$_E$, C_{All}), 67.1 (C-5_D), 62.4 (C-6$_D$), 56.6 (C-2_D), 29.4 ($C_{i\text{-}Pr}$), 19.5 ($C_{i\text{-}Pr}$), 18.5 (C-6_C), 18.2 (C-6_A).

4.17. Propyl (2/3-*O*-acetyl-α-L-rhamnopyranosyl)-(1→3)-(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→2)-[α-D-glucopyranosyl-(1→3)]-α-L-rhamnopyranoside (5)

Tetrasaccharide **27** (0.34 g, 0.323 mmol) was dissolved in EtOH (30 mL), treated with 10% Pd/C catalyst (300 mg), and the suspension was stirred at rt for 10 days, under a hydrogen atmosphere (45 bar). TLC (*i*-PrOH/H_2O/NH_3, 4:1:0.5 and Chex/EtOAc, 6:4) showed that **27** had been transformed into a major polar product. The suspension was filtered on Acrodisc LC 25 mm and the filtrate was concentrated. Reverse phase chromatography (H_2O/CH_3CN, 100:0→70:30) of the residue, followed by freeze-drying, gave **5** as a mixture of the non separable 2_C- and 3_C-*O*-acetyl isomers (132 mg, 76%). Compound **5**, isolated as a white foam, had R_f=0.5 (*i*-PrOH/H_2O/NH_3, 4:1:0.5); ^{1}H NMR (D_2O): δ (partial) 5.05 (m, 1H, H-1_E), 4.83–4.72 (m, 4H, H-1_A, H-1_C, H-1_D, H-2_C), 4.17 (m, 1H, H-2_A), 3.93 (m, 1H, H-5_E), 3.82–3.79 (m, 2H, H-3_A, H-5_C), 3.73–3.52 (m, 10H, H-2_D, H-6a$_D$, H-3_E, H-6a$_E$, H-6b$_E$, H-6b$_D$, H-3_C, H-5_A, H-2_E, H_{Pr}), 3.42–3.32 (m, 6H, H-4_E, H_{Pr}, H-5_D, H-4_C, H-4_D, H-3_D), 3.21 (pt, 1H, $J_{3,4}$=9.7 Hz, H-4_A), 2.07–2.01 (m, 6H, H_{Ac}, H_{NAc}), 1.48 (m, 2H, CH_2), 1.17–1.11 (d, 6H, H-6_A, H-6_C), 0.80 (t, 3H, J=7.4 Hz, CH_3); ^{13}C NMR (D_2O): (partial) δ 174.9, 174.5, 174.1, 173.6 (C_{NAc}, C_{Ac}), 101.8 (C-1_D), 101.5, 101.2 (C-1_C), 99.0, 98.8 (C-1_A), 94.8, 94.7 (C-1_E), 82.6, 81.7 (C-3_D), 76.4 (C-4_D), 74.7 (C-2_A), 74.3–73.9 (C-3_A, C-2_C, C-3_C), 73.5, 73.3 (C-3_E), 72.4 (C-4_C), 71.7, 71.6 (C-5_E, C-2_E), 71.0 (C-4_A), 70.0 (C_{Pr}), 69.6–68.5 (C-4_E, C-5_A, C-5_C, C-5_D), 60.9 (C-6$_D$), 60.6 (C-6$_E$), 55.8 (C-2_D), 23.1, 22.8 (C_{NAc}), 22.3 (CH_2), 20.8, 20.6 (C_{Ac}), 17.1–16.6 (C-6_A, C-6_C), 10.2 (CH_3); HRMS (ESI$^+$) for $C_{31}H_{53}NO_{20}$ ([M+Na]$^+$, 782.3058) found *m*/*z* 782.3066.

4.18. Propyl α-L-rhamnopyranosyl-(1→3)-(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→2)-[α-D-glucopyranosyl-(1→3)]-α-L-rhamnopyranoside (6)

Tetrasaccharide **28** (0.412 g, 0.36 mmol) was dissolved in EtOH (30 mL), treated with 10% Pd/C catalyst (300 mg), and the suspension was stirred at rt for 2 days, under a hydrogen atmosphere (45 bar). TLC (*i*-PrOH/H_2O/NH_3, 4:1:0.5 and Chex/EtOAc, 6:4) showed that **28** had been transformed into a major polar product. The suspension was filtered on Acrodisc LC 25 mm and the filtrate was concentrated. Reverse phase chromatography (H_2O/CH_3CN, 100:0→70:30) of the residue, followed by freeze-drying, gave target **6** (119 mg, 71%) as a white foam. Tetrasaccharide **6** had R_f=0.65 (*i*-PrOH/H_2O/NH_3, 4:1:0.5); ^{1}H NMR (D_2O): δ 5.06 (d, 1H, $J_{1,2}$=3.7 Hz, H-1_E), 4.83 (d, 1H, $J_{1,2}$=1.6 Hz, H-1_A), 4.76 (d, 1H, $J_{1,2}$=1.3 Hz, H-1_C), 4.73 (d, 1H, $J_{1,2}$=8.6 Hz, H-1_D), 4.18 (m, 1H, H-2_A), 3.95 (m, 1H, H-5_E), 3.88 (m, 1H, H-5_C), 3.83–3.79 (m, 2H, H-3_A, H-6a$_D$), 3.74 (m, 1H, H-2_D), 3.72 (m, 1H, H-3_E), 3.70–3.67 (m, 3H, H-2_C, H-6a$_E$, H-6b$_E$), 3.65–3.59 (m, 4H, H-6b$_D$, H-3_C, H-5_A, H-2_E), 3.52 (m, 1H, H_{Pr}), 3.42–3.28 (m, 6H, H-4_E, H_{Pr}, H-4_D, H-5_D, H-3_D, H-4_C), 3.23 (pt, 1H, $J_{3,4}$=9.7 Hz, H-4_A), 2.01 (s, 3H, H_{NAc}), 1.49 (sex, 2H, CH_2), 1.16 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_A), 1.12 (d, 3H, $J_{5,6}$=6.3 Hz, H-6_C), 0.80 (t, 3H, J=7.4 Hz, CH_3); ^{13}C NMR (D_2O): δ 174.5 (C_{NAc}), 101.8 (C-1_D, $^1J_{CH}$=160.3 Hz), 101.6 (C-1_C, $^1J_{CH}$=170.5 Hz), 99.0 (C-1_A, $^1J_{CH}$=172.7 Hz), 94.8 (C-1_E, $^1J_{CH}$=169.8 Hz), 81.7 (C-3_D), 76.4 (C-4_D), 74.7 (C-2_A), 74.1 (C-3_A), 73.5 (C-3_E), 72.2 (C-4_C), 71.7 (C-5_E), 71.6 (C-2_E), 71.2 (C-2_C), 71.0 (C-4_A), 70.5 (C-3_C), 70.0 (C_{Pr}), 69.6 (C-5_D), 69.3 (C-5_C), 69.1 (C-5_A), 68.6 (C-4_E), 60.9 (C-6$_D$), 60.6 (C-6$_E$), 55.9 (C-2_D), 22.8 (C_{NAc}), 22.3 (CH_2), 17.0, 16.7 (C-6_A, C-6_C), 10.2 (CH_3); HRMS (ESI$^+$) for $C_{29}H_{51}NO_{19}$ ([M+Na]$^+$, 740.2953) found *m*/*z* 740.2941.

4.19. Allyl (2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (31)

Methanolic MeONa (0.5 M, 4.8 mL, 2.4 mmol, 6 equiv) was added to a solution of **23** (0.5 g, 0.4 mmol) in CH_2Cl_2 (38 mL), and the mixture was stirred for 9 h. TLC (CH_2Cl_2/MeOH, 92:8) showed the complete disappearance of the triacetate and the presence of a single more polar product. MeOH (77 mL) and acetic anhydride (300 μL) were added. After 2 h, TLC (CH_2Cl_2/MeOH, 92:8) showed the complete disappearance of the aminotriol intermediate. Evaporation of the filtrate gave a syrup, which was purified by chromatography (CH_2Cl_2/MeOH, 98:2→95:5) to give compound **31** (371 mg, 90%) as a white foam. Triol **31** had R_f=0.4 (CH_2Cl_2/MeOH, 92:8); ^{1}H NMR ($CDCl_3$): δ 7.41–7.08 (m, 26H, NH, CH_{Ph}), 5.88 (m, 1H, CH=), 5.29 (m, 1H, J_{trans}=17.2 Hz, =CH_2), 5.21 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.09–5.06 (m, 2H, H-1_E, H_{Bn}), 5.01–4.96 (m, 2H, H-1_A, H_{Bn}), 4.91–4.87 (m, 2H, H_{Bn}), 4.81–4.76 (m, 2H, J=10.3 Hz, H_{Bn}), 4.63–4.58 (m, 2H, H_{Bn}), 4.50 (d, 1H, J=10.9 Hz, H_{Bn}), 4.62 (m, 1H, H-1_D), 4.34 (m, 1H, H_{Bn}), 4.19–4.08 (m, 4H, H-3_A, H-5_E, H_{All}, H-3_E), 4.01 (m, 1H, H_{All}), 3.91 (br s, 1H, H-2_A), 3.87–3.81 (m, 5H, H-2_E, H-4_E, H-2_D, H-6a$_D$, H-6b$_D$), 3.72 (m, 1H, H-5_A), 3.51 (pt, 1H, $J_{3,4}$=9.0 Hz, H-4_D), 3.51–3.45 (m, 3H, H-4_A, H-6a$_E$, H-6b$_E$), 3.13 (m, 1H, H-5_D), 2.80 (pt, 1H, $J_{2,3}$=9.2 Hz, H-3_D), 2.21 (s, 3H, H_{NAc}), 1.40 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_A); ^{13}C NMR ($CDCl_3$): δ 173.3 (C_{NAc}), 138.6–137.5 (C_{Ph}), 134.2 (CH=), 129.5–127.8 (CH_{Ph}), 117.8 (=CH_2), 103.0 (C-1_D, $^1J_{CH}$=155.6 Hz), 98.5 (C-1_A, $^1J_{CH}$=174.8 Hz), 94.6 (C-1_E, $^1J_{CH}$=167.9 Hz), 83.7 (C-3_E), 80.2 (C-4_A), 79.2, 79.0 (2C, C-2_E, C-4_E), 77.1 (C-3_D), 76.9 (C-2_A), 76.5, 75.8 (2C, C_{Bn}), 75.7 (C-5_D), 75.6, 75.3 (2C, C_{Bn}), 74.6 (C-3_A), 73.8 (C_{Bn}), 71.8 (C-4_D), 70.3 (C-5_E), 68.7 (C-5_A), 68.3 (C_{All}), 68.2 (C-6$_E$), 62.7 (C-6$_D$), 57.4 (C-2_D), 23.6 (C_{NAc}), 18.2 (C-6_A); HRMS (ESI$^+$) for $C_{58}H_{70}NO_{15}$ ([M+H]$^+$, 1020.4745) found *m*/*z* 1020.4739, ([M+H]$^+$, 1042.4565) found *m*/*z* 1042.4545.

4.20. Allyl (2-acetamido-2-deoxy-4,6-*O*-isopropylidene-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (32)

CSA (6.2 mg, 26 μmol) was added to a suspension of triol **31** (270 mg, 0.26 mmol) in a mixture of DMF (3 mL) and 2-methoxypropene (76 μL, 0.79 mmol, 3 equiv). After stirring for 2 h at rt, TLC (Chex/EtOAc, 1:1 and CH_2Cl_2/MeOH, 92:8) showed the complete disappearance of the triol and the presence of a less polar product. Et_3N (0.2 mL) was added and concentrated to dryness. Chromatography of the residue (Chex/EtOAc, 1:1) gave **32** (240 mg, 85%) as a white foam. Compound **32** had R_f=0.35 (Chex/EtOAc, 1:1); ^{1}H NMR ($CDCl_3$): δ 7.31–6.96 (m, 26H, NH, CH_{Ph}), 5.88 (m, 1H, CH=), 5.29 (m, 1H, J_{trans}=17.3 Hz, =CH_2), 5.21 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.09–5.06 (m, 2H, $J_{1,2}$=5.6 Hz, H-1_E, H_{Bn}), 4.98 (m, 1H, J=11.9 Hz, H_{Bn}), 4.86 (m, 2H, H_{Bn}), 4.84 (br s, 1H, $J_{1,2}$=1.7 Hz, H-1_A), 4.80–4.74 (m, 2H, H_{Bn}), 4.63–4.57 (m, 2H, J=11.9 Hz, H_{Bn}), 4.50 (m, 1H, J=9.6 Hz, H_{Bn}), 4.37–4.30 (m, 2H, $J_{1,2}$=8.3 Hz, H_{Bn}, H-1_D), 4.19–4.07

(m, 4H, H-3$_A$, H-5$_E$, H$_{All}$, H-3$_E$), 3.96 (m, 1H, H$_{All}$), 3.89–3.70 (m, 7H, H-2$_A$, H-6a$_D$, H-2$_E$, H-4$_E$, H-2$_D$, H-5$_A$, H-6b$_D$), 3.53 (pt, 1H, $J_{3,4}$=9.3 Hz, H-4$_D$), 3.51 (m, 2H, H-6a$_E$, H-6b$_E$), 3.45 (pt, 1H, $J_{3,4}$=9.6 Hz, H-4$_A$), 2.87 (m, 1H, H-5$_D$), 2.81 (pt, 1H, $J_{2,3}$=9.2 Hz, H-3$_D$), 2.20 (s, 3H, H$_{NAc}$), 1.52 (s, 3H, H$_{i\text{-}Pr}$), 1.48 (s, 3H, H$_{i\text{-}Pr}$), 1.39 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$); ^{13}C NMR ($CDCl_3$): δ 173.3 (C$_{NAc}$), 138.5–137.5 (C$_{Ph}$), 134.2 (CH=), 129.5–127.7 (CH$_{Ph}$), 117.7 (=CH$_2$), 102.8 (C-1$_D$, $^1J_{CH}$=155.2 Hz), 100.1 (C$_{i\text{-}Pr}$), 98.6 (C-1$_A$, $^1J_{CH}$=172.4 Hz), 94.6 (C-1$_E$, $^1J_{CH}$=169.1 Hz), 83.7 (C-3$_E$), 80.2 (C-4$_A$), 79.9 (C-2$_E$), 79.1 (C-4$_E$), 76.6 (C-2$_A$), 76.5, 76.1, 75.8, 75.4 (4C, C$_{Bn}$), 74.8 (C-3$_A$), 74.6 (C-3$_D$), 74.5 (C-4$_D$), 73.8 (C$_{Bn}$), 70.4 (C-5$_E$), 68.8 (C-5$_A$), 68.3 (C$_{All}$), 68.2 (C-6$_E$), 67.3 (C-5$_D$), 62.3 (C-6$_D$), 58.9 (C-2$_D$), 29.5 (C$_{i\text{-}Pr}$), 23.6 (C$_{NAc}$), 19.3 (C$_{i\text{-}Pr}$), 18.2 (C-6$_A$); HRMS (ESI$^+$) for $C_{58}H_{70}NO_{15}$ ([M+H]$^+$, 1060.5058) found *m*/*z* 1060.5066, ([M+H]$^+$, 1082.4878) found *m*/*z* 1082.4875.

4.21. Allyl (2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl)-(1→3)-2-*O*-acetyl-4-*O*-benzyl-α-L-rhamnopyranoside (35)

TMSOTf (125 μL, 0.7 mmol, 0.3 equiv) was added to a solution of **21** (780 mg, 2.3 mmol) and trichloroacetimidate **34** (1.5 g, 3.5 mmol, 1.5 equiv) in CH_2Cl_2 (60 mL) containing 4 Å MS (2 g), stirred at −78 °C. The reaction mixture was stirred for 6 h while slowly coming back to rt. TLC (Tol/EtOAc, 8:2) showed the complete disappearance of the acceptor and the presence of a major more polar product. Et_3N (1 mL) was added and the mixture was filtered and concentrated to dryness. Chromatography of the residue (Tol/EtOAc, 9:1→8:2) gave **35** (1.34 g, 95%) as a white foam. Disaccharide **35** had R_f=0.35 (Tol/EtOAc, 8:2); ^{1}H NMR ($CDCl_3$): δ 7.34–7.02 (m, 5H, CH$_{Ph}$), 5.87 (m, 1H, CH=), 5.33 (m, 1H, H-2$_B$), 5.28 (m, 1H, =CH$_2$), 5.25 (m, 1H, H-3$_B$), 5.20 (m, 1H, =CH$_2$), 5.18 (m, 1H, H-2$_C$), 5.07 (pt, 1H, $J_{3,4}$=9.9 Hz, H-4$_B$), 5.04 (d, 1H, $J_{1,2}$=1.5 Hz, H-1$_B$), 4.82 (d, 1H, J=10.8 Hz, H$_{Bn}$), 4.75 (d, 1H, $J_{1,2}$=1.6 Hz, H-1$_C$), 4.67 (d, 1H, H$_{Bn}$), 4.17–4.12 (m, 2H, H-3$_C$, H$_{All}$), 4.00–3.91 (m, 2H, H$_{All}$, H-5$_B$), 3.77 (m, 1H, H-5$_C$), 3.51 (pt, 1H, $J_{3,4}$=9.5 Hz, H-4$_C$), 2.21, 2.08, 2.07, 1.99 (4s, 12H, H$_{Ac}$), 1.34 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_C$), 1.21 (d, 3H, $J_{5,6}$=6.3 Hz, H-6$_B$); ^{13}C NMR ($CDCl_3$): δ 170.9, 170.4, 170.3, 170.2 (4C, C$_{Ac}$), 138.3 (C$_{Ph}$), 133.8 (CH=), 129.4–128.1 (CH$_{Ph}$), 117.9 (=CH$_2$), 99.8 (C-1$_B$, $^1J_{CH}$=173.0 Hz), 96.8 (C-1$_C$, $^1J_{CH}$=170.0 Hz), 81.1 (C-4$_C$), 77.2 (C-3$_C$), 75.6 (C$_{Bn}$), 72.5 (C-2$_C$), 71.1 (C-4$_B$), 70.2 (C-2$_B$), 69.5 (C-3$_B$), 68.5 (C$_{All}$), 68.3 (C-5$_C$), 67.6 (C-5$_B$), 21.4, 21.2, 21.1, 21.0 (4C, C$_{Ac}$), 18.3 (C-6$_C$), 17.7 (C-6$_B$); HRMS (ESI$^+$) for $C_{30}H_{40}O_{13}$ ([M+Na]$^+$, 631.2367) found *m*/*z* 631.2368, ([M+K]$^+$, 647.2106) found *m*/*z* 647.2124.

4.22. (2,3,4-Tri-*O*-acetyl-α-L-rhamnopyranosyl)-(1→3)-2-*O*-acetyl-4-*O*-benzyl-α-L-rhamnopyranose (38)

1,5-Cyclooctadiene-bis(methyldiphenylphosphine)iridium hexafluorophosphate (170 mg) was dissolved in THF (30 mL) and the resulting red solution was degassed under an argon stream. Hydrogen was bubbled through the solution, causing the color to change to yellow. The solution was then degassed again under an argon stream. A solution of **35** (1.34 g, 2.2 mmol) in THF (8 mL) was added. The mixture was stirred overnight at rt and TLC (Tol/EtOAc, 8:2) showed the complete disappearance of the starting material and the presence of a single less polar product. The mixture was treated with a solution of iodine (1.12 g, 4.4 mmol) in THF/water (15 mL, 4:1 v/v) and stirred for 1 h at rt. TLC (Tol/EtOAc, 8:2 and CH_2Cl_2/MeOH, 9.5:0.5) showed the complete disappearance of the intermediate and the presence of a single more polar product. Excess iodine was destroyed by adding a solution of freshly prepared 5% aq sodium bisulphite. CH_2Cl_2 (100 mL) was added and the organic phase was washed with brine (3×30 mL), water (3×30 mL), dried on Na_2SO_4, filtered, and concentrated to dryness. Chromatography of the residue (CH_2Cl_2/MeOH, 99:1→9:1) gave compound **38** (1.14 g, 91%) as a yellow syrup. Hemiacetal **38** had R_f=0.55 (CH_2Cl_2/MeOH, 9.5:0.5); ^{1}H NMR ($CDCl_3$): δ 7.33–7.26 (m, 5H, CH$_{Ph}$), 5.34 (m, 1H, H-2$_B$), 5.25 (m, 1H, H-3$_B$), 5.18 (m, 1H, H-2$_C$), 5.10 (s, 1H, H-1$_C$), 5.05 (pt, 1H, $J_{3,4}$=9.9 Hz, H-4$_B$), 5.04 (d, 1H, $J_{1,2}$=1.7 Hz, H-1$_B$), 4.80 (d, 1H, J=10.9 Hz, H$_{Bn}$), 4.65 (d, 1H, H$_{Bn}$), 4.19 (m, 1H, H-3$_C$), 4.01–3.91 (m, 2H, H-5$_C$, H-5$_B$), 3.58 (s, 1H, OH), 3.49 (pt, 1H, $J_{3,4}$=9.5 Hz, H-4$_C$), 2.21, 2.08, 2.07, 1.99 (4s, 12H, H$_{Ac}$), 1.31 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_C$), 1.19 (d, 3H, $J_{5,6}$=6.3 Hz, H-6$_B$); ^{13}C NMR ($CDCl_3$): δ 171.7, 171.0, 170.6, 170.3 (4C, C$_{Ac}$), 138.3–137.9 (C$_{Ph}$), 128.8–128.1 (CH$_{Ph}$), 99.7 (C-1$_B$, $^1J_{CH}$=172.7 Hz), 92.3 (C-1$_C$, $^1J_{CH}$=170.5 Hz), 81.1 (C-4$_C$), 76.6 (C-3$_C$), 75.9 (C$_{Bn}$), 72.9 (C-2$_C$), 71.1 (C-4$_B$), 70.2 (C-2$_B$), 69.5 (C-3$_B$), 68.2 (C-5$_C$), 67.6 (C-5$_B$), 21.4, 21.2, 21.1, 21.0 (4C, C$_{Ac}$), 18.3 (C-6$_C$), 17.6 (C-6$_B$); HRMS (ESI$^+$) for $C_{27}H_{36}O_{13}$ ([M+Na]$^+$, 591.2054) found *m*/*z* 591.2037, ([M+K]$^+$, 607.1793) found *m*/*z* 607.1838.

4.23. (2,3,4-Tri-*O*-acetyl-α-L-rhamnopyranosyl)-(1→3)-2-*O*-acetyl-4-*O*-benzyl-α/β-L-rhamnopyranose trichloroacetimidate (16)

Hemiacetal **38** (1.0 g, 1.7 mmol) was dissolved in DCE (15 mL), placed under argon, and cooled to −5 °C. Trichloroacetonitrile (2.15 mL, 21.5 mmol, 12 equiv) and then DBU (75 μL, 0.5 mmol, 0.28 equiv) were added. The mixture was stirred at −5 °C for 10 min. TLC (Chex/EtOAc+Et_3N, 7:3) showed the complete disappearance of **38** and the presence of a single less polar product. The mixture was directly chromatographed (Chex/EtOAc+5% Et_3N, 9:1→7:3) to give **16** (1.13 g, 89%) as a yellow syrup. Trichloroacetimidate **16** (α anomer) had R_f=0.5 (Chex/EtOAc, 6:4); ^{1}H NMR ($CDCl_3$): δ 8.70 (s, 1H, NH), 7.33–7.27 (m, 5H, CH$_{Ph}$), 6.18 (d, 1H, $J_{1,2}$=1.7 Hz, H-1$_C$), 5.35 (m, 2H, H-2$_B$, H-2$_C$), 5.22 (m, 1H, H-3$_B$), 5.08 (s, 1H, $J_{1,2}$=1.5 Hz, H-1$_B$), 5.07 (pt, 1H, $J_{3,4}$=9.9 Hz, H-4$_B$), 4.80 (d, 1H, J=10.8 Hz, H$_{Bn}$), 4.68 (d, 1H, H$_{Bn}$), 4.23 (m, 1H, H-3$_C$), 4.00–3.92 (m, 2H, H-5$_C$, H-5$_B$), 3.62 (pt, 1H, $J_{3,4}$=9.6 Hz, H-4$_C$), 2.26, 2.08, 2.07, 1.99 (4s, 12H, H$_{Ac}$), 1.37 (d, 3H, $J_{5,6}$=6.3 Hz, H-6$_C$), 1.19 (d, 3H, $J_{5,6}$=6.3 Hz, H-6$_B$); ^{13}C NMR ($CDCl_3$): δ 170.6, 170.5, 170.4, 170.2 (4C, C$_{Ac}$), 164.0 (C=NH), 137.8 (C$_{Ph}$), 128.8–128.3 (CH$_{Ph}$), 99.6 (C-1$_B$, $^1J_{CH}$=173.4 Hz), 95.1 (C-1$_C$, $^1J_{CH}$=178.6 Hz), 91.2 (CCl_3), 80.5 (C-4$_C$), 76.2 (C$_{Bn}$), 75.6 (C-3$_C$), 71.3 (C-5$_C$), 70.9 (C-4$_B$), 70.7 (C-2$_C$), 70.0 (C-2$_B$), 69.4 (C-3$_B$), 67.8 (C-5$_B$), 21.3, 21.2, 21.1, 21.0 (4C, C$_{Ac}$), 18.3 (C-6$_C$), 17.7 (C-6$_B$).

4.24. Allyl (2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl)-(1→3)-(2-*O*-acetyl-4-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (39)

TMSOTf (50 μL, 280 μmol, 0.3 equiv) was added to a solution of **15** (1.09 g, 935 mmol) and trichloroacetimidate **16** (935 mg, 1.3 mmol, 1.4 equiv) in toluene (10 mL) containing 4 Å MS (765 mg), stirred at −78 °C. The reaction mixture was stirred for 15 min at this temperature. TLC (Tol/EtOAc, 7:3) showed the complete disappearance of **15** and the presence of a major more polar product. Et_3N (0.5 mL) was added and the mixture was filtered, and concentrated to dryness. Chromatography of the residue (Tol/EtOAc, 9:1→4:6) gave first the fully protected **39** (1.3 g, 80%) as a white foam and next, diol **40** (R_f=0.24, Tol/EtOAc, 7:3, 108 mg, 7%) slightly contaminated by the hydrolyzed donor **38**. The former, **39**, had R_f=0.55 (Tol/EtOAc, 7:3); ^{1}H NMR ($CDCl_3$): δ 7.48–7.12 (m, 30H, CH$_{Ph}$), 6.95 (d, 1H, $J_{NH,2}$=8.8 Hz, NH), 5.92 (m, 1H, CH=), 5.38 (m, 1H, H-2$_B$), 5.29 (m, 1H, J_{trans}=16.9 Hz, =CH$_2$), 5.28 (m, 1H, H-3$_B$), 5.22 (d, 1H, $J_{1,2}$=4.1 Hz, H-1$_E$), 5.21 (m, 1H, J_{cis}=10.6 Hz, =CH$_2$), 5.17 (m, 1H, H-2$_C$), 5.15 (m, 4H, H-1$_B$, H-4$_B$, 2H$_{Bn}$), 5.05 (d, 1H, J=12.2 Hz, H$_{Bn}$), 4.95 (d, 1H, J=12.2 Hz, H$_{Bn}$), 4.86–4.82 (m, 3H, H-1$_A$, 2H$_{Bn}$), 4.76–4.70 (m, 3H, H$_{Bn}$, H-1$_C$, H$_{Bn}$), 4.62–4.53 (m, 4H, 2H$_{Bn}$, H-1$_D$, H$_{Bn}$), 4.36 (d, 1H, J=12.0 Hz, H$_{Bn}$), 4.22–4.14 (m, 6H, H-3$_E$, H$_{All}$, H-3$_C$, H-3$_A$, H-5$_B$, H-5$_E$), 4.09–4.04 (m, 3H, H-2$_D$, H-5$_C$, H-2$_A$), 3.99 (m, 1H, H$_{All}$), 3.93–3.88 (m, 2H, H-2$_E$, H-6a$_D$), 3.85 (pt, 1H, $J_{3,4}$=9.6 Hz,

H-4_E), 3.77–3.72 (m, 2H, H-5_A, H-$6b_D$), 3.57 (pt, 1H, $J_{3,4}$=9.2 Hz, H-4_D), 3.52–3.45 (m, 4H, H-4_C, H-4_A, H-$6a_E$, H-$6b_E$), 2.84–2.80 (m, 2H, H-5_D, H-3_D), 2.26, 2.13, 2.11, 2.03 (4s, 12H, H_{Ac}), 1.52 (s, 3H, $H_{i\text{-}Pr}$), 1.50 (s, 3H, $H_{i\text{-}Pr}$), 1.44 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_A), 1.37 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_B), 1.33 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_C); ^{13}C NMR ($CDCl_3$): δ 170.6, 170.5, 170.3, 170.2 (4C, C_{Ac}), 162.4 (C_{NTCA}), 138.6–137.8 (C_{Ph}), 134.3 (CH=), 129.8–127.7 (CH_{Ph}), 117.6 (=CH_2), 101.6 (C-1_D, $^1J_{CH}$=164.7 Hz), 99.9 ($C_{i\text{-}Pr}$), 99.2 (C-1_B, $^1J_{CH}$=174.2 Hz), 98.8 (C-1_A, $^1J_{CH}$=171.2 Hz), 98.4 (C-1_C, $^1J_{CH}$=170.5 Hz), 94.7 (C-1_E, $^1J_{CH}$=166.9 Hz), 93.4 (CCl_3), 83.5 (C-3_E), 81.5 (C-4_C), 80.7 (C-2_E), 80.2 (C-4_A), 79.2 (C-4_E), 78.7 (C-3_D), 76.5 (C_{Bn}), 75.6 (C-3_C), 75.7, 75.6, 75.4, 75.3 (4C, C_{Bn}), 74.9 (C-3_A), 74.1 (C-2_A), 73.8 (C_{Bn}), 72.9 (C-4_D), 72.5 (C-2_C), 71.2 (C-4_B), 70.3 (2C, C-2_B, C-5_E), 69.6 (C-3_B), 68.8 (C-5_A), 68.4 (C-6_E), 68.3 (C-5_C), 68.2 (C_{All}), 67.8 (C-5_B), 67.4 (C-5_D), 62.5 (C-6_D), 58.0 (C-2_D), 29.6 ($C_{i\text{-}Pr}$), 21.4, 21.3, 21.2, 21.1 (4C, C_{Ac}), 19.5 ($C_{i\text{-}Pr}$), 18.5 (C-6_C), 18.3 (C-6_A), 17.7 (C-6_B); HRMS (ESI$^+$) for $C_{88}H_{104}Cl_3NO_{27}$ ([M+Na]$^+$, 1734.5759) found *m/z* 1734.5825, ([M+NH_4]$^+$, 1729.6205) found *m/z* 1729.6278.

4.25. Allyl α-L-rhamnopyranosyl-(1→3)-(2-*O*-acetyl-4-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (41) and allyl α-L-rhamnopyranosyl-(1→3)-(4-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-deoxy-4,6-*O*-isopropylidene-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (42)

Anhydrous K_2CO_3 (42 mg, 0.30 mmol, 1 equiv) was added to a stirred solution of pentasaccharide **39** (525 mg, 0.30 mmol) in dry MeOH (20 mL). The mixture was stirred at rt for 25 min, at which time TLC (CH_2Cl_2/MeOH, 9.6:0.4 and Tol/EtOAc, 8:2) indicated total conversion of **39** into two products. Neutralization by addition of Dowex X8-200 ion exchange resin (H^+), filtration, and evaporation of the volatiles gave a syrup, which was chromatographed (Chex/Acetone, 6:4→4:6) to give first mono-acetylated **41** (414 mg, 85%), then tetraol **42** (33 mg, 7%), both as white foams. Triol **41** had R_f=0.3 (CH_2Cl_2/MeOH, 9.6:0.4); ^{1}H NMR ($CDCl_3$) δ 7.42–7.07 (m, 30H, CH_{Ph}), 6.95 (d, 1H, $J_{NH,2}$=8.8 Hz, NH), 5.92 (m, 1H, CH=), 5.26 (m, 1H, J_{trans}=17.2 Hz, =CH_2), 5.18 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.15 (d, 1H, $J_{1,2}$=3.4 Hz, H-1_E), 5.09–5.05 (m, 4H, H-2_C, H-1_B, 2H_{Bn}), 4.98 (d, 1H, J=12.2 Hz, H_{Bn}), 4.87 (d, 1H, J=12.2 Hz, H_{Bn}), 4.80–4.74 (m, 3H, H-1_A, 2H_{Bn}), 4.70 (d, 1H, J=11.2 Hz, H_{Bn}), 4.66–4.63 (m, 3H, H_{Bn}, H-1_C, H_{Bn}), 4.56–4.47 (m, 3H, 2H_{Bn}, H-1_D), 4.30 (d, 1H, J=11.9 Hz, H_{Bn}), 4.14–4.05 (m, 5H, H_{All}, H-3_E, H-3_A, H-5_E, H-3_C), 4.00–3.94 (m, 4H, H-2_D, H_{All}, H-2_A, H-5_C), 3.87–3.84 (m, 4H, H-$6a_D$, H-2_B, H-5_B, H-2_E), 3.79 (pt, 1H, $J_{3,4}$=9.1 Hz, H-4_E), 3.70–3.65 (m, 3H, H-$6b_D$, H-5_A, H-3_B), 3.53 (pt, 1H, $J_{3,4}$=9.2 Hz, H-4_D), 3.46–3.37 (m, 5H, H-4_B, H-$6a_E$, H-$6b_E$, H-4_C, H-4_A), 2.81–2.71 (m, 2H, H-5_D, H-3_D), 2.14 (s, 3H, H_{Ac}), 1.47 (s, 3H, $H_{i\text{-}Pr}$), 1.43 (s, 3H, $H_{i\text{-}Pr}$), 1.38 (d, 3H, $J_{5,6}$=5.9 Hz, H-6_A), 1.36 (d, 3H, $J_{5,6}$=6.0 Hz, H-6_B), 1.25 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_C); ^{13}C NMR ($CDCl_3$): δ 170.5 (C_{Ac}), 162.6 (C_{NTCA}), 138.7–138.1 (C_{Ph}), 134.2 (CH=), 129.8–127.7 (CH_{Ph}), 117.7 (=CH_2), 101.6 (C-1_B, $^1J_{CH}$=170.5 Hz), 101.4 (C-1_D, $^1J_{CH}$=159.5 Hz), 99.9 ($C_{i\text{-}Pr}$), 98.7 (C-1_A, $^1J_{CH}$=172.0 Hz), 98.2 (C-1_C, $^1J_{CH}$=169.1 Hz), 94.6 (C-1_E, $^1J_{CH}$=166.9 Hz), 93.3 (CCl_3), 83.4 (C-3_E), 81.3 (C-4_C), 80.6 (C-2_E), 80.1 (C-4_A), 79.1 (C-4_E), 78.7 (C-3_D), 76.5 (C_{Bn}), 76.0 (C-3_C), 75.7, 75.6, 75.5, 75.3 (4C, C_{Bn}), 74.8 (C-3_A), 73.9 (C-2_A), 73.8 (C-4_B), 73.7 (C_{Bn}), 72.9 (C-2_C), 72.7 (C-4_D), 71.8 (C-3_B), 71.4 (C-2_B), 70.2 (C-5_E), 69.2 (C-5_B), 68.7 (C-5_A), 68.3 (C-5_C), 68.2 (2C, C-6_E, C_{All}), 67.3 (C-5_D), 62.4 (C-6_D), 57.9 (C-2_D), 29.6 ($C_{i\text{-}Pr}$), 21.6 (C_{Ac}), 19.5 ($C_{i\text{-}Pr}$), 18.4 (C-6_A), 18.3 (C-6_C), 17.8 (C-6_B); HRMS (ESI$^+$) for $C_{82}H_{98}Cl_3NO_{24}$ ([M+Na]$^+$, 1608.5542) found *m/z* 1608.5582, ([M+NH_4]$^+$, 1603.5889) found *m/z* 1603.6035, ([M+K]$^+$, 1624.5182) found *m/z* 1624.5436.

Tetraol **42** had R_f=0.25 (CH_2Cl_2/MeOH, 9.6:0.4); ^{1}H NMR ($CDCl_3$): δ 7.38–7.04 (m, 30H, CH_{Ph}), 6.93 (d, 1H, $J_{NH,2}$=8.8 Hz, NH), 5.86 (m, 1H, CH=), 5.26 (m, 1H, J_{trans}=17.2 Hz, =CH_2), 5.18 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.15 (d, 1H, $J_{1,2}$=3.5 Hz, H-1_E), 5.09–4.95 (m, 4H, H-1_B, 3H_{Bn}), 4.89 (d, 1H, J=12.3 Hz, H_{Bn}), 4.78 (d, 1H, J=11.0 Hz, H_{Bn}), 4.75 (d, 1H, $J_{1,2}$=1.0 Hz, H-1_A), 4.73–4.61 (m, 4H, 2H_{Bn}, H-1_C, H_{Bn}), 4.57 (d, 1H, J=12.0 Hz, H_{Bn}), 4.51–4.47 (m, 2H, H_{Bn}), 4.41 (d, 1H, $J_{1,2}$=8.4 Hz, H-1_D), 4.32 (d, 1H, J=12.0 Hz, H_{Bn}), 4.14–4.07 (m, 4H, H_{All}, H-3_A, H-3_E, H-5_E), 4.03 (d, 1H, $J_{1,2}$=9.2 Hz, H-2_D), 4.00–3.91 (m, 4H, H-5_C, H-2_A, H-3_C, H_{All}), 3.89–3.79 (m, 6H, H-2_C, H-2_B, H-2_E, H-$6a_D$, H-4_E, H-3_B), 3.75–3.64 (m, 3H, H-5_B, H-$6b_D$, H-5_A), 3.52–3.48 (pt, 2H, $J_{3,4}$=9.2 Hz, H-4_D, H-4_B), 3.44 (m, 2H, H-$6a_E$, H-$6b_E$), 3.48 (pt, 1H, $J_{3,4}$=9.9 Hz, H-4_C), 3.48 (pt, 1H, $J_{3,4}$=9.5 Hz, H-4_A), 2.74–2.69 (m, 2H, H-3_D, H-5_D), 1.46 (s, 3H, $H_{i\text{-}Pr}$), 1.42 (s, 3H, $H_{i\text{-}Pr}$), 1.41 (d, 3H, $J_{5,6}$=6.0 Hz, H-6_B), 1.37 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_A), 1.22 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_C); ^{13}C NMR ($CDCl_3$): δ 162.3 (C_{NTCA}), 138.8–138.2 (C_{Ph}), 134.2 (CH=), 129.8–127.7 (CH_{Ph}), 117.6 (=CH_2), 102.0 (C-1_B, $^1J_{CH}$=175.6 Hz), 101.4 (C-1_D, $^1J_{CH}$=162.5 Hz), 100.2 (C-1_C, $^1J_{CH}$=171.2 Hz), 99.8 ($C_{i\text{-}Pr}$), 98.7 (C-1_A, $^1J_{CH}$=172.0 Hz), 94.4 (C-1_E, $^1J_{CH}$=166.1 Hz), 93.3 (CCl_3), 83.5 (C-3_E), 80.7 (C-4_C), 80.5 (C-2_E), 80.1 (C-4_A), 79.4 (C-3_C), 79.1 (C-4_E), 78.0 (C-3_D), 76.6, 75.8, 75.6, 75.4, 75.3 (5C, C_{Bn}), 74.5 (C-3_A), 73.8 (C-4_B), 73.7 (C_{Bn}), 73.6 (C-2_A), 72.5 (C-4_D), 72.0 (C-3_B), 71.5 (C-2_C), 71.4 (C-2_B), 70.1 (C-5_E), 69.2 (C-5_B), 68.7 (C-5_A), 68.2 (2C, C-6_E, C_{All}), 68.0 (C-5_C), 67.3 (C-5_D), 62.4 (C-6_D), 58.1 (C-2_D), 30.1 ($C_{i\text{-}Pr}$), 19.5 ($C_{i\text{-}Pr}$), 18.3, 18.2 (C-6_A,C-6_C), 17.8 (C-6_B); HRMS (ESI$^+$) for $C_{80}H_{96}Cl_3NO_{23}$ ([M+Na]$^+$, 1566.5337) found *m/z* 1566.5404, ([M+NH_4]$^+$, 1561.5782) found *m/z* 1561.5812.

4.26. Allyl α-L-rhamnopyranosyl-(1→3)-(2-*O*-acetyl-4-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-deoxy-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (43)

Aq TFA (50%, 2 mL) was added, at 0 °C, to a solution of pentasaccharide **41** (292 mg, 0.18 mmol) in CH_2Cl_2 (5 mL), and the biphasic mixture was stirred vigorously at rt for 1 h. TLC (CH_2Cl_2/MeOH, 9.5:0.5) showed the complete disappearance of the starting material and the presence of a major more polar product. Repeated coevaporation with toluene and chromatography of the residue (CH_2Cl_2/MeOH, 95:5→93:7) provided pentaol **43** (274 mg, 95%) as a white foam. Compound **43** had R_f=0.3 (CH_2Cl_2/MeOH, 9.5:0.5); ^{1}H NMR ($CDCl_3$): δ 7.39–7.05 (m, 31H, CH_{Ph}, NH), 5.88 (m, 1H, CH=), 5.28 (m, 1H, J_{trans}=17.2 Hz, =CH_2), 5.22–5.20 (m, 2H, H-1_E, =CH_2), 5.11 (m, 1H, H-2_C), 5.09–5.02 (m, 3H, H_{Bn}), 4.98 (m, 1H, H-1_B), 4.93 (d, 1H, J=12.5 Hz, H_{Bn}), 4.84 (d, 1H, $J_{1,2}$=1.3 Hz, H-1_A), 4.81–4.73 (m, 3H, H_{Bn}), 4.63–4.60 (m, 3H, H_{Bn}, H-1_D, H_{Bn}), 4.57 (m, 1H, H-1_C), 4.54–4.49 (m, 2H, H_{Bn}), 4.33 (d, 1H, J=12.0 Hz, H_{Bn}), 4.17–4.07 (m, 6H, H-3_A, H_{All}, H-3_E, H-5_E, H-3_C, H-2_A), 4.00–3.95 (m, 2H, H-2_D, H_{All}), 3.90 (m, 1H, H-5_C), 3.88–3.85 (m, 2H, H-2_B, H-$6a_D$), 3.84–3.78 (m, 2H, H-2_E, H-4_E), 3.77–3.61 (m, 4H, H-$6b_D$, H-5_B, H-3_B, H-5_A), 3.51–3.41 (m, 5H, H-4_A, H-$6a_E$, H-$6b_E$, H-4_C, H-4_B), 3.53 (pt, 1H, $J_{3,4}$=8.9 Hz, H-4_D), 3.04 (m, 1H, H-5_D), 2.29 (m, 1H, H-3_D), 2.19 (s, 3H, H_{Ac}), 1.25 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_B), 1.36 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_C), 1.38 (d, 3H, $J_{5,6}$=6.2 Hz, H-6_A); ^{13}C NMR ($CDCl_3$): δ 170.5 (C_{Ac}), 162.8 (C_{NTCA}), 138.9–138.2 (C_{Ph}), 134.3 (CH=), 129.7–127.8 (CH_{Ph}), 117.7 (=CH_2), 102.1 (C-1_B, $^1J_{CH}$=167.9 Hz), 101.1 (C-1_D, $^1J_{CH}$=164.0 Hz), 98.7 (C-1_C, $^1J_{CH}$=170.3 Hz), 98.6 (C-1_A, $^1J_{CH}$=170.3 Hz), 94.5 (C-1_E, $^1J_{CH}$=167.9 Hz), 93.2 (CCl_3), 86.6 (C-3_D), 83.4 (C-3_E), 80.7 (C-2_E), 80.3 (C-4_C), 79.9 (C-4_A), 79.1 (C-4_E), 77.7 (C-3_C), 76.6, 75.9, 75.7, 75.4, 75.3 (5C, C_{Bn}), 75.2 (C-5_D), 74.8 (C-3_A), 74.0 (C-2_A), 73.8 (C-4_B), 73.7 (C_{Bn}), 72.5 (C-2_C), 71.9 (C-3_B), 71.4 (C-2_B), 70.9 (C-4_D), 70.3 (C-5_E), 69.5 (C-5_C), 69.4 (C-5_A), 68.8 (C-5_B), 68.4 (C-6_E), 68.2 (C_{All}), 63.1 (C-6_D), 55.8 (C-2_D), 21.4 (C_{Ac}), 18.4 (C-6_C), 18.3 (C-6_B), 17.8 (C-6_A); HRMS (ESI$^+$) for $C_{79}H_{94}Cl_3NO_{24}$ ([M+Na]$^+$, 1568.5129) found *m/z* 1568.5162, ([M+NH_4]$^+$, 1563.5575) found *m/z* 1563.5681.

4.27. Allyl α-L-rhamnopyranosyl-(1→3)-(4-*O*-benzyl-α-L-rhamnopyranosyl)-(1→3)-(2-deoxy-2-trichloroacetamido-β-D-glucopyranosyl)-(1→2)-[2,3,4,6-tetra-*O*-benzyl-α-D-glucopyranosyl-(1→3)]-4-*O*-benzyl-α-L-rhamnopyranoside (45)

50% aq TFA (2 mL) was added, at 0 °C, to a solution of pentasaccharide **42** (340 mg, 0.18 mmol) in CH_2Cl_2 (5 mL), and the biphasic mixture was stirred vigorously at rt for 1 h. TLC (CH_2Cl_2/MeOH, 9.4:0.6) showed the complete disappearance of the starting material and the presence of a major more polar product. Repeated coevaporation with toluene and chromatography of the residue (CH_2Cl_2/MeOH, 95:5→93:7) provided hexaol **45** (314 mg, 95%) as a white foam. The later had R_f=0.2 (CH_2Cl_2/MeOH, 9.4:0.6); ^{1}H NMR ($CDCl_3$): δ 7.34–7.05 (m, 30H, CH_{Ph}), 6.93 (d, 1H, $J_{NH,2}$=8.7 Hz, NH), 5.86 (m, 1H, CH=), 5.26 (m, 1H, J_{trans}=17.2 Hz, =CH_2), 5.20 (m, 1H, J_{cis}=10.4 Hz, =CH_2), 5.17 (d, 1H, $J_{1,2}$=3.6 Hz, H-1$_E$), 5.06 (d, 1H, J=11.0 Hz, H_{Bn}), 5.02 (m, 1H, H-1$_B$), 5.01–4.97 (m, 2H, H_{Bn}), 4.88 (d, 1H, J=12.3 Hz, H_{Bn}), 4.81 (d, 1H, $J_{1,2}$=1.4 Hz, H-1$_A$), 4.78–4.69 (m, 3H, H_{Bn}), 4.62–4.56 (m, 3H, H_{Bn}, H-1$_D$, H_{Bn}), 4.51–4.47 (m, 3H, H_{Bn}, H-1$_C$, H_{Bn}), 4.32 (d, 1H, J=12.0 Hz, H_{Bn}), 4.15–4.13 (m, 2H, H-3$_A$, H_{All}), 4.11–4.07 (m, 2H, H-3$_E$, H-5$_E$), 4.02 (m, 1H, H-2$_A$), 3.98–3.95 (m, 2H, H-3$_C$, H_{All}), 3.93–3.87 (m, 4H, H-2$_C$, H-2$_D$, H-5$_C$, H-2$_B$), 3.84 (m, 1H, H-6a$_D$), 3.82–3.71 (m, 5H, H-5$_B$, H-2$_E$, H-4$_E$, H-6b$_D$, H-3$_B$), 3.69 (m, 1H, H-5$_A$), 3.48 (pt, 1H, $J_{3,4}$=9.2 Hz, H-4$_B$), 3.47–3.37 (m, 5H, H-4$_C$, H-6a$_E$, H-6b$_E$, H-4$_A$, H-4$_D$), 3.04 (m, 1H, H-5$_D$), 2.38 (pt, 1H, $J_{3,4}$=9.1 Hz, H-3$_D$), 1.27 (d, 3H, $J_{5,6}$=6.5 Hz, H-6$_C$), 1.36 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$), 1.37 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_B$); ^{13}C NMR ($CDCl_3$): δ 162.4 (C_{NTCA}), 138.2–137.9 (C_{Ph}), 134.2 (CH=), 129.2–127.7 (CH_{Ph}), 117.7 (=CH_2), 101.4 (C-1$_B$, $^1J_{CH}$=167.6 Hz), 101.1 (C-1$_D$, $^1J_{CH}$=159.5 Hz), 100.9 (C-1$_C$, $^1J_{CH}$=168.3 Hz), 98.6 (C-1$_A$, $^1J_{CH}$=174.2 Hz), 94.3 (C-1$_E$, $^1J_{CH}$=169.1 Hz), 93.3 (CCl_3), 85.8 (C-3$_D$), 83.4 (C-3$_E$), 80.6 (C-2$_E$), 80.3 (C-4$_A$), 80.0 (C-4$_C$), 79.2 (C-4$_E$), 78.8 (C-3$_C$), 76.6, 75.7, 75.6, 75.5 (4C, C_{Bn}), 75.3 (C-5$_D$), 75.2 (C_{Bn}), 74.5 (C-3$_A$), 74.0 (C-2$_A$), 73.7 (C_{Bn}), 73.6 (C-4$_B$), 71.9 (C-3$_B$), 71.2 (C-2$_B$), 70.9 (C-2$_C$), 70.6 (C-4$_D$), 70.3 (C-5$_E$), 69.4 (2C, C-5$_B$, C-5$_C$), 68.8 (C-5$_A$), 68.3 (C-6$_E$), 68.1 (C_{All}), 63.0 (C-6$_D$), 56.3 (C-2$_D$), 18.2, 18.1, 18.0 (3C, C-6$_A$, C-6$_B$, C-6$_C$); HRMS (ESI$^+$) for $C_{77}H_{92}Cl_3NO_{23}$ ([M+Na]$^+$, 1526.5023) found *m*/*z* 1526.5076, ([M+NH_4]$^+$, 1521.5470) found *m*/*z* 1521.5582, ([M+K]$^+$, 1542.4763) found *m*/*z* 1542.4871.

4.28. Propyl α-L-rhamnopyranosyl-(1→3)-(2-*O*-acetyl-α-L-rhamnopyranosyl)-(1→3)-(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→2)-[α-D-glucopyranosyl-(1→3)]-α-L-rhamnopyranoside (7)

The benzylated pentasaccharide **43** (0.27 g, 0.18 mmol) was dissolved in EtOH (20 mL), treated with 10% Pd/C catalyst (280 mg), and the suspension was stirred at rt for 10 days, under a hydrogen atmosphere (45 bar). TLC (*i*-PrOH/H_2O/NH_3, 4:1:0.5 and CH_2Cl_2/MeOH, 9.5:0.5) showed that starting material had been transformed into a major polar product. The suspension was filtered on Acrodisc LC 25 mm and the filtrate was concentrated. Reverse phase chromatography (H_2O/CH_3CN, 1000→70/30) of the residue, followed by freeze-drying, gave the target pentasaccharide **7** (111 mg, 70%) as a white foam. Pentasaccharide **7** had R_f=0.3 (*i*-PrOH/H_2O/NH_3, 4:1:0.5); ^{1}H NMR (D_2O): δ 5.04 (d, 1H, $J_{1,2}$=3.7 Hz, H-1$_E$), 4.91 (m, 1H, H-2$_C$), 4.90 (d, 1H, $J_{1,2}$=1.4 Hz, H-1$_B$), 4.83 (d, 1H, $J_{1,2}$=1.7 Hz, H-1$_A$), 4.79 (d, 1H, $J_{1,2}$=1.4 Hz, H-1$_C$), 4.72 (d, 1H, H-1$_D$), 4.17 (m, 1H, H-2$_A$), 4.00 (m, 1H, H-5$_C$), 3.96 (m, 1H, H-5$_E$), 3.91 (m, 1H, H-2$_B$), 3.86 (dd, 1H, $J_{2,3}$=3.2 Hz, $J_{3,4}$=9.7 Hz, H-3$_C$), 3.82–3.79 (m, 2H, H-3$_A$, H-6a$_D$), 3.76 (m, 1H, H-2$_D$), 3.71 (pt, 1H, $J_{3,4}$=9.5 Hz, H-3$_E$), 3.69 (m, 2H, H-6a$_E$, H-6b$_E$), 3.67–3.52 (m, 5H, H-6b$_D$, H_{Pr}, H-5$_A$, H-2$_E$, H-3$_B$), 3.48 (pt, 1H, $J_{3,4}$=9.9 Hz, H-4$_C$), 3.44 (m, 1H, H-5$_B$), 3.40 (m, 1H, H_{Pr}), 3.38 (m, 1H, H-4$_E$), 3.33 (m, 1H, H-4$_B$), 3.33–3.28 (m, 3H, H-5$_D$, H-4$_D$, H-3$_D$), 3.23 (pt, 1H, $J_{3,4}$=9.7 Hz, H-4$_A$), 2.07 (s, 3H, H_{Ac}), 2.04 (s, 3H, H_{NAc}), 1.49 (m, 2H, CH_2), 1.17 (d, 3H, $J_{5,6}$=6.1 Hz, H-6$_A$), 1.16 (m, 3H, $J_{5,6}$=6.0 Hz, H-6$_B$), 1.15 (d, 3H, $J_{5,6}$=6.4 Hz, H-6$_C$), 0.80 (t, 3H, J=7.4 Hz, CH_3); ^{13}C NMR (D_2O): δ 174.7 (C_{NAc}), 173.5 (C_{Ac}), 103.1 (C-1$_B$, $^1J_{CH}$=172.0 Hz), 101.9 (C-1$_D$, $^1J_{CH}$=163.9 Hz), 99.0 (C-1$_A$, $^1J_{CH}$=174.2 Hz), 98.7 (C-1$_C$, $^1J_{CH}$=171.2 Hz), 94.7 (C-1$_E$, $^1J_{CH}$=170.5 Hz), 83.0 (C-3$_D$), 77.4 (C-3$_C$), 76.4 (C-4$_D$), 74.7 (C-2$_A$), 74.0 (C-3$_A$), 73.5 (C-3$_E$), 72.8 (C-2$_C$), 72.1 (C-4$_B$), 71.7 (C-5$_E$), 71.6 (C-2$_E$), 71.5 (C-4$_C$), 71.2 (C-4$_A$), 70.5 (C-2$_B$), 70.3 (C-3$_B$), 70.0 (C_{Pr}), 69.4 (2C, C-4$_E$, C-5$_D$), 69.2 (C-5$_C$), 69.1 (C-5$_A$), 68.5 (C-5$_B$), 61.0 (C-6$_D$), 60.6 (C-6$_E$), 55.8 (C-2$_D$), 23.1 (C_{NAc}), 22.3 (CH_2), 20.6 (C_{Ac}), 17.1, 16.9, 16.7 (3C, C-6$_A$, C-6$_B$, C-6$_C$), 10.2 (CH_3); HRMS (ESI$^+$) for $C_{37}H_{63}NO_{24}$ ([M+Na]$^+$, 928.3638) found *m*/*z* 928.3630, ([M+H]$^+$, 906.3818) found *m*/*z* 906.3823.

4.29. Propyl α-L-rhamnopyranosyl-(1→3)-α-L-rhamnopyranosyl-(1→3)-(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→2)-[α-D-glucopyranosyl-(1→3)]-α-L-rhamnopyranoside (8)

Trichloroacetamide **45** (0.20 g, 0.13 mmol) was dissolved in EtOH (15 mL), treated with 10% Pd/C catalyst (250 mg), and the suspension was stirred at rt for 2 days, under a hydrogen atmosphere (45 bar). TLC (*i*-PrOH/H_2O/NH_3, 4:1:0.5 and CH_2Cl_2/MeOH, 9.5:0.5) showed that **45** had been transformed into a major polar product. The suspension was filtered on Acrodisc LC 25 mm and the filtrate was concentrated. Reverse phase chromatography (H_2O/CH_3CN, 100:0→70:30) of the residue, followed by freeze-drying, gave **8** (81 mg, 71%) as a white foam. Pentasaccharide **8** had R_f=0.2 (*i*-PrOH/H_2O/NH_3, 4:1:0.5); ^{1}H NMR (D_2O): δ 4.94 (d, 1H, $J_{1,2}$=3.6 Hz, H-1$_E$), 4.78 (br s, 1H, H-1$_B$), 4.71 (br s, 1H, H-1$_A$), 4.63 (br s, 1H, H-1$_D$), 4.61 (br s, 1H, H-1$_C$), 4.07 (m, 1H, H-2$_A$), 3.83–3.78 (m, 3H, H-2$_B$, H-5$_E$, H-5$_C$), 3.71–3.68 (m, 2H, H-3$_A$, H-6a$_D$), 3.66–3.64 (m, 2H, H-2$_C$, H-2$_D$), 3.62–3.59 (m, 2H, H-3$_E$, H-3$_B$), 3.59–3.52 (m, 5H, H-6a$_E$, H-6b$_E$, H-3$_C$, H-5$_B$, H-6b$_D$), 3.50–3.39 (m, 2H, H-5$_A$, H-2$_E$), 3.41 (m, 1H, H_{Pr}), 3.32–3.18 (m, 7H, H-4$_E$, H-4$_C$, H_{Pr}, H-3$_D$, H-5$_D$, H-4$_B$, H-4$_D$), 3.10 (pt, 1H, $J_{3,4}$=9.7 Hz, H-4$_A$), 1.89 (s, 3H, H_{NAc}), 1.38 (m, 2H, CH_2), 1.09 (m, 3H, $J_{5,6}$=6.2 Hz, H-6$_B$), 1.05 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_A$), 1.01 (d, 3H, $J_{5,6}$=6.2 Hz, H-6$_C$), 0.29 (t, 3H, J=7.4 Hz, CH_3); ^{13}C NMR (D_2O): δ 174.4 (C_{NAc}), 102.8 (C-1$_B$, $^1J_{CH}$=172.0 Hz), 102.0 (C-1$_D$, $^1J_{CH}$=163.2 Hz), 101.7 (C-1$_C$, $^1J_{CH}$=171.2 Hz), 99.1 (C-1$_A$, $^1J_{CH}$=172.7 Hz), 95.0 (C-1$_E$, $^1J_{CH}$=170.5 Hz), 82.1 (C-3$_D$), 78.5 (C-3$_C$), 76.5 (C-4$_D$), 74.8 (C-2$_A$), 74.4 (C-3$_A$), 73.6 (C-3$_E$), 72.5 (C-4$_B$), 71.9 (C-5$_E$), 71.8 (C-2$_E$), 71.7 (C-4$_C$), 71.3 (C-4$_A$), 71.0 (C-2$_C$), 70.7 (C-3$_B$), 70.6 (C-2$_B$), 70.1 (C_{Pr}), 69.9 (C-5$_D$), 69.5 (2C, C-5$_B$, C-5$_C$), 69.3 (C-5$_A$), 68.8 (C-4$_E$), 61.2 (C-6$_D$), 60.8 (C-6$_E$), 55.9 (C-2$_D$), 23.1 (C_{NAc}), 22.5 (CH_2), 17.2, 17.1, 16.9 (3C, C-6$_A$, C-6$_B$, C-6$_C$), 10.3 (CH_3); HRMS (ESI$^+$) for $C_{35}H_{61}NO_{23}$ ([M+Na]$^+$, 886.3532) found *m*/*z* 886.3461, ([M+H]$^+$, 864.3713) found *m*/*z* 864.3652.

Acknowledgements

This work was supported by the ANR (Grant NT05-1_42479), the Institut Pasteur, and the MENRT (fellowship to J.B.). The authors thank F. Bonhomme (CNRS URA 2128) for running the NMR and Mass spectra.

References and notes

1. Niyogi, S. K. *J. Microbiol.* **2005**, *43*, 133–143.
2. von Seidlein, L.; Kim, D. R.; Ali, M.; Lee, H.; Wang, X.; Thiem, V. D.; Canh do, G.; Chaicumpa, W.; Agtini, M. D.; Hossain, A.; Bhutta, Z. A.; Mason, C.; Sethabutr, O.; Talukder, K.; Nair, G. B.; Deen, J. L.; Kotloff, K.; Clemens, J. *PLoS Med.* **2006**, *3*, 1556–1568.
3. Levine, M. M.; Kotloff, K. L.; Barry, E. M.; Pasetti, M. F.; Sztein, M. B. *Nat. Rev. Microbiol.* **2007**, *5*, 540–553.
4. Kotloff, K. L.; Winickoff, J. P.; Ivanoff, B.; Clemens, J. D.; Swerdlow, D. L.; Sansonetti, P. J.; Adak, G. K.; Levine, M. M. *Bull. World Health Organ.* **1999**, *77*, 651–666.
5. Lindberg, A. A.; Karnell, A.; Weintraub, A. *Rev. Infect. Dis.* **1991**, *13*, S279–S284.
6. Mulard, L. A.; Ughetto-Monfrin, J. *J. Carbohydr. Chem.* **2000**, *19*, 193–220.

7. Clément, M. J.; Imberty, A.; Phalipon, A.; Perez, S.; Simenel, C.; Mulard, L. A.; Delepierre, M. *J. Biol. Chem.* **2003**, *278*, 47928–47936.
8. Mulard, L. A.; Costachel, C.; Sansonetti, P. J. *J. Carbohydr. Chem.* **2000**, *19*, 849–877.
9. Bélot, F.; Wright, K.; Costachel, C.; Phalipon, A.; Mulard, L. A. *J. Org. Chem.* **2004**, *69*, 1060–1074.
10. West, N. P.; Sansonetti, P.; Mounier, J.; Exley, R. M.; Parsot, C.; Guadagnini, S.; Prevost, M. C.; Prochnicka-Chalufour, A.; Delepierre, M.; Tanguy, M.; Tang, C. M. *Science* **2005**, *307*, 1313–1317.
11. Ferreccio, C.; Prado, V.; Ojeda, A.; Cayyazo, M.; Abrego, P.; Guers, L.; Levine, M. M. *Am. J. Epidemiol.* **1991**, *134*, 614–627.
12. Formal, S. B.; Oaks, E. V.; Olsen, R. E.; Wingfield-Eggleston, M.; Snoy, P. J.; Cogan, J. P. *J. Infect. Dis.* **1991**, *164*, 533–537.
13. Noriega, F. R.; Liao, F. M.; Maneval, D. R.; Ren, S.; Formal, S. B.; Levine, M. M. *Infect. Immun.* **1999**, *67*, 782–788.
14. Pinto, B. M.; Reimer, K. B.; Morissette, D. G.; Bundle, D. R. *Carbohydr. Res.* **1990**, *196*, 156–166.
15. Tsvetkov, Y. E.; Bairamova, N. E.; Bakinovskii, L. V.; Kochetkov, N. K.; Lankina, N. F. *Bioorg. Khim.* **1986**, *12*, 1213–1224.
16. Mulard, L. A.; Ughetto-Monfrin, J. *J. Carbohydr. Chem.* **1999**, *18*, 721–753.
17. Schmidt, R. R.; Kinzy, W. *Adv. Carbohydr. Chem. Biochem.* **1994**, *50*, 21–123.
18. Blatter, G.; Beau, J. M.; Jacquinet, J. C. *Carbohydr. Res.* **1994**, *260*, 189–202.
19. Boutet, J.; Kim, T. H.; Guerreiro, C.; Mulard, L. A. *Tetrahedron Lett.* **2008**, *49*, 5339–5342.
20. Bakinovskii, L. V.; Gomtsyan, A. R.; Bairamova, N. E.; Kochetkov, N. K. *Bioorg. Khim.* **1984**, *10*, 79–87.
21. Wessel, H. P.; Bundle, D. R. *J. Chem. Soc., Perkin Trans. 1* **1985**, 2251–2260.
22. Mulard, L. A.; Clément, M. J.; Segat-Dioury, F.; Delepierre, M. *Tetrahedron* **2002**, *58*, 2593–2604.
23. Castro-Palomino, J. C.; Hernandez Rensoli, M.; Verez Bencomo, V. *J. Carbohydr. Chem.* **1996**, *15*, 137–146.
24. Schmidt, R. R.; Michel, J.; Roos, M. *Liebigs Ann. Chem.* **1984**, 1343–1357.
25. Schmidt, R. R.; Michel, J. *Tetrahedron Lett.* **1984**, *25*, 821–824.
26. Pinto, B. M.; Reimer, K. B.; Tixidre, A. *Carbohydr. Res.* **1991**, *210*, 199–219.
27. Gigg, J.; Payne, S.; Conant, R. *J. Carbohydr. Chem.* **1983**, *2*, 207–223.
28. Pinto, B. M.; Morissette, D. G.; Bundle, D. R. *J. Chem. Soc., Perkin Trans. 1* **1987**, 9–14.
29. Zhang, K. Q.; Li, S. C.; Mao, J. M.; Chen, H. M.; Cai, M. S. *Chem. J. Chin. Univ.* **1997**, *18*, 1469–1473.
30. Lindhorst, T. K. *Essentials of Carbohydrate Chemistry and Biochemistry*; Wiley-VCH: Weinheim, 2000; p 42.
31. Spijker, N. M.; van Boeckel, C. A. A. *Angew. Chem., Int. Ed. Engl.* **1991**, *30*, 180–183.
32. Yang, F.; He, H. M.; Du, Y. G.; Lu, M. J. *Carbohydr. Res.* **2002**, *337*, 1165–1169.
33. Zeng, Y.; Ning, J.; Kong, F. Z. *Tetrahedron Lett.* **2002**, *43*, 3729–3733.
34. Ikeda, T.; Yamauchi, K.; Nakano, D.; Nakanishi, K.; Miyashita, H.; Ito, S.; Nohara, T. *Tetrahedron Lett.* **2006**, *47*, 4355–4359.
35. Fekete, A.; Gyergyoi, K.; Kover, K. E.; Bajza, I.; Liptak, A. *Carbohydr. Res.* **2006**, *341*, 1312–1321.
36. Geyer, K.; Seeberger, P. H. *Helv. Chim. Acta* **2007**, *90*, 395–403.
37. Adamo, R.; Kovac, P. *Eur. J. Org. Chem.* **2007**, 988–1000.
38. Whitfield, D. M.; Nukada, T. *Carbohydr. Res.* **2007**, *342*, 1291–1304.
39. Segat-Dioury, F.; Mulard, L. A. *Tetrahedron: Asymmetry* **2002**, *13*, 2211–2222.
40. Das, S. K.; Roy, N. *J. Carbohydr. Chem.* **1995**, *14*, 417–428.
41. Szurmai, Z.; Liptak, A.; Snatzke, G. *Carbohydr. Res.* **1990**, *200*, 201–208.
42. Kitagawa, I.; Baek, N. I.; Ohashi, K.; Sakagami, M.; Yoshikawa, M.; Shibuya, H. *Chem. Pharm. Bull.* **1989**, *37*, 1131–1133.
43. Lubineau, A.; Basset-Carpentier, K.; Augé, C. *Carbohydr. Res.* **1997**, *300*, 161–167.
44. Baeschlin, D. K.; Green, L. G.; Hahn, M. G.; Hinzen, B.; Ince, S. J.; Ley, S. V. *Tetrahedron: Asymmetry* **2000**, *11*, 173–197.
45. Pozsgay, V.; Coxon, B. *Carbohydr. Res.* **1994**, *257*, 189–215.
46. Oltvoort, J. J.; van Boeckel, C. A. A.; der Koning, J. H.; van Boom, J. H. *Synthesis* **1981**, 305–308.
47. Nashed, M. A.; Anderson, L. *J. Chem. Soc., Chem. Commun.* **1982**, 1274–1276.
48. Donohoe, T. J.; Logan, J. G.; Laffan, D. D. *Org. Lett.* **2003**, *5*, 4995–4998.