EFFICIENT SYNTHESIS OF BUILDING BLOCKS FOR THE PREPARATION OF PECTIN FRAGMENTS BY MODULAR DESIGN PRINCIPLE

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‘*Strategy is the art of a warrior: commanders must embody it, and the soldiers - to know the Way.’*

Miyamoto Musashi, The Book Of Five Rings

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Amayak Pogosyan

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1. INTRODUCTION

1.1. PLANT CELL WALLS

Plant cell walls are usually divided into two categories: primary walls that surround growing cells or cells capable of growth and secondary walls that are thickened structures containing lignin and surrounding specialized cells, such as vessel elements or fiber cells. However, in reality all differentiated cells contain walls with distinct compositions, resulting in a spectrum of specialized cell walls with primary and secondary walls as two extremes.[1] In the primary plant cell wall the most common carbohydrates are cellulose, hemicellulose and pectin. The cellulose microfibrils are linked via hemicellulosic tethers to form the cellulose-hemicellulose network which is embedded in the pectin matrix (**Fig. 1**).

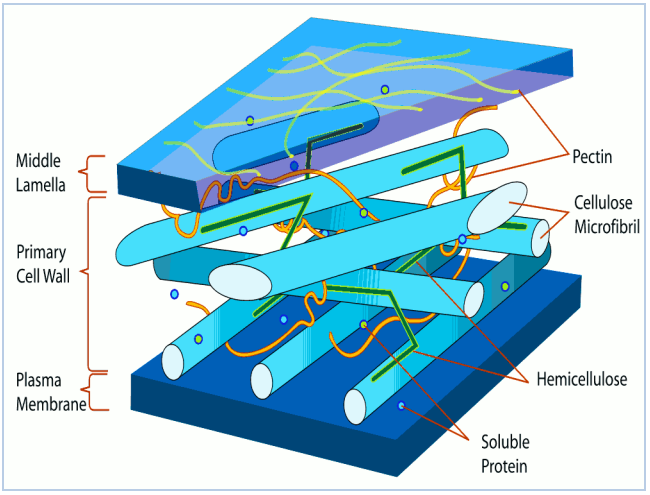


Fig.1. The plant cell wall diagram[2]

Pectins are a family of complex polysaccharides. The extracted pectin can be devided into homogalacturonan (HG), rhamnogalacturonan-I (RG-I), rhamnogalacturonan-II (RG-II) and xylogalacturonan (XGA).[3] The different pectic polysaccharides are not separate molecules but covalently linked domains.[4] Unbranched homopolymer chains of $\alpha(1\rightarrow4)$ linked D-GalA are described as HG. The GalA residues of HG can be methyl-esterified at *C*-6 and carry acetyl groups on *O*-2 and *O*-3. XGA is a branched galacturonan with β-D-Xylp-(1→3) side chains.[5,6] The GalA residues of XGA can be methyl-esterified as in HG. Homogalacturonans can contain clusters of four different (heterooligomeric) side chains with very peculiar sugar residues (such as Api, AceA, Dha, and Kdo). These side chains, together with the approximately nine galacturonyl residues to which they are connected, are referred to as RG-

II.[7,8] The RG-I is composed of the disaccharide unit galacturonic acid–rhamnose [(1→4)-α-D-GalpA-(1→2)-α-L-Rhap-]$_n$, 20–80% of the Rha*p* residues being substituted with neutral oligosaccharides, mainly arabinofuranose and galactose (α-L-Ara*f* and β-D-Gal*p*).[9,10,11] Furthermore, fucose, glucopyranuronic acid and 4-*O*-methylglucopyranuronic(α-l-Fuc*p*, β-d-Glc*p*A, and 4-O-methyl-β-d-Glc*p*A) can be found as terminal residues of the side chains (**Fig. 2**). The galacturonyl residues can carry acetyl groups on *O*-2 and *O*-3. The branched RG-I domain is the so called "hairy region".

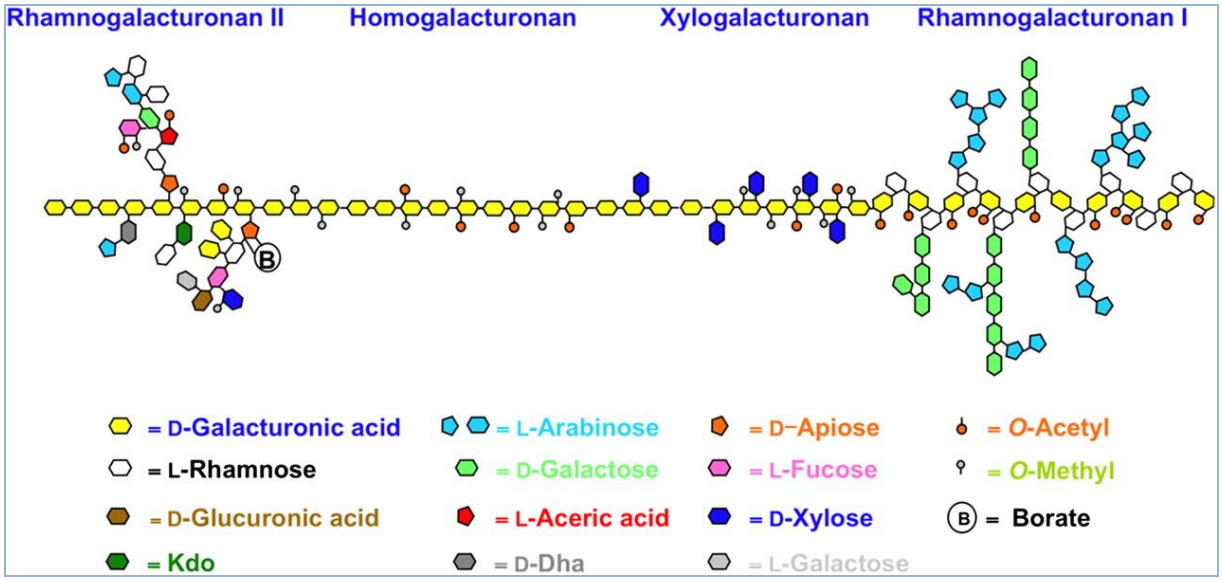


Fig. 2. Schematic structure of pectin. Pectin consists of four different types of polysaccharides, and their structures are shown.[4]

1.2. THE ROLE OF PECTIN

The main role of pectin is to participate in giving physical strength to the plant and providing a barrier against the outside environment together with other polymers.[4] Especially HG and RG-II are well known to be involved in strengthening the cell wall. The mechanical properties of HG and RG-II have been reviewed and described by Ryden at al. .[12] Furthermore, HG plays additional roles besides pure mechanical support. Oligogalacturonides, i.e. $\alpha(1\rightarrow4)$ linked oligomers of GalA, are well established to be part of a signaling cascade that senses wall degradation upon pathogen attack.[8,13] In the plant cell wall these macromolecules assemble is in large networks, where different kinds of crosslinks between pectic molecules exist. Two unesterified HG chains can engage in a complex, in which the carboxyl groups of two GalA residues form a negatively charged pocket.[15] This pocket can accommodate a Ca^{2+} cation.[16,17] The interaction through insertion of Ca^{2+} ions between the unesterified carboxyl groups of the galacturonosyl residues of two HG chains is shown (**Fig.3** A). This regulation may prevent

the formation of Ca^{2+}-mediated interactions between HG regions and hence, the removal of arabinan may induce a stiffening of the cell wall. Furthermore, it was reported that two molecules of RG-II can complex with boron, forming a borate-diol ester (**Fig.3 B**).[17] Only the apiofuranosyl residues of the 2-*O*-ethyl-D-Xyl-containing side chains in each of the subunits of the dimer participate in the cross-linking.[18] Because RG-II is an integral part of HG, borate-diol esters can cross-link two HG chains.[19] Ishii at al. have reported, that certain cations, such as Ca^{2+}, Pb^{2+}, Sr^{2+}, and La^{3+}, promote dimer formation in vitro in a concentration- and pH-dependent manner.[18] The widespread occurrence of RG-II in the plant kingdom and its structural conservation indicate a distinct role in wall integrity for this constituent of pectin.[20]

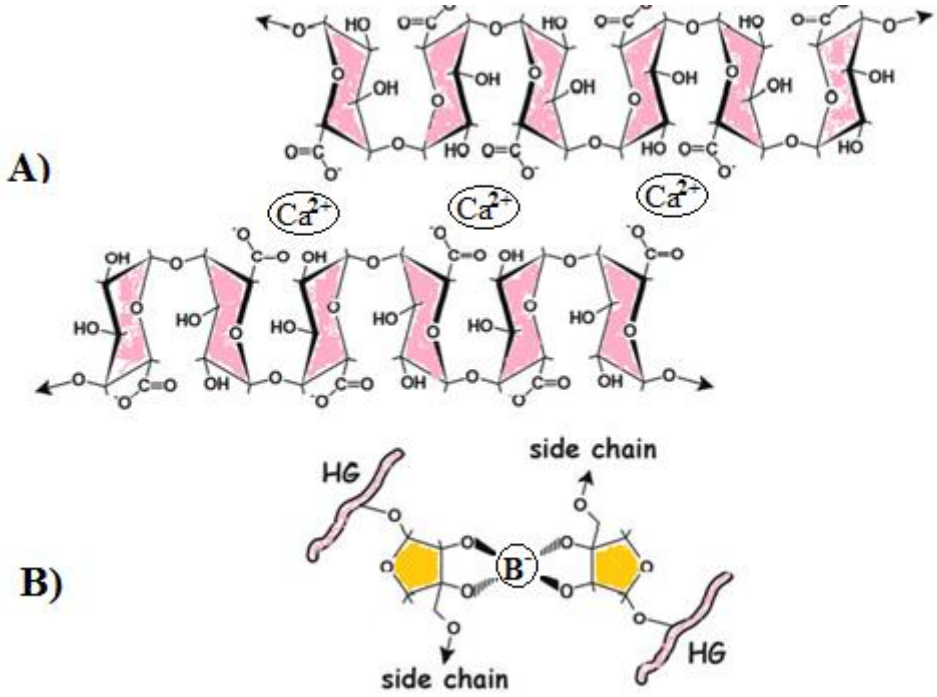


Fig.3. A) Ca^{2+}-mediated interactions between HG regions. B) HG molecules cross-linked by borate-diol esters.

Compared with the numerous studies of HG and RG-II function, far less is known about the function of RG-I. Treatment of leaf epidermis with arabinanase resulted in blocking of the opening and closing of the stomata.[21] Further evidence for the role of RG-I side chains in the physical properties of the wall come from the investigation of transgenic plants.[22] The elastic properties of the tubers were also altered, with a stiffening of the cell wall, as observed in stomatal cells.[22,23] Absence of arabinan in the side chains of the pectic polysaccharides are strongly associated with cell walls of *Nicotiana plumbaginifolia* non-organogenic callus with loosely attached constituent cells.[24] Willats et al. reviewed those different forms of RG-I,

bearing either galactan or arabinan, occur in a developmental fashion at definite locations in the plant. The authors are suggest that those fragments have a specific function.[25] The removal of RG-I arabinan side-chains by the expression of an apoplast-directed endo-1,5-α-arabinanase resulted severe phenotypic changes in transgenic potato plants: the plants did not produce side shoots, flowers or stolons, and were unable to produce tubers.[26] This information confirms the importance of RG-I fragments, but the specific arrangement and the biochemistry of the process are still undefined.

1.3. PECTIN IN THE HUMAN DIET

The development of isolation, purification and characterization methods during the last 25 years made it possible to investigate a biochemical basis of traditional use pectic polysaccharides isolated from plant as immunostimulatory, antitumor, antimutagen or anti-inflammatory agents.[27] Pectin is used as natural food ingredient because of their gelling and thickening properties.[28] Food applications of pectin have been revised exhaustively by Voragen et al..[29] The ability of pectins to bind cations is due to the anionic character of non-methyl esterified GalA residues. Pectins have also been employed as thickener, water binder and stabilizer in beverages and dairy products. The addition of pectic polysaccharides to the human diet has been shown to reduce the uptake of toxic metals, lhanthanides and actinides. Yablokov *et al.*, writing in *Chernobyl: Consequences of the Catastrophe for People and the Environment* , that "adding pectin preparations to the food of inhabitants of the Chernobyl-contaminated regions promotes an effective excretion of incorporated radionuclides´´. The authors report on the positive results of using pectin food additive preparations in a number of clinical studies conducted on children in severely polluted areas, with up to 50% improvement over control groups.[30]

Pectin, as a soluble fiber, helps to lower LDL (low-density lipoprotein) levels, thereby helping balance cholesterol. Cholesterol belongs to the class of lipids. It is produced by the liver and found in diet, and helps body function. Due to modern diet several people have more cholesterol in the body than needed. The LDL transports cholesterol to all organs. This excess cholesterol can accumulate in organs and arteries and form plaque that can reduce the blood flow. The introduction of pectin in the human diet may well effect on the blood flow.

It has been shown that the pectic polysaccharides play critical therapeutic roles against cancer.[31] Modified pectin has been evaluated for the efficacy in cancer treatment. Their effect

is suggested to be the ability to bind to cancer cell surface galectins (galactose-binding lectins) and cause mitochondrial disruption.[32,33,34]

The presence of a rigid pectin gel inside the particulates imparts a stronger and more stable vehicle in acidic and alkaline solutions, which could prolong drug release. This particulate system may have potential use as a carrier for drugs which are poorly absorbed after oral employ.[35,36]

All those positive effects belongs to pectin fragments, but which kind of fragments are responsible for the exact biological activity has not been clearly defined yet. Isolation of HG, RG-I, RG-II or XGA separate fragments from natural materials is difficult. The discovery of new molecular tools for biosynthesis could lead to advances for the use of pectin in the future. The new methods for synthesize of pectin fragments are requested to investigate the structural-biological activity relationship and to elucidate the biological role of pectin in cell wall.

1.4 OBJECTIVES

It has been shown that pectin fragments play significant roles in biology of plants and that they have positive effects on human health. The repeating unit of pectin fragments are often linked by α(1→4) or α(1→2) glycosidic bonds between D-galacturonic acid itself and L-rhamnose residues respectively. The synthesis of such homogalacturonan is based on two main strategies. Ogawa and Nakahara prepared α(1→4) linked galactose derivates.[37,38] The primary hydroxyl groups were deprotected and converted by selective oxidation into carboxyl groups. The alternative way for the synthesis of homogalacturonan fragments is the preparation of glycosyl acceptors and donors directly synthesized from D-galacturonic acid, followed by the glycosylation.[39,40] This seems to be advantageous in comparison to the approach involving D-galactose-derived intermediates, because the crucial oxidation step can be avoided.[41]

In our working group the synthesis of modules starting from D-galacturonic acid have been investigated for synthesizing homogalacturonan and rhamnogalacturonan-I fragments by modular design principle.[42] This type of blockwise build-up of homogalacturonan and rhamnogalacturonan fragments is based on an orthogonal protecting group strategy.[42]

To realize α(1→4) or α(1→2) linkages between D-galacturonic acid itself and L-rhamnose residues, D-galacturonic donors are needed, which carry at the 2-position a nonparticipating protection group.[43,44] On the other hand, to realize the blockwise synthesis oligomers of

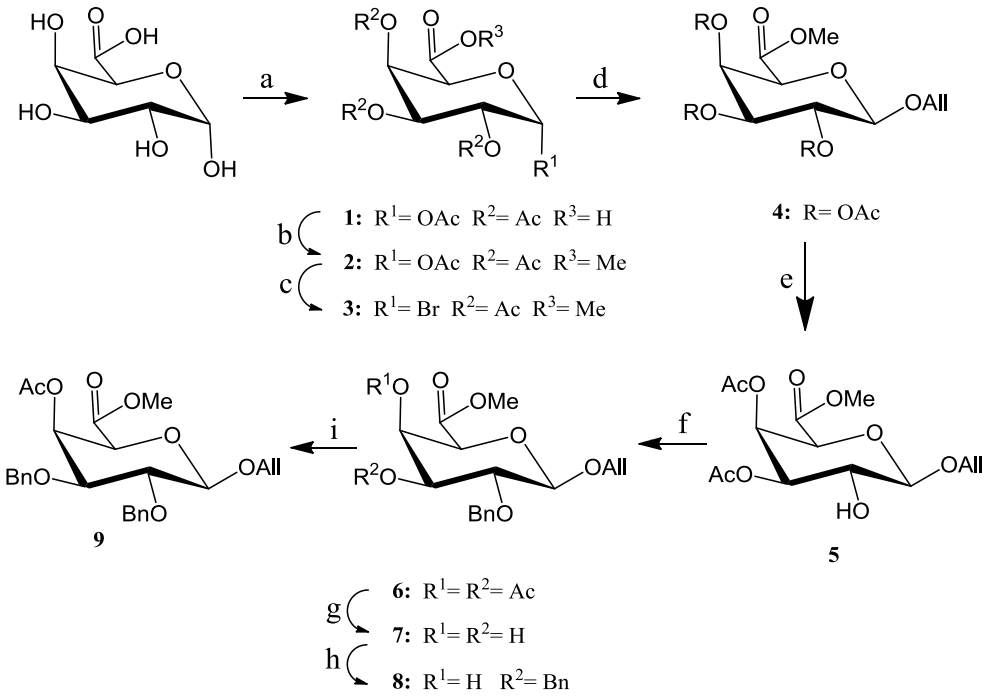
rhamnogalacturonates D-galacturonic and L-rhamnose acceptors are needed which will be able to bind at 4-OH and 2-OH with aforementioned donors, respectively. Based on the current knowledge the following tasks should be performed in this work:

- Preparation of a new glycosyl donor and acceptor derived from D-galacturonic acid
- Preparation of a new rhamnosyl acceptor and donor derived from L-rhamnose
- Synthesis of RG-I fragments by modular design principle using new modules
- Synthesis of RG-I fragments bearing a D-galactose residue as a branching unit.

2. RESULTS AND DISCUSSION

2.1. IMPROVED SYNTHESIS OF ALLYL GALACTOPYRANOSIDURONATE BUILDING BLOCK **9** SUITABLE FOR MODULAR DESIGN PRINCIPLE

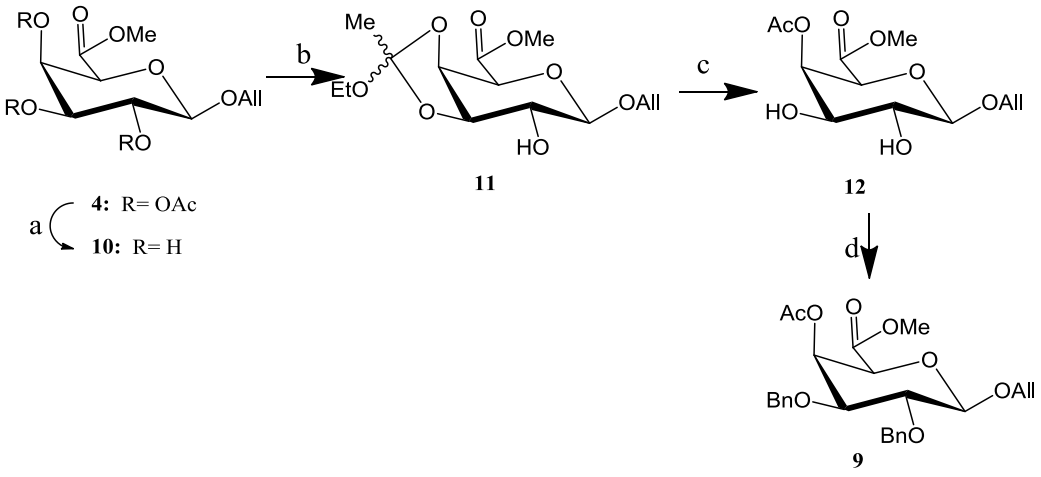
Following our modular design principle strategy a D-galacturonic acid derivative was needed suitable as glycosyl donor and as glycosyl acceptor. Required glycosyl acceptor and donor could be synthesized from monosaccharide compound **9** in one and two steps, respectively. In our working group the preparation of the key compound **9** and some other similar galacturonic acid derivatives were previously shown starting directly from commercially available D-galacturonic acid (**Scheme 1**).[41,45]



Scheme 1. Synthesis of allyl galactopyranosiduronate building block suitable for modular design principle. (a) Ac_2O, *cat.* 70% $HClO_4$, 5 h, 0 °C→RT (**1**, 85%); (b) ethereal CH_2N_2, $CHCl_3$, 1 h, RT (**2**, 95%); (c) 40% HBr in AcOH, 3 h, 0 °C→RT (**3**, 90%); (d) $Hg(CN)_2$, $HgBr_2$, AllOH, MS 3Å, 12 h, RT (**4**, 91%); (e) KH_2PO_4-Na_2HPO_4, EtOH-H_2O, Acylase I (from hog kidney), 5 h, 25 °C (**5**, 95%); (f) $BnO(HN=)CCl_3$, CH_2Cl_2-heptane, *cat.* $FCSO_3H$, 2 h, 20 °C (**6**, 62%); (g) 0.28 M methanolic HCl, 12 h, RT (**7**, 90%); (h) 1. *n*-Bu_2SnO, toluene, reflux on Dean-Stark apparatus, 2 h, 2. *n*-Bu_4NBr, BnBr, 60°C→85°C, 4 h (**8**, 58%); (i) Ac_2O, pyridine, -20 °C to 20 °C, 5 h, Ar atmosphere (**9**, 90%).

This synthesis[41,45] started with tetra-*O*-acetyl-D-galactopyranuronic acid **1**, which was earlier reported by Tajima and used by Steglich et al..[46,47] Later, preparation of compound **1** in 85%

yields was reported by the acetylation glacturonic acid with acetic anhydride in presence of perchloric acid.[48] Esterification of compound **1** was achieved with diazomethane to provide compound **2** in 95% yield.[48] The Helferich glycosylation with bromide **3**, obtained by treatment of compound **2** with HBr in acetic acid (90%), led to the allyl glycoside **4** (91%).[41] Enzyme-catalyzed, regioselective deacetylation under optimized conditions gave compound **5**.[41] The acid catalyzed benzylation[5,13] achieved compound **6** in 62% yield.[41,49] The deacetylation with methanolic 0.28 M HCl provided compound **7**. Since the esters of galacturonic acid tend to undergo base-catalyzed β-elimination, most protection and deprotection operations were performed under acidic conditions.[50] One exception was the regioselective benzylation of compound **7** via 3,4-*O*-butylstannyl intermediate, which gave the desired glycosyl acceptor **8** in 58% yield, together with benzyl ester in 25% yield as corresponding side product.[51,52] This compound can also be used as acceptor in glycosylation reactions. Finally, acetylation with acetic anhydride in pyridine provided derivative **9** in 90% yield. In *Carbohydrate Chemistry Proven Synthetic Methods* we reported an improved synthesis of compound **9**.[53] Accordingly to the article,[53] deacetylation of compound **4** with 0.28 M methanolic HCl (90% yield)[42] followed by treatment of product **10** with triethyl orthoacetat and regioselective opening of the orthoester structures formed 4-*O*-acetyl derivative **12** in 85% yield (**Scheme 2**).[52,54]



Scheme 2. Improved synthesis of allyl galactopyranosiduronate building block **9** suitable for modular design principle. (a) 0.28 M methanolic HCl, 24 h, RT (**10**, 90%); (b) $H_3C(OEt)_3$, *cat.* camphersulfonic acid, CH_2Cl_2, 1.5 h, RT, Ar atmosphere (**11**); (c) aq 95% AcOH, 10 min, RT (**12**, 85%); (d) $BnO(HN=)CCl_3$, dioxane, TfOH, 15-30 min, 0 ^oC (**9**, 89%).

Benzylation of compound **12** according to Madsen and Lauritsen gave the compound **9** in 89% yield.[55] Thus, compared to the former pathway, the overall yield of module **9**

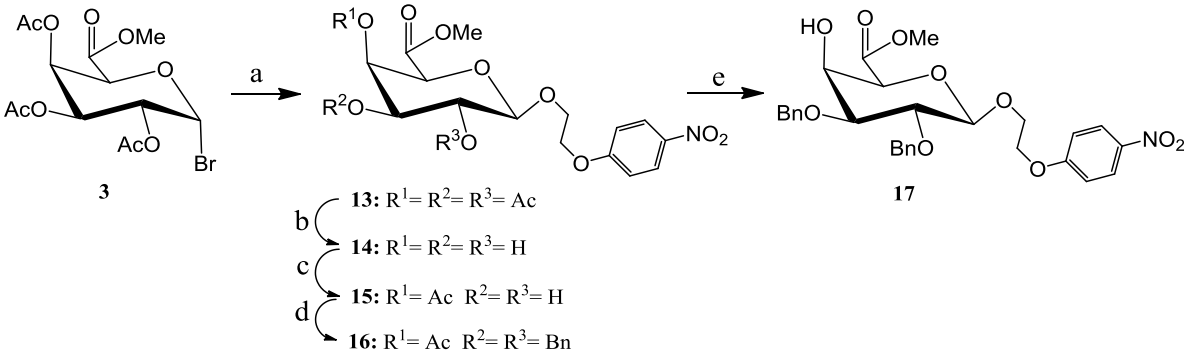
significantly increased (from 18% to nearly 40%), the total number of synthetic steps was reduced from 9 to 7, and the formation of the benzyl ester as a side product of the conversions was avoided. In addition, every synthetic step led to a crystalline product, which makes the laboratory work more convenient.

2.2. SYNTHESIS OF D-GALACTOPYRANOSIDURONATE ACCEPTOR **17** WITH SPACER

Michael Heidelberger's research proceeded along a clearly defined line from his and Osvald Avery's finding in 1923 that type-specific antigens of pneumococcus bacteria were polysaccharides.[56] Bacterial capsular polysaccharides are cell surface antigens composed of identical repeat units which form extended saccharide chains. Conjunction of polysaccharide antigens to thymus dependent antigens such as proteins enhances their immunogenicity. The protein stimulates carrier-specific T-helper cells which play a role in the induction of anti-carbohydrate antibody synthesis.[56,57] The development of vaccines, based on polysaccharides, has been going on for many years, and many studies are still in progress. Oligosaccharide and polysaccharide conjugates are reported to be immunogenic in infants and elicit a thymus dependent response.[58,59,60,61,62,63] Porro establish methods to couple esterified N. meningitidis oligosaccharides to carrier proteins.[64] Tsay and Collins have been developed that the conjugate vaccines containing polysaccharides of Pseudomonas aeruginosa coupled by the periodate procedure to detoxified protein from the same organism.[65] Cryz and Furer used adipic acid dihydrazide as a spacer arm to produce conjugate vaccines against P. aeruginosa.[66]

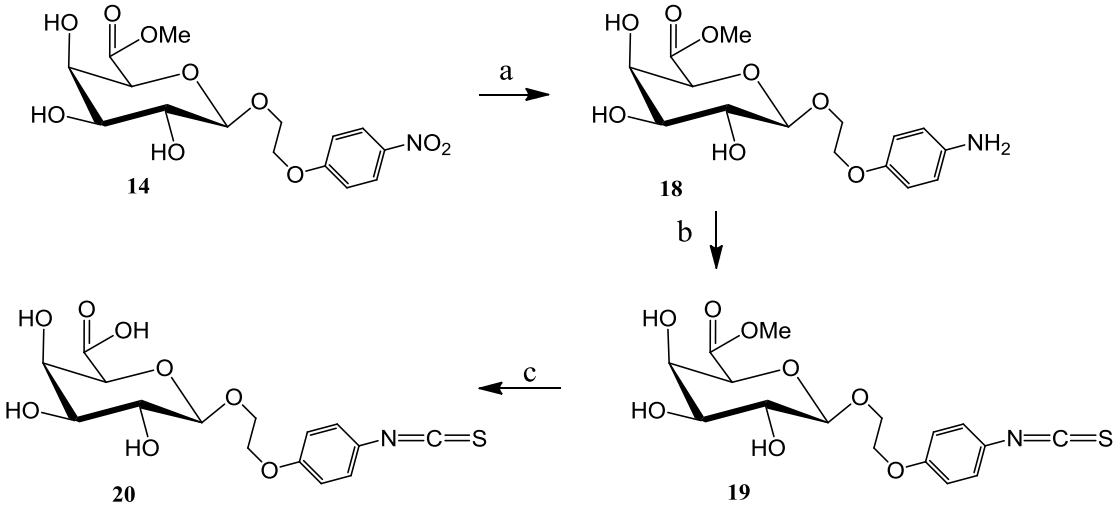
We were interested in preparation of several pectin fragments with spacer, which can be connected with peptides in future. These conglomerates can then be used to produce monoclonal antibodies against carbohydrate structures.

The Helferich glycosylation of bromide **3** with 2-(4-nitrophenoxy)ethanol in acetonitrile gave galactopyranosiduronate-spacer **13.**



Scheme 3. Synthesis of a galactopyranosiduronate acceptor with spacer **17**. (a) 2-(4-nitrophenoxy)ethanol, $Hg(CN)_2$, $HgBr_2$, acetonitrile, MS 3Å, 12 h, RT (**13**, 86%); (b) 0.28 M methanolic HCl, 24 h, RT (**14**, 74%); (c) $H_3C(OEt)_3$, *cat.* camphersulfonic acid, CH_2Cl_2, 1.5 h, RT, Ar atmosphere, aq 95% AcOH, 10 min, RT (**15**, 92%); (d) BnO(HN=)CCl_3, dioxane, TfOH, 15-30 min, 0 ^oC (**16**, 72%);(e) 0.28 M methanolic HCl, 24 h, RT (**17**, 88%).

Accordingly to synthesis of compound **10**, deacetylation of compound **13** with 0.28 M methanolic HCl (74% yield),[42] followed by the treatment of product **14** with triethyl orthoacetat and regioselective opening of the orthoester structures, gave compound **15** with the acetyl group in 4-*O* position (92% yield) (**Scheme** 3).[52,54] Benzylation of compound **15** with benzyl 2,2,2-trichloroacetimidate and cat. trifluoromethansulfonic acid gave compound **16** in 72% yield. After deacetylation with 0.28 M methanolic HCl, acceptor **17** was obtained in 88% yield.

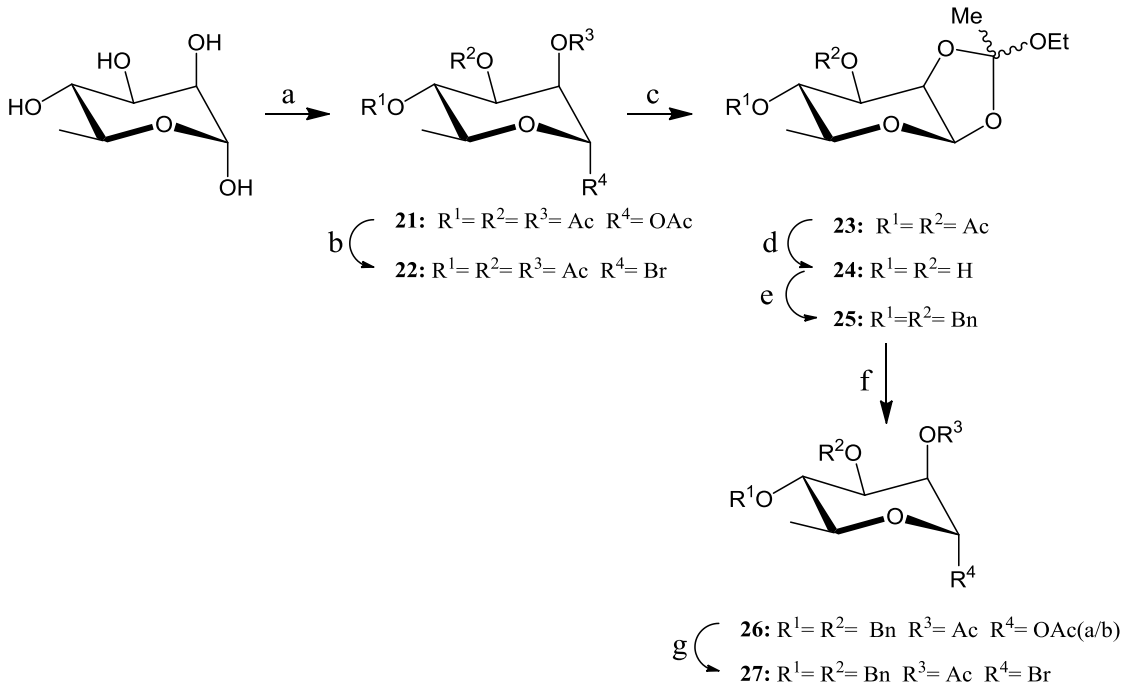


Scheme 4. Galactopyranosiduronate with spacer suitable for coupling with protein **19**. (a) Pd/C, H_2, MeOH/EtOAc, 1h, RT (**18**, 90%); (b) thiophosgen, $BaCO_3$, EtOH/H_2O, 1 h, RT (**19**, 77%); (c) LiOH, MeOH/H_2O, 15 min, RT (**20**, 92%)

In evidence that such galactopyranosiduronate-spacer can be connect with proteins, the nitro-group was converted into an amino-group by using hydrogenation in presence of $PdCl_2$ to give compound **18** in 90% yield (**Scheme** 4). Isothiocyanates are a class of heteroallenic compounds which are a suitable functional group to get covalent connections with proteins. The amino-group of compound **18** was reacted with thiophosgen in an ethanol/water solution in the presence of $BaCO_3$ as base to afford isothiocyanate **19** in 77% yield. The ester cleavage with lithium hydroxide in methanol/water solution was achieved[27] to obtain galacturonic acid derivative **20** connected with the isothiocyanate-spacer in 92% yield. Thus it seems to be sure that in future we can achieve the same reactions with larger pectin fragments caring 2-(4-nitrophenoxy)ethyl group as a spacer.

2.3. IMPROVED SYNTHESIS OF L-RHAMNOPYRANOSYL DONOR **27**

In addition to galacturonic acid donor and acceptor, a rhamnopyranosyl donor was needed for the synthesis of the repeating units of rhamnogalacturonan fragments. The preparation of several L-rhamnose derivatives were done before by co-workers in our laboratory.[68,69] B. Nolting reported the synthesis of a series of rhamnopyranosyl donor.[68] M. Farouk presented a simple approach to benzylated rhamnopyranosides with an *O*-acetyl group in 2-position.[69] This strategy was the perspective way for our purpose. The pathway started with acetylation of L-rhamnopyranose performed in acetanhydride with a small amount of perchloric acid. The exchange of the acetyl group in 1-position of compound **21** to form bromide **22** was achieved with 40% HBr solution in acetic acid according to literature.[70] 3,4-Di-*O*-acetyl-1,2-*O*-(1-*exo*-ethoxyethyliden)-β-L-rhamnopyranose (**23)** was prepared by the reaction of bromide **22** with dry EtOH in the presence of *sym*-collidine and tetra-*n*-butylammonium bromide (**Scheme 5**).[71,69] This procedure is extremely sensitive to water. For this reason, the reaction was carried out in the presence of molecular sieves and under an atmosphere of argon. Thus, the yield of compound **23** increased from 81% to 95%. Compound **23** was deacetylated under Zemplén conditions. But the following neutralization with acid solution reduced the yield of the product, because the cyclic orthoester structure is extremely sensitive to acid. Instead of Zemplén conditions, deacetylation was done by refluxing **23** with KOH in dry toluene to obtain compound **24**. Without further purification, the benzylation of compound **24** was achieved with benzylchloride in an one-pot reaction.[72]



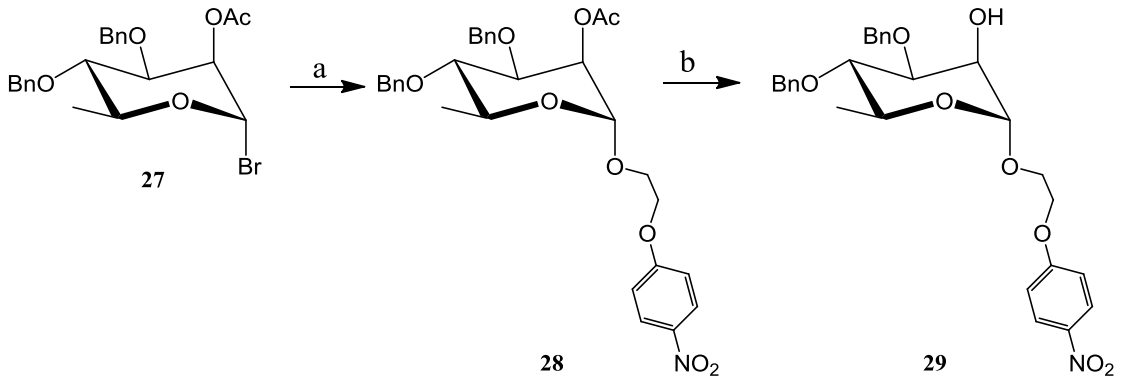
Scheme 5. Improved synthesis of rhamnopyranosyl donor **27**. (a) Ac_2O, *cat.* 70% $HClO_4$, 1.5 h, 0 $^oC \rightarrow$RT (**21**, 98%); (b) 40% HBr in AcOH, 40 min, 0 $^oC \rightarrow$RT (**22**, 96%); (c) EtOH, *sym*-collidine tetrabutylammonium bromide, MS 4Å, CH_2Cl_2, 9 h, RT, Ar atmosphere (**23**, 95%); (d) KOH, toluene, 20 min, under reflux (**24**); (e) BnCl, 2.5 h, under reflux (**25**, 88%); (f) 70% AcOH in H_2O, 7 min, RT, Ac_2O, pyridine, 1 h, 0 $^oC \rightarrow$RT (**26**, 83%); (g) oxalyl bromide, CH_2Cl_2, 4 h, -40 °C→RT (**27**, 96%).

Compound **25** was obtained as a crystalline product after classical work up. In this case, the yield was increased from 82% to 88%. In the ^{1}H-NMR spectrum of compound **25**, the exchange of the acetyl groups at O-3 and O-4 positions by benzyl groups caused a significant upfield shift (ca. 1.5 ppm) of the H-3 and H-4 ring protons. The X-ray diffraction studies of compound **25** established the configuration at C-1, C-2 and provided information on the $^1C_4$ chair conformation of the pyranose ring.[69] The ring opening with 70% aq. acetic acid was followed by classical acetylation with acetic anhydride in pyridine to give compound **26** in 83% yield. Purification by column chromatography provided the isomers **26α** and **26β** (69% and 14%, respectively). ^{1}H-NMR study showed that the coupling constant between H-1 and H-2 of compound **26α** is twice as big compared with compound **26β.** The NOESY spectrum secures the configuration at 1-position of compounds **26α** and **26β.** Compound **26** can be used as a donor in coupling reaction with galacturonate acceptors in the presence of trimethylsilyl triflouromethanesulfonate.[73,74,75] According to the procedure of Wessel and Bundle, compound **26**(**α**/**β**) was converted into bromide **27** in 96% yield.[76] Compound **27** was unstable on storage and was used directly without further purification. Practical experience showed

that it is better to use compound **27** instead of compound **26** as a donor to become higher yield in glycosylation reaction.

2.4. SYNTHESIS OF RHAMNOPYRANOSYL ACCEPTOR **29** WITH SPACER

We were interested in the preparationof a rhamnosyl acceptor, which have some similarity to galacturonate acceptor **17**. The Helferich glycosylation of bromide **27** with 2-(4-nitrophenoxy)ethanol in acetonitrile gave rhamnopyranosid-spacer **28** in 96% yield**.** Finally deacetylation of compound **28** with 0.28 M methanolic HCl gave acceptor **29** in 95% yield(**Scheme 6**).[42]

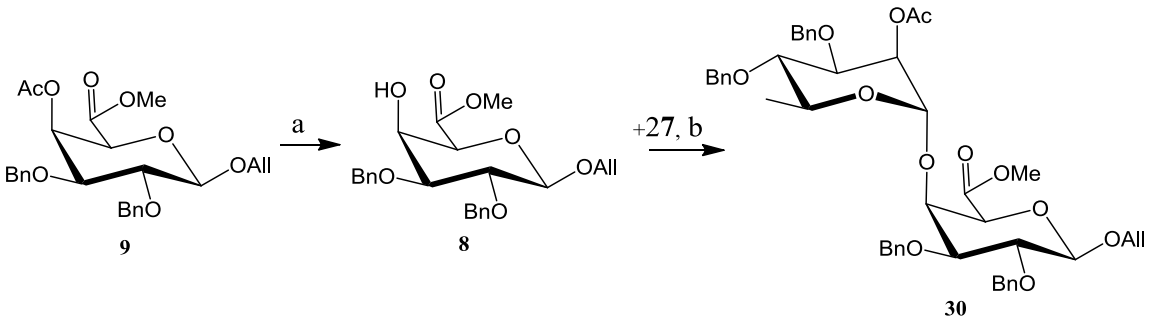


Scheme 6. Synthesis of rhamnopyranosyl acceptor **29** with spacer. (a) 2-(4-nitrophenoxy)ethanol, $Hg(CN)_2$, $HgBr_2$, acetonitrile, MS 4Å, 12 h, RT (**28**, 96%); (b) 0.28 M methanolic HCl, 24 h, RT (**29**, 95%).

Compound **21** as an acceptor can either used to get rhamnogalacturonan oligomers or with the spacer arm it has potential for coupling with proteins.

2.5. SYNTHESIS OF A RHAMNOGALACTURONAN BUILDING BLOCK **30** SUITABLE FOR MODULAR DESIGN PRINCIPLE

Our strategy for the synthesis of RG-I oligomers is based on the preparation of building blocks suitable for modular design principle. To achieve this aim, monosaccharide module **9** was deacetylated with 0.28 M methanolic HCl to provide acceptor **8** in 90% yield bearing only a free hydroxyl group in 4-position. For the preparation of disaccharide module **30,** bromide **27** was employed as glycosyl donor and coupled with the galacturonate acceptor **8** (**Scheme 7**).

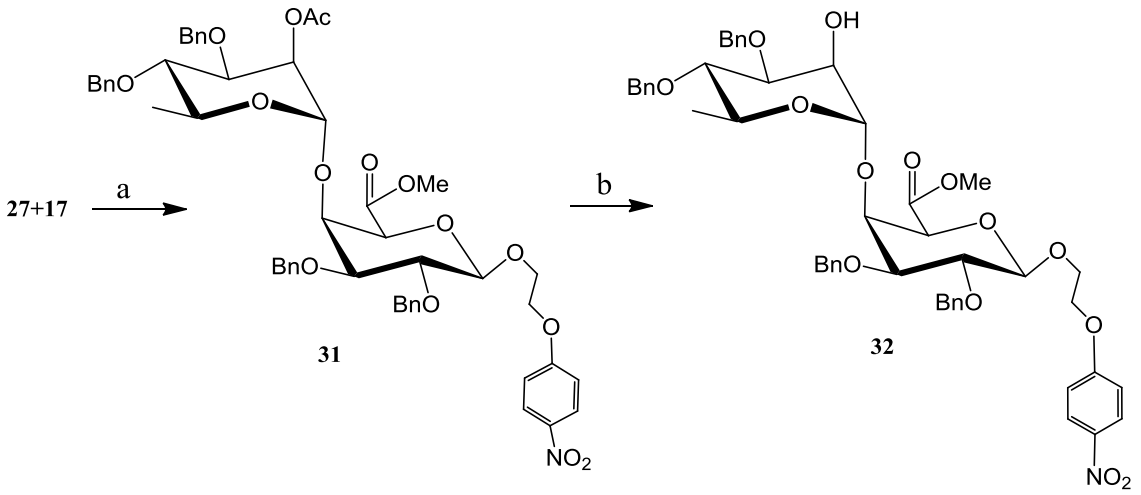


Scheme 7. Synthesis of a rhamnogalacturonan building block **30** suitable for modular design principle. (a) 0.28 M methanolic HCl, 24 h, RT (**8**, 90%); (b) $Hg(CN)_2$, $HgBr_2$, acetonitrile, MS 4Å, 24 h, RT (**30**, 67%).

The Helferich glycosylation in the presence of mercuric cyanide and mercuric bromide provided compound **30** in 67% yield.[77,78] In the ^{1}H NMR spectrum the signified anomeric signals appeared for H-1´ proton at δ = 5.22 ppm shows a coupling constant of $^3J_{1',2'}$ 1.9 Hz. Due to the *manno*-configuration of the donor, the stereochemical outcome of the glycosylation reaction cannot be only proven on the basis of chemical shift and the coupling constant $^3J_{1',2'}$. The absence of a correlation between protons H-1´↔ H-5´ and H-1´↔ H-3´ in a NOESY spectrum of compound **30** confirmed still the α(1→4) coupling. Now, this building block can be used as a donor or an acceptor due to the 2-*O*-acetyl group in the rhamnosyl residue and the *O*-allyl group in the galacturonic residue, respectively.

2.6 Synthesis of a rhamnogalacturonan acceptor **32** with a spacer connected to galacturonate

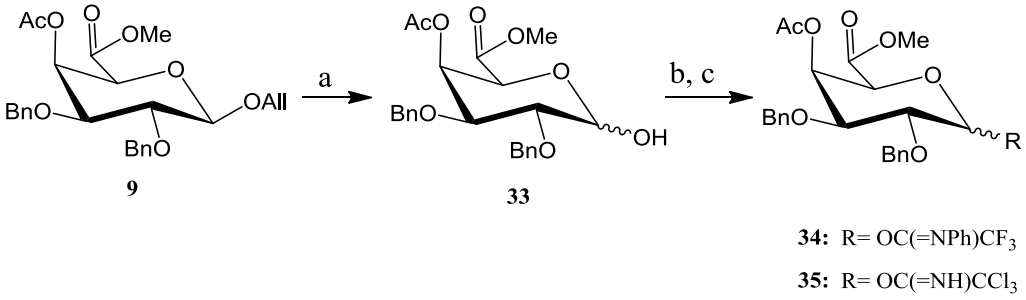
To furnish blockwise buildup of RG-I fragments with a spacer connected to the galacturonate moiety, acceptor **32** was synthesized (**Scheme 8**). The Helferich glycosylation between Donor **27** and acceptor **17** in the presence of mercuric cyanide and mercuric bromide provided compound **31** in 68% yield.[77,78] Deacetylation with 0.28 M methanolic HCl gave rhamnogalacturonan-spacer **32** in 87% yield. This compound can be used as an acceptor in consecutive blockwise buildup of rhamnogalacturonana fragments with spacer.



Scheme 8. Synthesis of a rhamnogalacturonan acceptor **32** with spacer connected to galacturonate. (a) $Hg(CN)_2$, $HgBr_2$, acetonitrile, MS 4Å, 24 h, RT (**31**, 68% α 15% β-is); (b) 0.28 M methanolic HCl, 24 h, RT (**32**, 87%).

2.7. SYNTHESIS OF A NEW GALACRURONIC DONOR **34**

After successful preparation of glycosyl acceptors for blokwise buildup of RG-I fragments a new galacturonate glycosyl donor **34** was synthesized (**Scheme 9**).



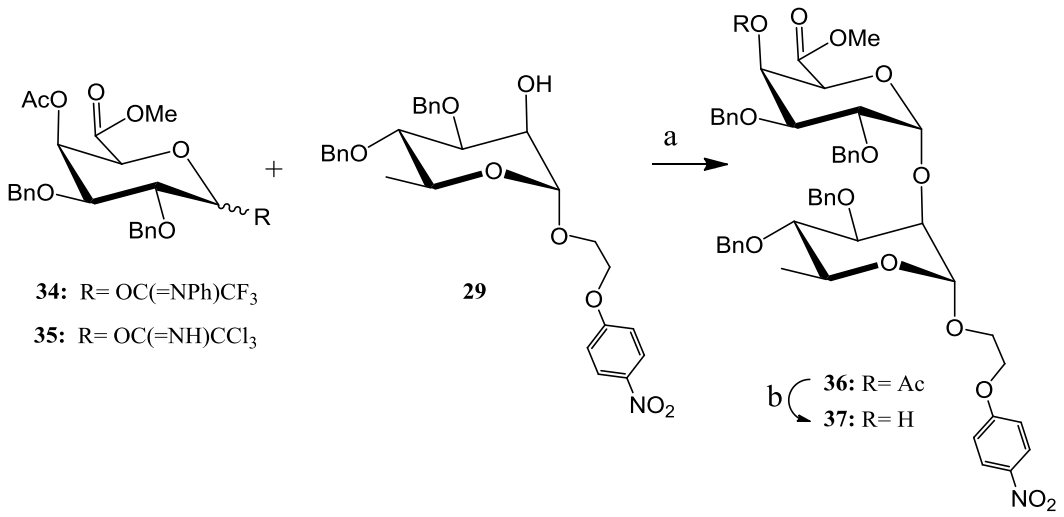
Scheme 9. Synthesis of galacturonate glycosyl donors **34** and **35**. (a) $PdCl_2$, AcOH, NaOAc, H_2O, 3 h, 45 °C (**33**, 75%); (b) Cs_2CO_3, 2,2,2-trifluoro-*N*-phenyl-acetimidoyl chloride, acetone, 3 h, RT (**34**, 88%); (c) trichloroacetonitrile, *cat.* DBU, CH_2Cl_2, 2 h, -20 °C→RT (**35**, 75%).

Compound **9** was converted to hemiacetal **33** with the aid of the system $PdCl_2$/NaOAc/HOAc/H_2O in 75% yield.[79] In the ^{1}H NMR spectrum, the assignment of the signals to α and β anomers, which appears in chloroform as an α,β mixture in a ratio of 4:1, is based on the vicinal couplings of protons H-1 and H-2. The doublet at δ = 5.37 shows a coupling constant of $^3J_{1,2}$ 3.6 Hz (H-1α) and the doublet at δ = 4.69 has a coupling constant of

$^3J_{1,2}$ 7.5 Hz (H-1β),. In the ^{1}C-NMR spectrum, deallylation was evidenced by the expected downfield shift of C-1 δ = 92.1 ppm and δ = 97.4 ppm for α and β, respectively. To get an glycosyl donor from hemiacetal **33**, which can allows stereoselective α(1→2) coupling, a new leaving group was introduced which has not been used for D-galacturonate donor before. Treatment of **33** with *N*-phenyltrifluoroacetimidoyl chloride[39] in the presence of Cs_2CO_3 in acetone[40] led to the formation of *N*-phenyltrifluoroacetimidate **34** which was isolated as an α,β mixture in a ratio of 1:5 in overall 88% yield.[80,81,82] The anomeric proton signals appeared broadened at room temperature due to a dynamic process in the *N*-phenyltrifluoroacetimidate moiety. Therefore, ^{1}H NMR spectra were recorded at lower temperature to allow the assignment of the corresponding isomer signal. At –40 ^{o}C both anomeric signals appear as doublets at δ = 6.83 ppm ($^3J_{1,2}$ 3.3 Hz, H-1α) and at δ = 5.78 ppm ($^3J_{1,2}$ 8.3 Hz, H-1β), respectively. Accordingly to literature,[75,69] D-galacturonate glycosyl donor **35** was synthesized as α/β mixture in a ratio of 3:1 in overall 75% yield. Earlier experiments using the α- or β-stereoisomers of the corresponding trichloroacetimidates have shown that the α- or β-configuration at the anomeric centre of such glycosyl donors had no influence on the stereoselectivity of the subsequent glycosylation reaction.[75] Therefore the α/β mixture of compound **34** and **35** were used in glycosylation reactions.

2.8. SYNTHESIS OF A RHAMNOGALACTURONAN ACCEPTOR **37** WITH A SPACER CONNECTED TO RHAMNOSE

To compare the suitability of the leaving groups of donors **34** and **35** the disaccharide **36** was synthesized by using both glycosyl donors (**Scheme 10**). For the glycosylation reaction with glycosyl acceptor **29** an α/β (1:5) mixture of **34** was used. The reaction was started at -20 ^{o}C using TMSOTf as promoter. Disaccharide **36** was obtained in 85% yield as a α/β (20:1) mixture. In the ^{1}H NMR spectrum of **36** proton H-1´ appears as a doublet at δ = 5.08 ppm with a coupling constant $^3J_{1',2'}$ 3.6 Hz, proving an α-linkage. This is also supported by the NOESY spectrum where no correlation was found between H-1´ and H-5´. The same disaccharide **36** was synthesized using glycosyl donor **35**. The reaction was started at -70 ^{o}C using TMSOTf as promoter and gave compound **36** in 63% yield as a α/β (9:1) mixture.



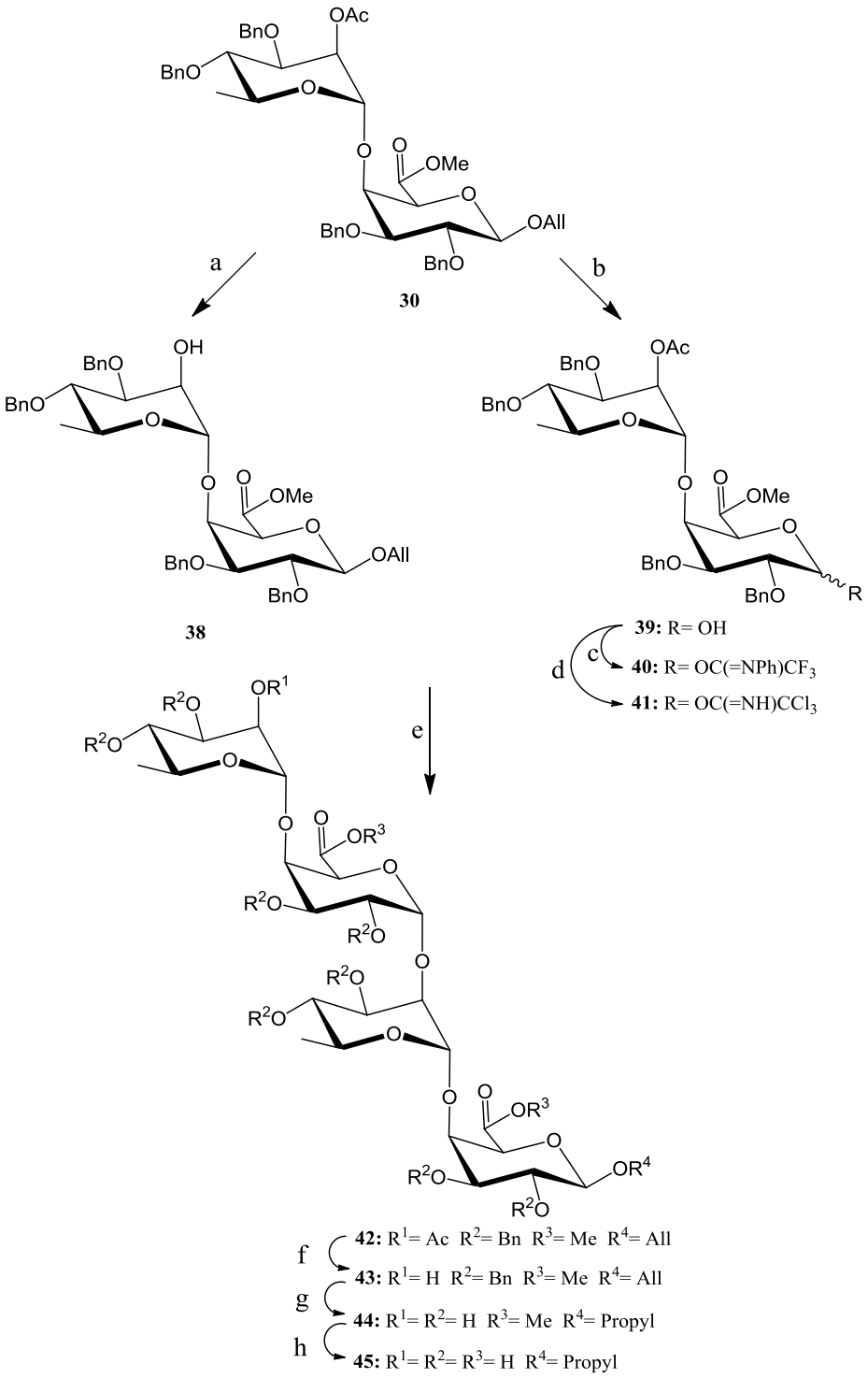
Scheme 10. Synthesis of a rhamnogalacturonan acceptor **37** with a spacer connected to rhamnose. (a) via **34**, *cat.* TMSOTf, MS 4Å, CH_2Cl_2, 3 h, -20 ^oC-RT (**36**, 85%), via **35**, *cat*. TMSOTf, MS 4Å, CH_2Cl_2, 13 h, -70 ^oC-RT (**36**, 67%); (b) 0.28 M methanolic HCl, 24 h, RT (**37**, 90%).

On the basis of these results it seems to be clear that the glycosyl donor **34** is better to use for glycosylation reactions compared with donor **35**. The treatment of compound **36** with 0.28 M methanolic HCl gave acceptor **37** in 90% yield.

2.9. SYNTHESIS OF RG-I TETRASACCHARIDE **45** BY MODULAR DESIGN PRINCIPLE

To compare the suitability of the *N*-phenyltrifluroacetimidate and trichloracetimidate glycosyl donors higher RG-I derivatives were synthesized by using both donors. The working group Prof. Paulsen from Norway asked us to synthesize rhamnogalacturonan fragments for investigation of the bioactivity of these structures, which were observed as a motif of plants isolated from medicinal plants.[83] In the framework of this joint work a tetrasaccharide and hexasaccharide of rhamnogalacturonan fragments were synthesized for the investigation of the structure-bioactivity relationship. In order to achieve this aim, we used the strategy of blockwise build-up by modular design principle. After one or two steps modification of disaccharide module **30** can be used as an acceptor or as a donor, respectively. Deacetylation of compound **30** with 0.28 M methanolic HCl gave acceptor **38** (**Scheme 11**). Compound **30** was converted to hemiacetal **39** with the aid of the system $PdCl_2$/NaOAc/HOAc/H_2O in 76% yield.[79] Treatment of **39** with *N*-phenyltrifluoroacetimidoyl chloride in the presence of

Cs_2CO_3 in acetone led to the formation of *N*-phenyltrifluoroacetimidate **40** which was isolated as an α,β mixture in a ratio of 1:3 in 91% yield. The anomeric proton signals appeared broadened at room temperature due to a dynamic process in the *N*-phenyl trifluoroacetimidate moiety. Therefore, ^{1}H NMR spectra were recorded at lower temperature to allow the assignment of the corresponding isomeric signals. At –40 ^{o}C, both anomeric signals appear as doublets, at δ = 6.78 ppm ($^3J_{1,2}$ 3.3 Hz, H-1α) and at δ = 5.70 ppm ($^3J_{1,2}$ 8.3 Hz, H-1β), respectively.



Scheme 11. Synthesis of RG-I tetrasaccharide **45** by modular design principle. (a) 0.28 M methanolic HCl, 24 h, RT (**38**, 90%); (b) $PdCl_2$, AcOH, NaOAc, H_2O, 2.5 h, 45 ^oC (**39**, 76%); (c) Cs_2CO_3, 2,2,2-trifluoro-*N*-phenyl-acetimidoyl chloride, acetone, 3 h, RT (**40**, 91%); (d) trichloroacetonitrile, *cat*. DBU, CH_2Cl_2, 2 h, -20 $^oC \rightarrow$RT (**41**, 67%); (e) via **40**, *cat.* TMSOTf, MS 4Å, CH_2Cl_2, 3 h, -20 $^oC \rightarrow$RT (**42**, 90%), via **41**, *cat.* TMSOTf, MS 4Å, CH_2Cl_2, 13 h, -70 $^oC \rightarrow$RT (**42**, 67%); (f) 0.28 M methanolic HCl, 24 h, RT (**43**, 86%); (g) Pd/C, H_2, MeOH, 24 h, RT (**44**, 97%); (h) LiOH, MeOH, H_2O, 15 min, RT (**45**, 92%).

Accordingly to literature,[35] the D-galacturonate glycosyl donor **41** was synthesized. To compare the suitability of the leaving groups in the glycosyl donors, the disaccharide **42** was synthesized via **40** and via **41.** The α/β- mixture of donor **41** and acceptor **38** in the presence of TMSOTf as promoter gave tetrasaccharide **42** in 90% yield. In the ^{1}H NMR spectrum of compound **42,** the proton H-1´´ appears as doublet at δ = 4.98 ppm $^3J_{1'',2''}$ 3.6 Hz proving an α-linkage. However, the deacetylation of compound **42** with 0.28 M methanolic HCl gave acceptor **43**. In the ^{1}H NMR spectrum of compound **43** proton H-1´´ appears as a doublet at δ = 5.02 ppm with a coupling constant $^3J_{1'',2''}$ 3.6 Hz, proving an α-linkage too. In the ^{13}C NMR spectrum the signal at δ = 96.5 ppm for C-1´´ confirms an α-linkage, too. This is also supported by the NOESY spectrum where no correlation was found between H-1´´ and H-5´´. The glycosylation between donor **41** and acceptor **38** in presence of TMSOTf as promoter gave tetrasaccharide **42** in 67% yield.

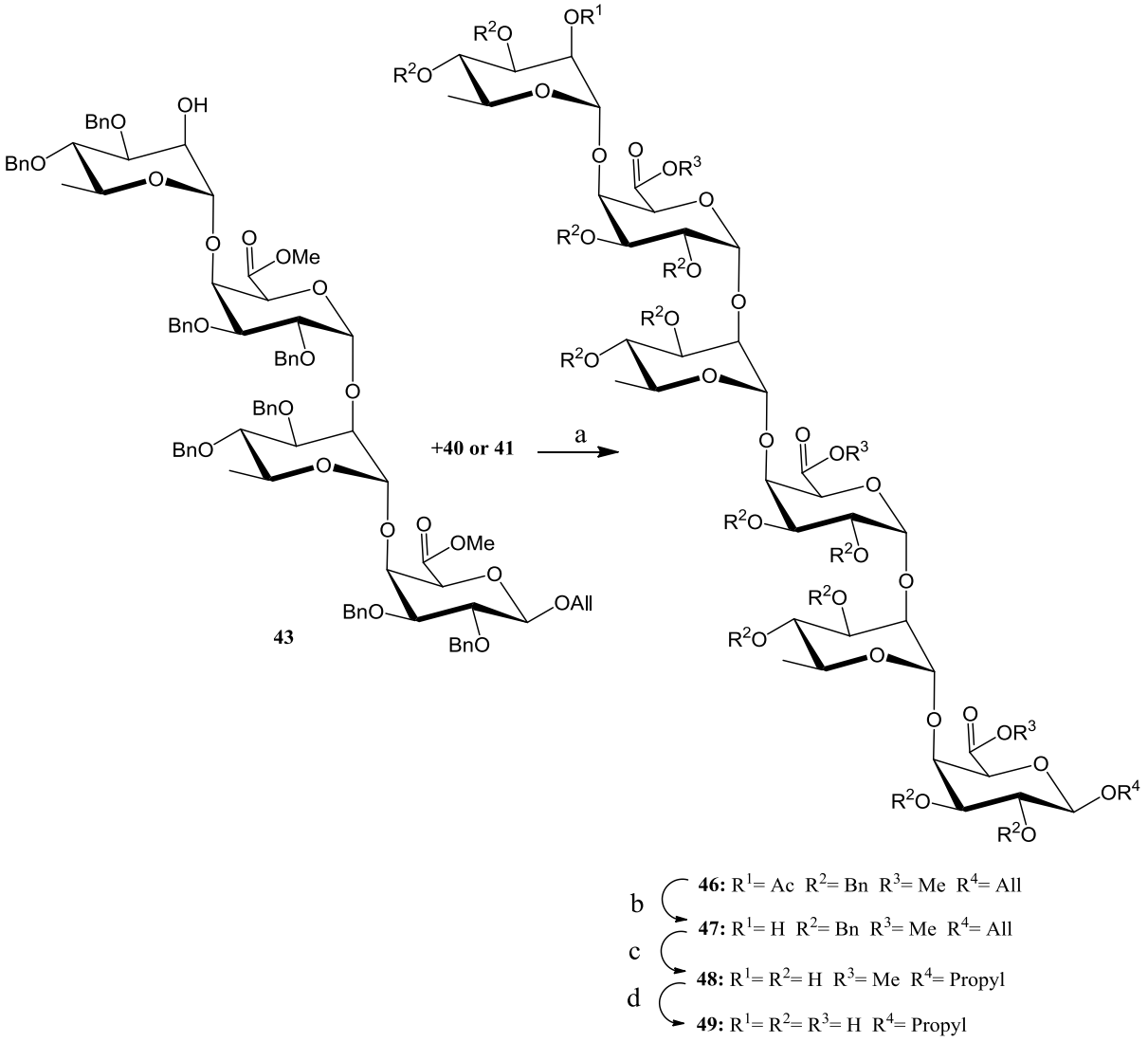
These results confirm the effectivity of of *N*-phenyl trifluoroacetimidate as a new leaving group for glycosylation reaction again.

The benzyl protecting groups of compound **43** were removed by hydrogenolysis over Pd/C to obtain the propyl glycoside **44** in 97% yield. The compound **44** has been sent to colleague from Norway for their biological tests. The ester cleavage with lithium hydroxide in methanol/water solution gave fully deprotected tetrasaccharide **45** in 92% yield.[68]

2.10. SYNTHESIS OF RG-I HEXASACCHARIDE **49** BY MODULAR DESIGN PRINCIPLE

Our strategy adopted for the synthesis of rhamnogalacturonan-I fragments was extended for the synthesis of higher rhamnogalacturonan-I oligomers. In the next phase of our collaboration with our Norwegian colleagues, the hexasaccharide **46** was synthesized with acceptor **43** and donors **40** or **41** (**Scheme 12**). The donor **40** and acceptor **43** in the presence of TMSOTf as promoter gave hexasaccharide **46** in 79% yield. In the ^{1}H NMR spectrum of

tetrasaccharide **46** proton H-1´´´´ appears as an overlapped multiplet at δ = 4.98 ppm with a proton from CH_2Ph. Because of that the coupling constant $^3J_{1'',2''}$ could not be determined and can not prove an α-linkage. But, in the ^{13}C NMR spectrum the signal at δ = 96.6 ppm for C-1´´´´ confirms an α-linkage. This is also supported by the NOESY spectrum where no correlation was found between H-1´´´´ and H-5´´´´. The glycosylation using donor **41** and acceptor **43** gave hexasaccharide **46** in 60% yield. Deacetylation of compound **46** with 0.28 M methanolic HCl provided compound **47** in 93% yield.

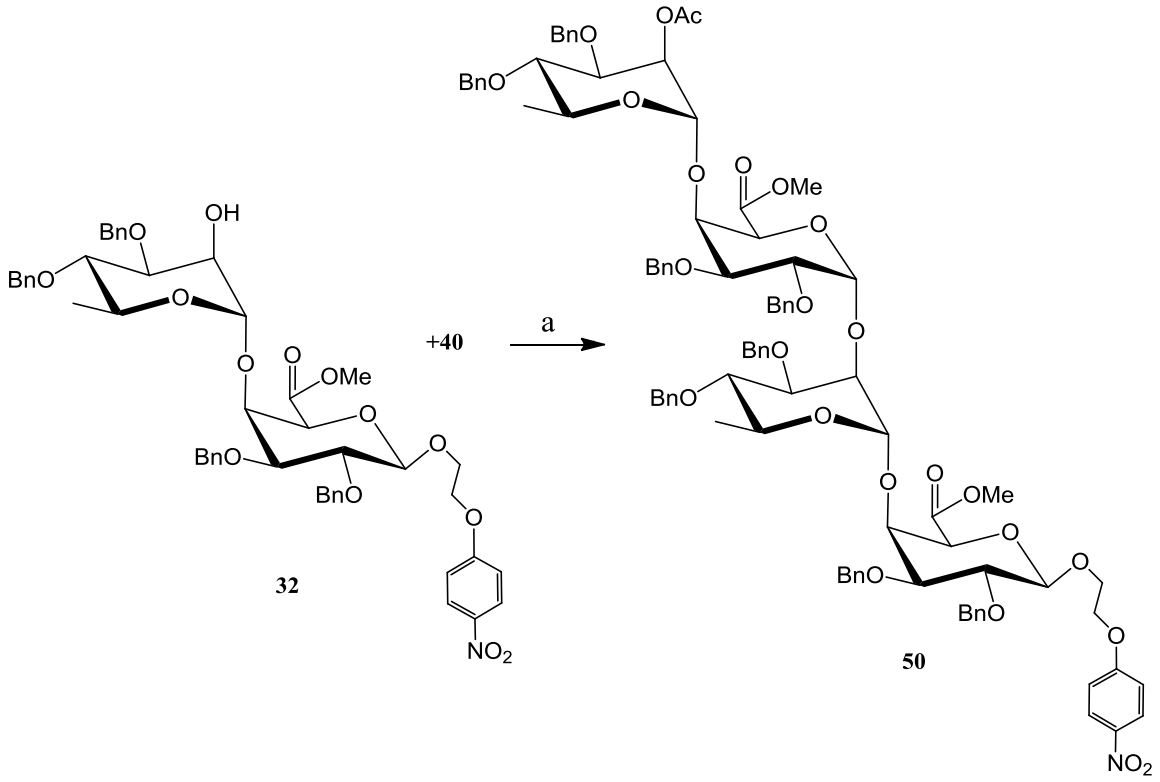


Scheme 12. Synthesis of RG-I hexasaccharide **49** by modular design principle. (a) via **40**, *cat.* TMSOTf, MS 4Å, CH_2Cl_2, 3 h, -20 ^{o}C-RT (**46**, 79%), via **41**, *cat.* TMSOTf, MS 4Å, CH_2Cl_2, 13 h, -70 ^{o}C-RT (**46**, 60%); (b) 0.28 M methanolic HCl, 24 h, RT (**47**, 93%); (g) Pd/C, H_2, MeOH, 28 h, RT (**48**, 95%); (h) LiOH, MeOH, H_2O, 15 min, RT (**49**, 93%).

The cleavage of the benzyl protecting groups of compound **47** by hydrogenolysis over Pd/C provided propyl glycoside **48** in 95% yield. The ester cleavage with lithium hydroxide in methanol/water solution gave hexasaccharide **49** in 93% yield.[68] The hexasacchride **49** was used by the colleagues from Norway for their biological tests.

2.11. SYNTHESIS OF RG-I TETRASACCHARIDE **50** BY MODULAR DESIGN PRINCIPLE CONNECTED TO A SPACER

Following our modular design principle the rhamnogalacturonana-I tetrasaccharide **50** was synthesized (**Scheme 13**). Because of the better yields in former glycosylation reactions, only compound **40** was used as donor for this synthesis. The donor **40** and acceptor **32** in presence of TMSOTf as a promoter provided compound **50** in 77% yield. In the ^{1}H NMR spectrum of **50** proton H-1´´ appears as a doublet at δ = 4.97 ppm with a coupling constant $^{3}J_{1'',2''}$ 3.6 Hz confirms an α-linkage. In the ^{13}C NMR spectrum the signal at δ = 96.7 ppm for C-1´´ confirms an α-linkage, too. This is also supported by the NOESY spectrum where no correlation was found between H-1´´ and H-5´´.

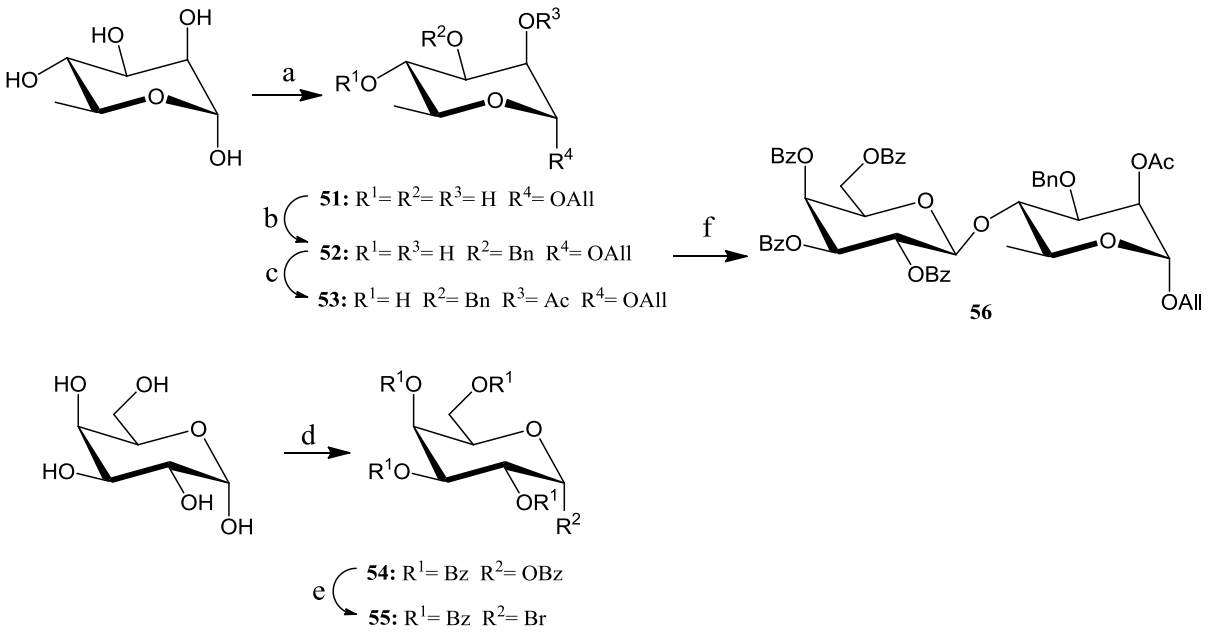


Scheme 13. Synthesis of RG-I tetrasaccharide **50** by modular design principle connected to a spacer. (a) *cat.* TMSOTf, MS 4Å, CH_2Cl_2, 3 h, -20 ^{o}C-RT(**50**, 77%).

After selective deacetylation, compound **50** may be used as an acceptor similar to compound **43** to obtain higher RG-I fragments, connected with a spacer. Additionaly, compound **50** may be used for immunological studies after cleavage of all protecting groups and conversion of the nitro group into an isothiocyanate group and coupling of this oligosaccharide with protein.

2.12. SYNTHESIS OF GALACTOPYRANOSYL-RHAMNOPYRANOSIDE BUILDING BLOCK **56** BEARING A D-GALACTOSE RESIDUE AS A BRANCHING UNIT

Highly branched pectins, which are comprised of a rhamnogalacturonan (RG-I) backbone carrying galactan and arabinan side-chains, are generally referred to as hairy regions. The backbone of the RG-I polymer is composed of repeating units of the disaccharide [→ 2)-L-Rha-α(1→4)-L-GalA-α(1→]. In these oligomers, the first D-galactopyranose residue is β-glycosidically linked to the O-4 position of a rhamnose moiety. Our strategy adopted for the synthesis of building blocks for D-galactose-branched RG-I fragments involved the preparation of a β-D-galactose-(1→4)-L-rhamnose intermediate **56** which allowed either as a donor the stereoselective formation of the required α(1→4)-glycosidic bond to a D-galact-uronate, or as an acceptor the α(1→2)-linkage with a D-galacturonate. For the synthesis of a suitable galactosylrhamnose disaccharide L-rhamnose was glycosylated with allyl alcohol to obtain allyl α-L-rhamnopyranoside **51** in 81% yield(**Scheme 14**).[84]



Scheme 14. Synthesis of galactopyranosyl-rhamnopyranoside building block **56** bearing a D-galactose residue as a branching unit. (a) AcCl, AllOH, 3 h, under reflux (**51**, 81%); (b)

Dibutylitin oxide, toluene, reflux, 3.5 h; then CsF, BnBr, DMF, 12 h (**52**, 70%); AcCl in toluene, pyridine, 14 h, -40 ^{o}C→-10 ^{o}C, Ar atmosphere (**53**, 60%); (d) BzCl, MS 4Å, pyridine, 18 h, -7 ^{o}C→RT, Ar atmosphere (**54**, 99%); (e) 40% HBr in AcOH, 40 min, 0 ^{o}C→RT (**55**, 97%); (f) $Hg(CN)_2$, $HgBr_2$, acetonitrile, MS 4Å, 24 h, RT, Ar atmosphere (**56**, 82%).

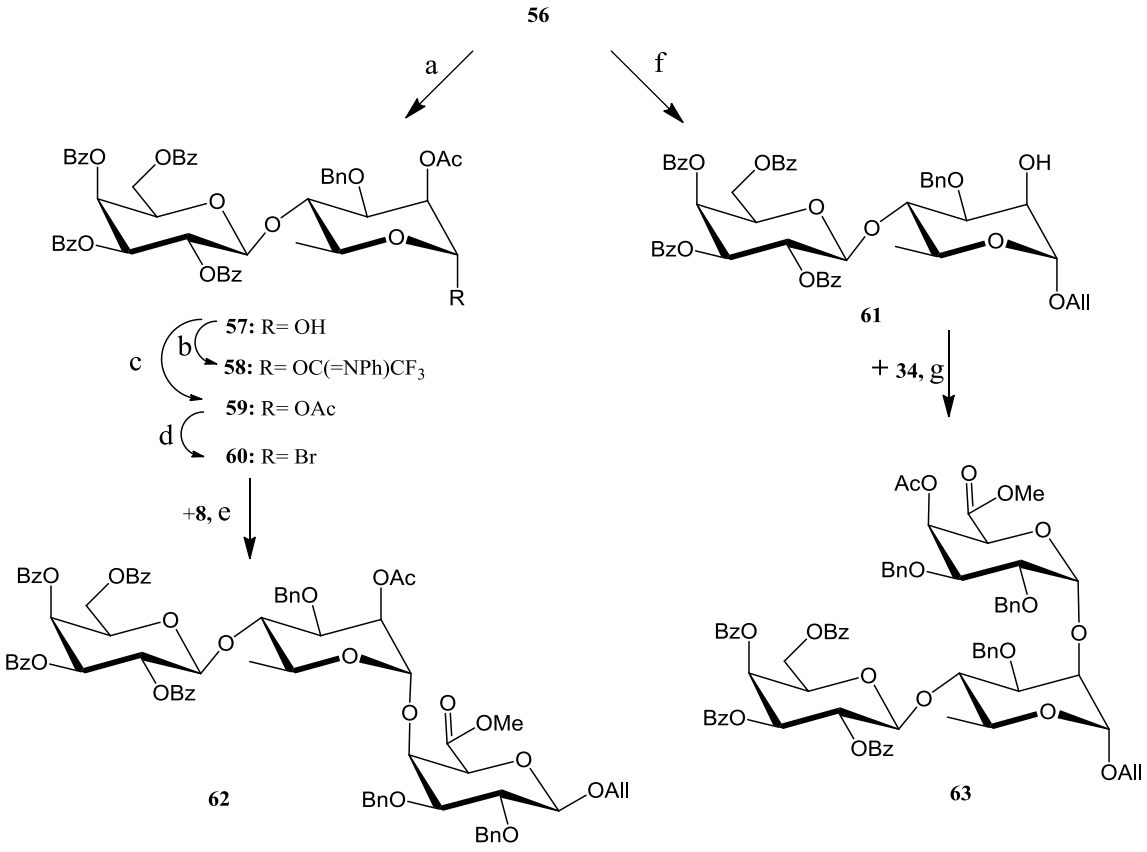
Compound **51** was regioselectively mono-benzylated to achieve compound **52** in 70% yield by stannylation methodology.[85,86] The regioselective esterification of benzyl derivative **52** was achieved by dropwise addition of diluted acetyl chloride at low temperature to provide the rhamnosyl acceptor **53** in 60% yield.[87] In ^{1}H NMR spectrum a significant downfield shift of about $\Delta\delta$ = 1.34 ppm of proton H-2 in compound **53** compared to compound **52** confirmed the acetylation at the 2-position. Nemati and all. has reported the synthesis of another rhamnosyl acceptor with methyl group instead of allyl, which can be coupled with a donor at 4-position. After glycosylation at 4-position, in this case, reported module in future step can be used only as an acceptor at 2-position.[88] In compare of this work the synthesis of acceptor **53** is more efficient (3 steps instead of 6). Now, compound **53** can be used as an acceptor for the cupling with a galactose donor at 4-position.

To provide a galactopyranose donor commercial D-galactose was benzoylated with benzoyl chloride in pyridine at -7 ^{o}C. The reaction gave compound **54** in quantitative yield.[89,90] The benzoylated galactosyl donor **55** was derived from penta-*O*-benzoyl-α-D-galactopyranose **54** using the procedure by Kochetkov and co-workers. [91,92,93,94] Details for the experimental procedure as well as analytical data for the perbenzoylated D-galactose and the corresponding bromide **55** are provided in the experimental section, since the available literature contains abridged information only.[82]

Acceptor **53** was glycosylated with bromide **55** in the presence of Helferich promotors[53,37] to give disaccharide **56** in 82% yield.[95,78] The β(1→4) linkage was confirmed by 1 D and 2 D NMR experiments. In the ^{1}H NMR spectrum of compound **56**, proton H-1´ appears as a doublet at δ = 5.33 ppm with a coupling constant $^{3}J_{1',2'}$ 7.9 Hz, while the HMBC spectrum shows a correlation between proton H-1´ and carbon atom C-4. This galactopyranosyl-rhamnopyranoside building block allowed either as donor to provide the stereoselective formation of the required α(1→4)-glycosidic bond or as an acceptor to achieve the α(1→2)-linkage to a D-galacturonate.

2.13. EFFICIENT SYNTHESIS OF BUILDING BLOCKS **62** AND **63** FOR BRANCHED RG-I FRAGMENTS

In this part of my work an efficient synthesis of branched RG-I fragments is presented, which can be used as a building block for the synthesis of higher branched rhamnnogalacturonan oligosaccharides. After deallylation of disaccharide **56** using palladium(II)chloride, resulting hemiacetal **57** was converted to donor **58** in 79% yield.[75,79] On the other hand, to obtain additional donor, the hemiacetal **57** was acetylated, and then converted into bromide **60** in 85% yield applying the procedure of Wessel and Bundle.[76] In parallel, selective cleavage of the 2-O-acetyl group of disaccharide **56** provided the glycosyl acceptor **61** in 63% yield taking advantage of the differences in the reactivity between the acetyl and benzoyl esters (**Scheme 15**).[96,97]



Scheme 15. Efficient synthesis of building blocks **62** and **63** for branched RG-I fragments. (a) $PdCl_2$, AcOH, NaOAc, H_2O, 2 h, 45 ^oC (**57**, 78%); (b) Cs_2CO_3, 2,2,2-trifluoro-*N*-phenyl-acetimidoyl chloride, acetone, 2 h, RT (**58**, 79%); (c) Ac_2O, pyridine, 20 ^oC, 24 h (**59**, 77%); (d) oxalyl bromide, CH_2Cl_2, 5 h, -40 °C→RT, Ar atmosphere (**60**, 85%); ; (e) $Hg(CN)_2$, $HgBr_2$, acetonitrile, MS 4Å, 24 h, RT (**62**, 65%); (f) 0.28 M methanolic HCl, 24 h, RT (**61**, 63%); (g) *cat*. TMSOTf, MS 4Å, CH_2Cl_2, 3 h, -40 °C→RT, Ar atmosphere (**63**, 66%).

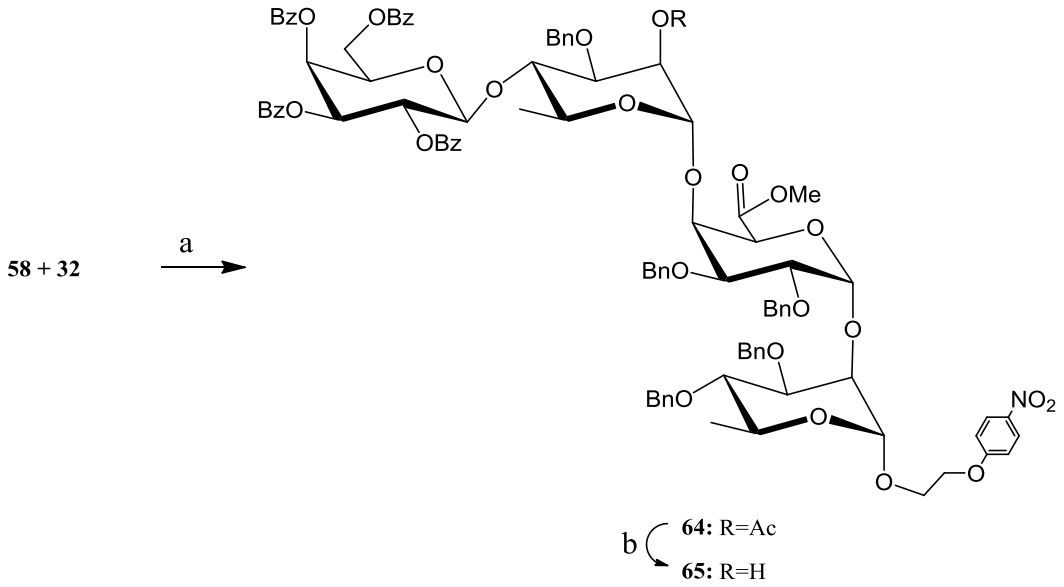
The galacturonate acceptor **8** was coupled with rhamnosyl bromide **60** to provide trisaccharide **2** in 65% yield. Due to the *manno*-configurated glycosyl donor, the stereochemical outcome of the glycosylation reaction cannot be proven on the basis of chemical shift and the coupling constant $^{3}J_{1,2}$ alone, but again both, the absence of a correlation between protons H-1´ and H-5´ in a NOESY spectrum of compound **62** and the C,H coupling constant ($^{1}J_{C\text{-}1',H\text{-}1'}$ = 174 Hz), suggest an α-linkage.

The potential of methyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-galactopyranosyluronate *N*-phenyl trifluoroacetimidate **40** as glycosyl donor has been proven once more. The galacturonate donor **40** and acceptor **61** in the presence of TMSOTf were glycosylated and gave compound **63** in 66% yield. In the ^{1}H NMR spectrum of compound **63** proton H-1´ appears at δ = 4.97 ppm as a doublet with a coupling constant $^{3}J_{1',2'}$ 3.8 Hz, proving an α-linkage. This is also supported by the NOESY spectrum where no correlation was found between H-1´ and H-5´ and the C,H coupling constant $^{1}J_{C\text{-}1',H\text{-}1'}$ = 170 Hz, which is in the range of α-*manno* configurated *O*-glycosides.[98]

The obtained trisaccharides **62** and **63** are suitable modules for branched pectin fragment synthesis by modular design principle.

2.14. SYNTHESIS OF BRANCHED RG-I ACCEPTOR **65** WITH SPACER

Following our strategy, several tetrasaccharide building blocks were synthesized by modular design principle. In order to compare with glycosylation reaction with bromide **60** rhamnosyl *N*-phenyl trifluoroacetimidate **58** was used as donor, too. The glycosylation reaction in presence of TMSOTf between acceptor **58** and rhamnogalacturonate with spacer **32** provided tetrasaccharide **64** in 77% yield (**Schemie 16**). Due to the *manno*-configurated glycosyl donor, as for compound **62**, the stereochemical outcome of the glycosylation reaction cannot be proven only on the basis of chemical shift of proton H-1´´, wich appears as a doublet at δ = 5.36 ppm with a coupling constant $^{3}J_{1'',2''}$ 1.7 Hz.

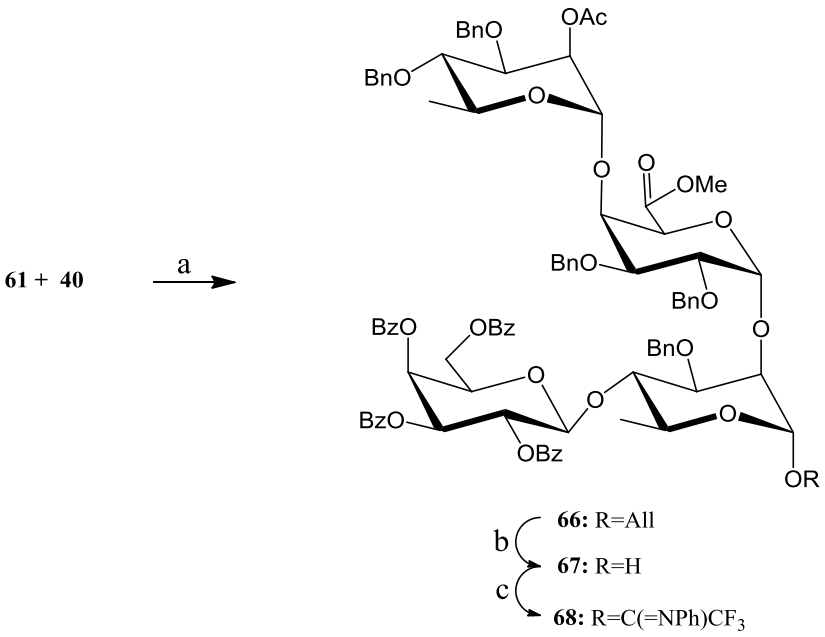


Scheme 16. Synthesis of RG-I acceptor **65** with spacer. (a) TMSOTf (cat.), MS 4Å, CH_2Cl_2, 3 h, -25 ^{o}C-RT (**64**, 77%); (b) 0.28 M methanolic HCl, 20 h, RT (**65**, 82%).

The absence of a correlation between protons H-1´´ and H-5´´ or H-1´´ and H-3´´ in a NOESY spectrum of compound **64** proved α-linkage, too. The selective cleavage of the 2-*O*-acetyl group of tetrasaccharide **62** furnished the branched RG-I glycosyl acceptor with spacer **65** in 82% yield taking advantage of the differences in the reactivity between the esters of acetic and benzoic acid.[96,97] This acceptor **65** was then used for the synthesis of higher rhamnogalacturonan-I fragments.

2.15. SYNTHESIS OF BRANCHED RG-I DONOR **68**

The synthesis of additional branched RG-I tetrasaccharide **66** was achieved by glycosylation between acceptor **61** and donor **40** in the presence of TMSOTf in 80% yield (**Scheme 17**). In the ^{1}H NMR spectrum of compound **66** proton H-1´ appears as a doublet at δ = 4.91 ppm with a coupling constant $^{3}J_{1',2'}$ 3.7 Hz, confirm an α-linkage. This is also supported by the NOESY spectrum where no correlation was found between H-1´ and H-5´. After deallylation of tetrasaccharide **66** using palladium(II)chloride, resulting hemiacetal **67** was converted into donor **68** in 86% yield.[99] This donor was also used for the synthesis of higher rhamnogalacturonan-I fragments.

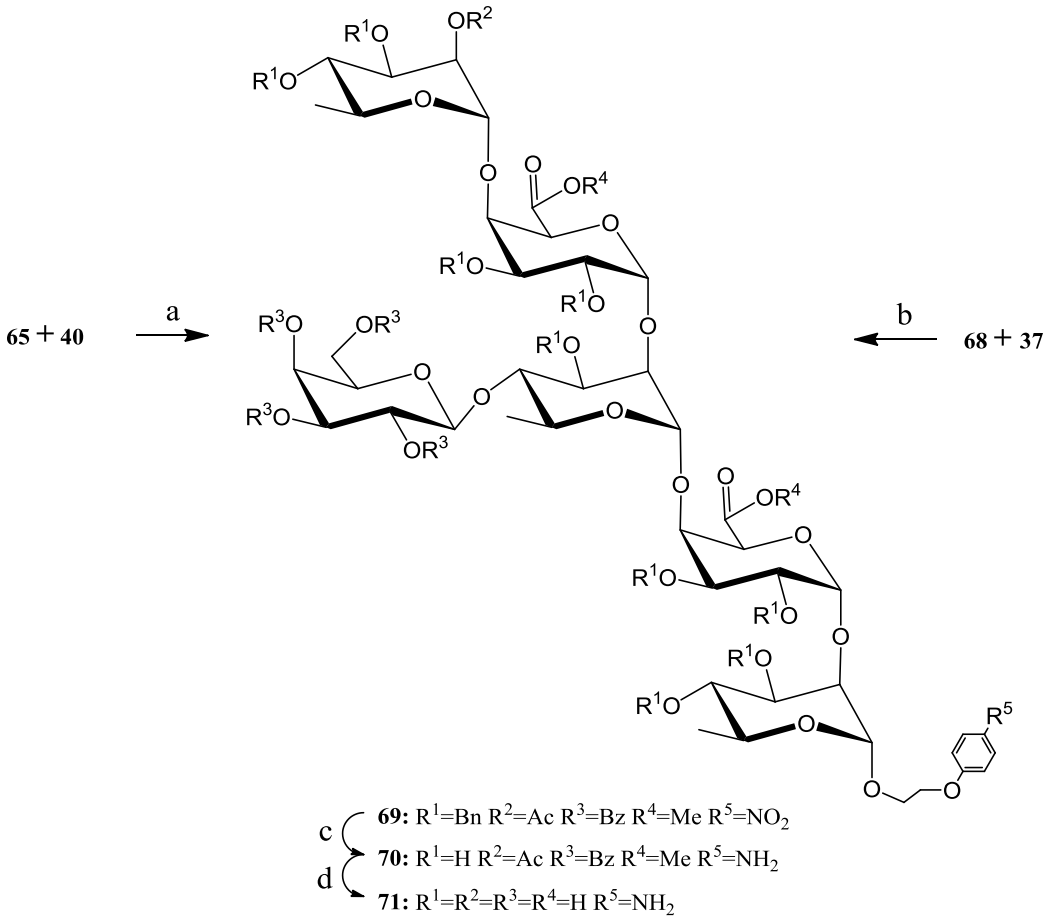


Scheme 17. Synthesis of branched RG-I donor **68**. (a) TMSOTf (cat.), MS 4Å, CH_2Cl_2, 3 h, -25 $^oC \rightarrow$RT (**66**, 80%); (b) $PdCl_2$, MeOH, CH_2Cl_2, 16 h, RT (**67**, 88%); (c) Cs_2CO3, 2,2,2-trifluoro-*N*-phenyl-acetimidoyl chloride, acetone, 3 h, RT (**68**, 86%).

2.16. SYNTHESIS OF BRANCHED RG-I HEXASACCHARIDE **71** WITH SPACER

The final step in this work was the synthesis of the branched rhamnogalacturonan-I hexasaccharide **69** connected with the spacer to a rhamnosyl derivative. To achieve this target two different disaccharides and tetrasaccharides were used followed to blockwise buildup strategy. Acceptor **65** and donor **40** were used to provide hexasaccharide **69** in 30% yield (**scheme 18**). In the ^{1}H NMR spectrum of compound **69** proton H-1´´´ appears as a doublet at δ = 4.97 ppm with a coupling constant $^3J_{1´´´,2´´´}$ 3.7 Hz proving an α-linkage. This is also supported by the NOESY spectrum where no correlation was found between H-1´´´ and H-5´´´.

On the other hand, glycosylation of donor **68** with acceptor **37** gave compound **69** in 51% yield. Due to the *manno*-configurated glycosyl donor, the stereochemical outcome of a glycosylation reaction cannot be proven only on the basis of chemical shift of proton H-1´´, which appears as a doublet at δ = 5.60 ppm with a coupling constant $^3J_{1´´,2´´}$ 1.3 Hz, similar to compound **62**. The absence of a correlation between protons H-1´´ and H-5´´ or H-1´´ and H-3´´ in a NOESY spectrum of compound **69** proved the α-linkage too.



Scheme 18. Synthesis of branched RG-I hexasaccharide **71** with spacer. (a) TMSOTf (cat.), MS 4Å, CH_2Cl_2, 3 h, -25 $^oC \rightarrow$RT (**69**, 30%); (b) TMSOTf (cat.), MS 4Å, CH_2Cl_2, 3 h, -25 $^oC \rightarrow$RT(**69**, 51%); (c) Pd/C, H_2, MeOH, EtOAc, 28 h, RT(**70**); (d) LiOH, MeOH, H_2O, 15 min, RT (**71**, 85%).

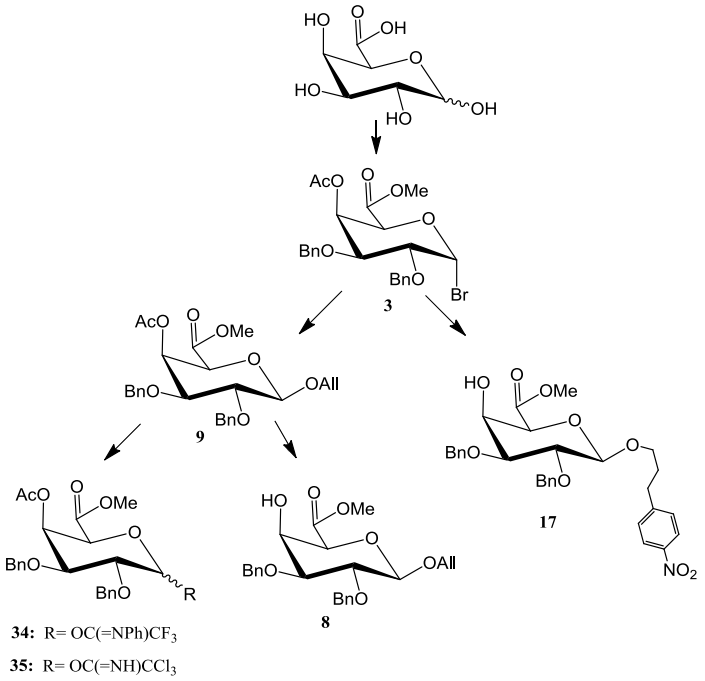
The deprotection of compound **69** was succeeded stepwise. The hydrogenation of compound **69** in methanol-ethylacetat solution in presence of Pd/C provided compound **70.** The ester cleavage of the acetyl, benzoyl and methyl groups, was achieved, similar to compound **49**, with lithium hydroxide in methanol/water solution to obtain branched rhamnogalacturonan-I hexasaccharide with spacer **71** in 85% yield.[68]

3. SUMMARY

Pectins are complex polysaccharides, which are an important part of plants cell walls. Furthermore, they play a significant role in human diet and have positive effects on health. Due to the complexity of the structure of pectins fragments of defined structure are difficult to obtain in sufficient quantity. Therefore, new methods for the synthesis of pectin fragments are requested.

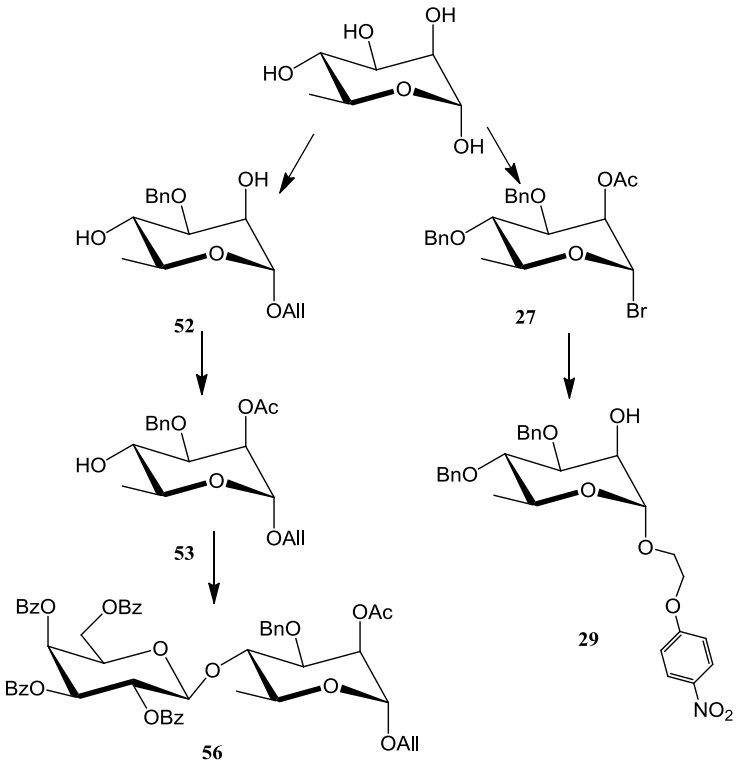
The task of the present work was the efficient synthesis of building blocks for the preparation of pectin fragments by modular design principle. In order to achieve this aim, the following syntheses were carried out. In general all D-galacturonic derivatives were synthesized stepwise starting from D-galacturonic acid directly.

- First, the synthesis of module **9** was significantly improved. Compared to the known pathway, the overall yield of module **9** increased from 18% to nearly 40%, and the total number of synthetic steps was reduced from 9 to 7 (**Scheme 19**).
- Using bromide **3** a galacturonan acceptor with spacer **17** was synthesized. In future used this structural element for the connection of pectin fragments with proteins to get monoclonal antibodies for immunological investigations.
- On the base of module **9** the known glycosyl acceptor **8** and glycosyl donor **35** can be achieved. Additionally, a new glycosyl donor bearing *N*-phenyltrifluoroacetimidate group **34** was prepared.



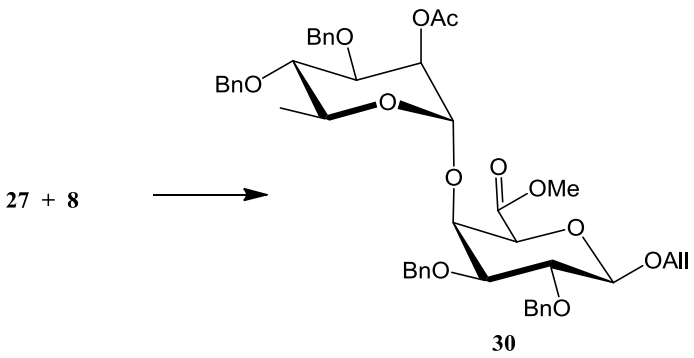
Scheme 19. Synthesis of galacturon donors and acceptors starting from D-galacturonicacid.

- In order to get suitable L-rhamnose building blocks for the synthesis of RG-I fragments glycosyl acceptor **53** was prepared *via* known intermediate **52**. Regioselective acetylation of compound **52** at -40 ^{o}C gave acceptor 53 in 60% yield. This step simplified significantly the pathway to get **53** (from 6 to 3 synthetic steps) which was then coupled with perbenzoylated D-galactosyl bromide (**55**) to furnish disaccharide **56** (**Scheme 20**).
- The synthesis of donor **27** was significantly improved. Compared to the known pathway, the overall yield of bromide **27** was increased from 49% to nearly 62%.
- Using rhamnosyl bromide **27** we got a spacer modified monosaccharide (**29**), aswell.



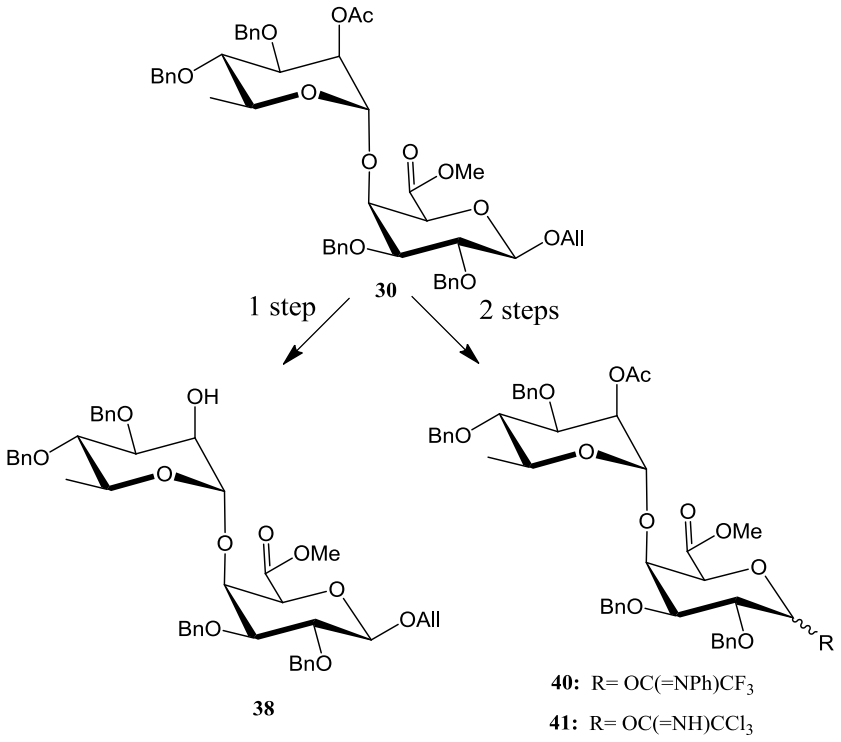
Scheme 20. Synthesis of rhamnosyl donor and acceptors starting from L-rhamnose.

- Furthermore bromide **27** was used to provide the RG-I-module **30** in 67% yield by incorporation of galacturonate acceptor **8** (**Scheme 21**).



Scheme 21. Synthesis of rhamnogalacturonan module **30**.

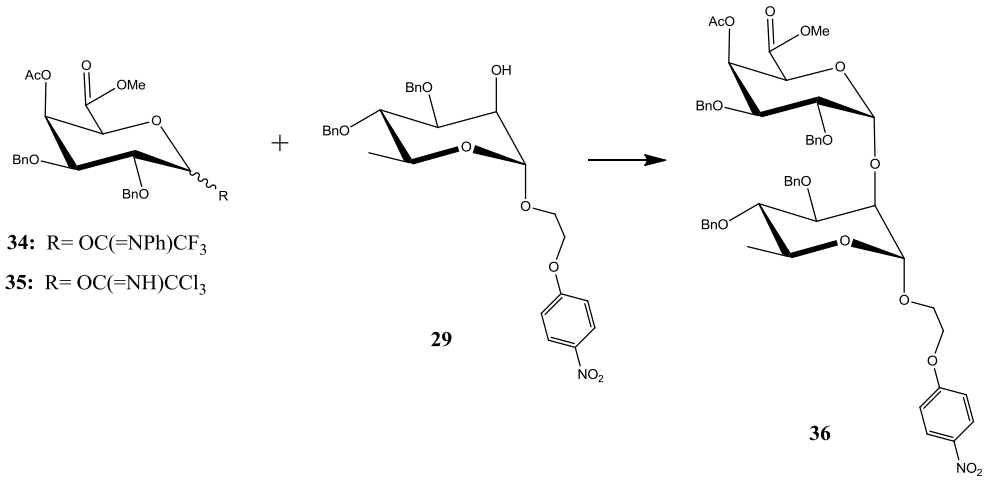
- According to our modular design principle, RG-I-module **30** can be transformed in one step into glycosyl acceptor **38** in 90% yield and in two steps in glycosyl donors **40** and **41** in 69% and 51% yield, respectively (**Scheme 22**).



Scheme 22. Synthesis of RG-I acceptor **38** and donors **40** and **41**.

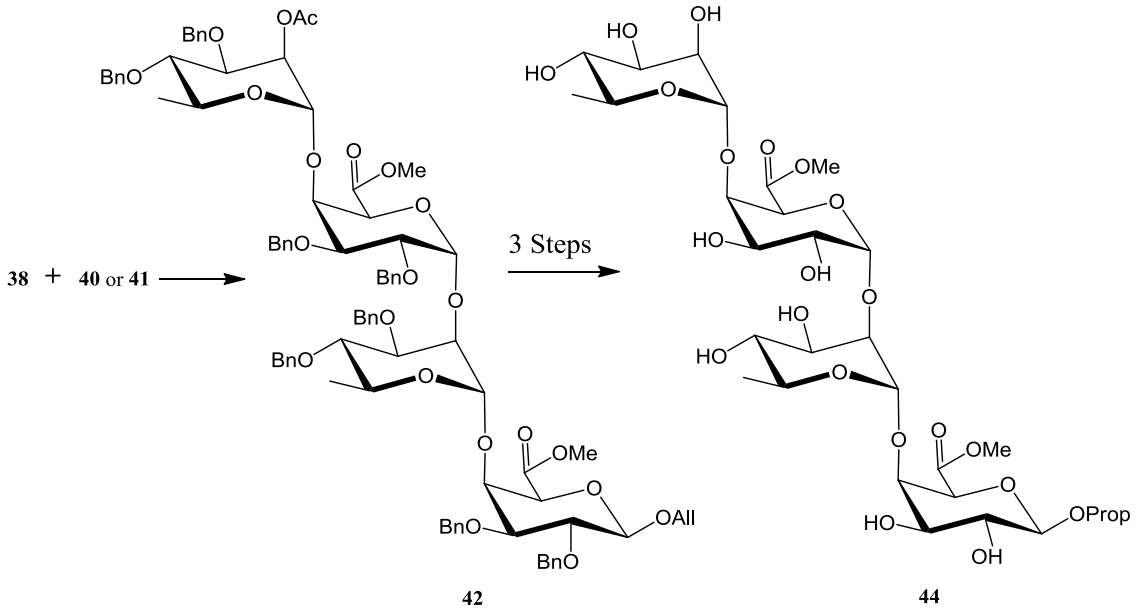
- To get a RG-I building block where the rhamnosyl moiety carries the spacer function, acceptor **29** was glycosylated with both trichloracetimidate **35** and *N*- phenyltrifluoro-acetimidate **34** donors (**Scheme 23**). *Via* donor **35** at -70 ^{o}C the RG-I **36** with spacer

was obtained in 67% yield. *Via* new donor **34** at -20 ^{o}C the same RG-I **36** was obtained in 85% yield.



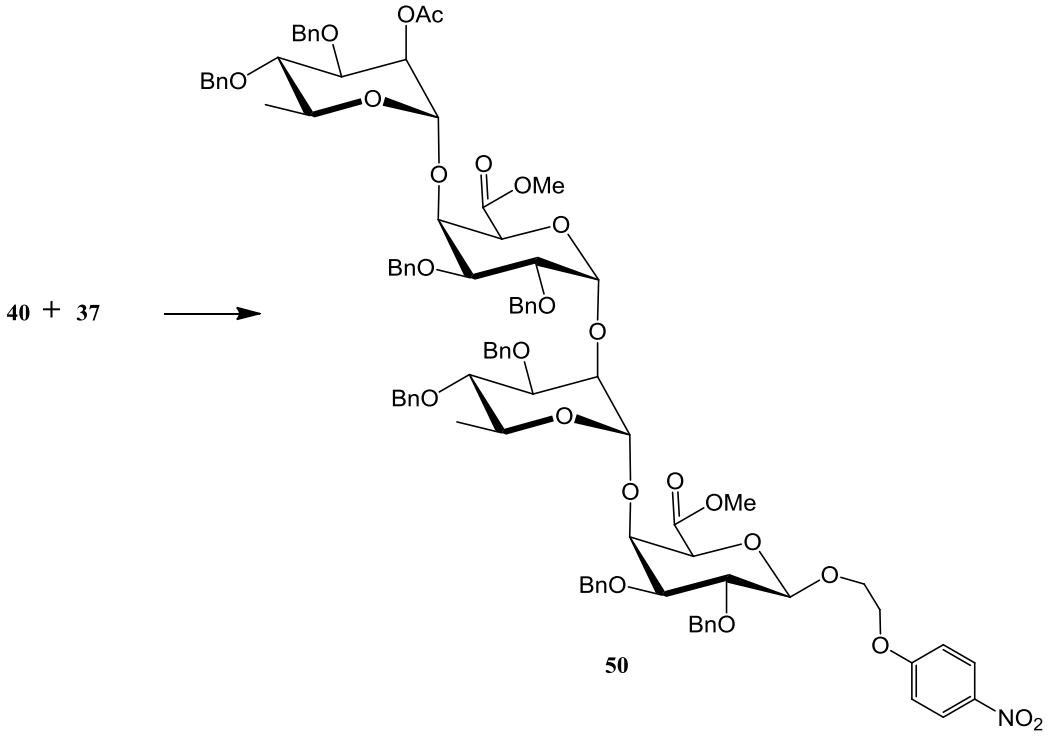
Scheme 23. Synthesis of rhamnogalacturonan **36** with spacer.

- To get a RG-I tetrasaccharide **42** acceptor **38** was glycosylated with both trichloracetimidate **41** and *N*- phenyltrifluoroacetimidate **40** donors (**Scheme 24**). *Via* donor **41** at -70 ^{o}C the RG-I **42** was obtained in 67% yield. *Via* new donor **40** at -20 ^{o}C the same RG-I **42** was obtained in 90% yield. Tetrasaccharide **42** was deprotected to obain tetrasaccharide **44**.



Scheme 24. Synthesis of rhamnogalacturonan **44**.

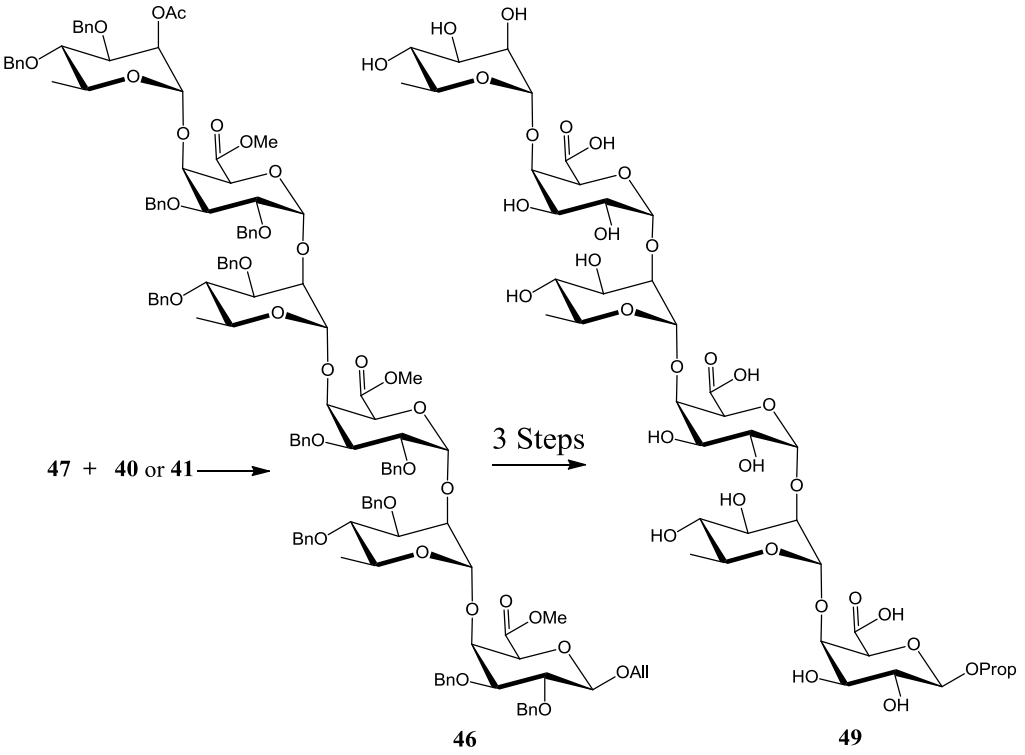
- To get a RG-I tetrasaccharide with spacer acceptor **37** was glycosylated with donor **41** and provided compound **50** in 77% yield (**Scheme 25**). Compound **50** may be used for immunological studies after cleavage of all protecting groups and conversion of the nitro group into an isothiocyanate group.



50

Scheme 25. Synthesis of rhamnogalacturonan **50** with spacer.

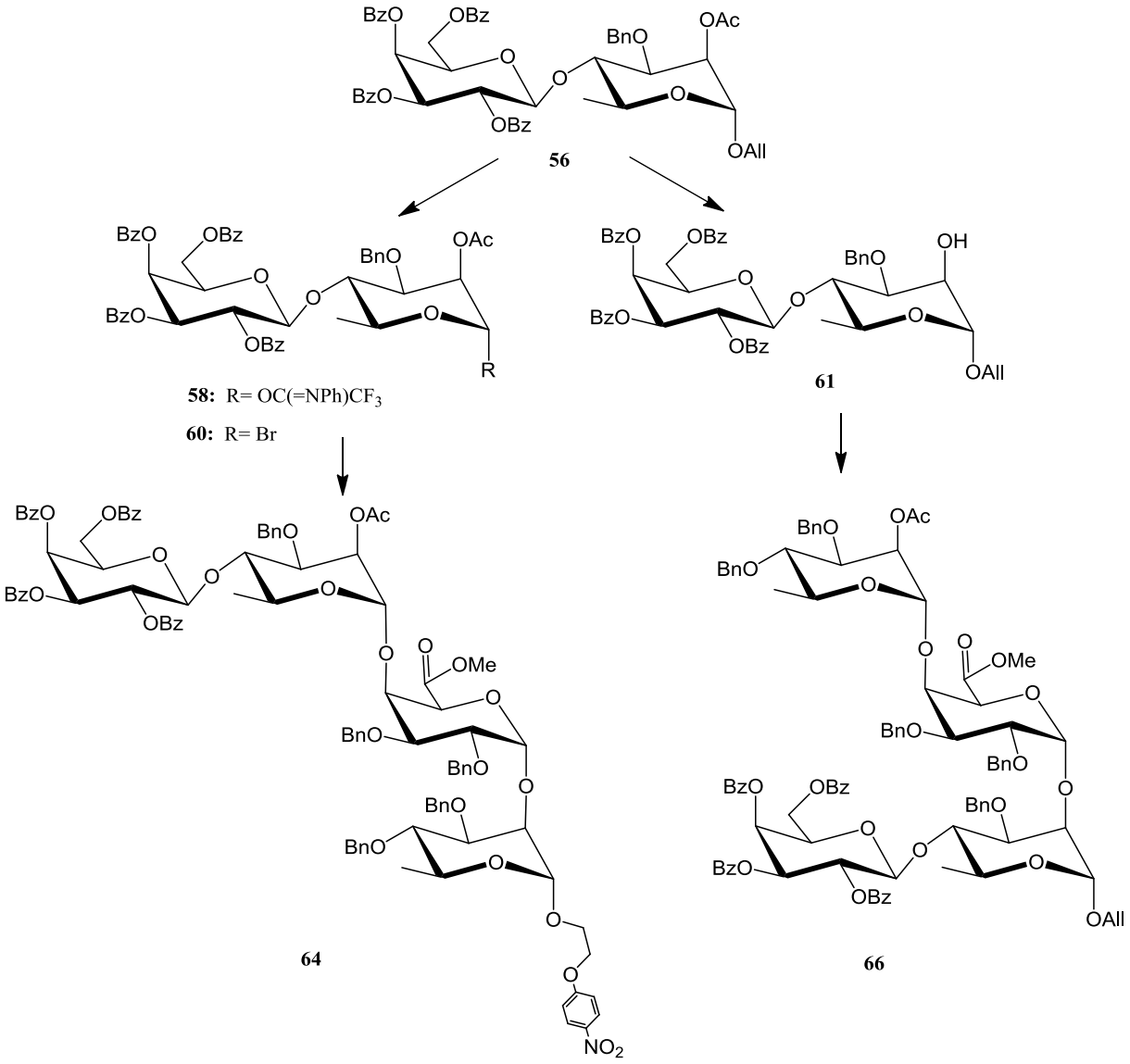
- To get a RG-I hexasaccharide acceptor **47** was glycosylated with both trichloracetimidate **41** and *N*- phenyltrifluoroacetimidate **40** (**Scheme 26**). *Via* donor **41** at -70 ^{o}C the RG-I **46** was obtained in 60% yield. *Via* new donor **40** at -20 ^{o}C the same RG-I **46** was obtained in 79% yield. Hexasaccharide **46** was deprotected to furnish RG-I **49**. The tetrasaccharide **44** and hexasaccharide **49** has been sent to colleagues from Norway for the biological tests.



Scheme 26. Synthesis of rhamnogalacturonan **49**.

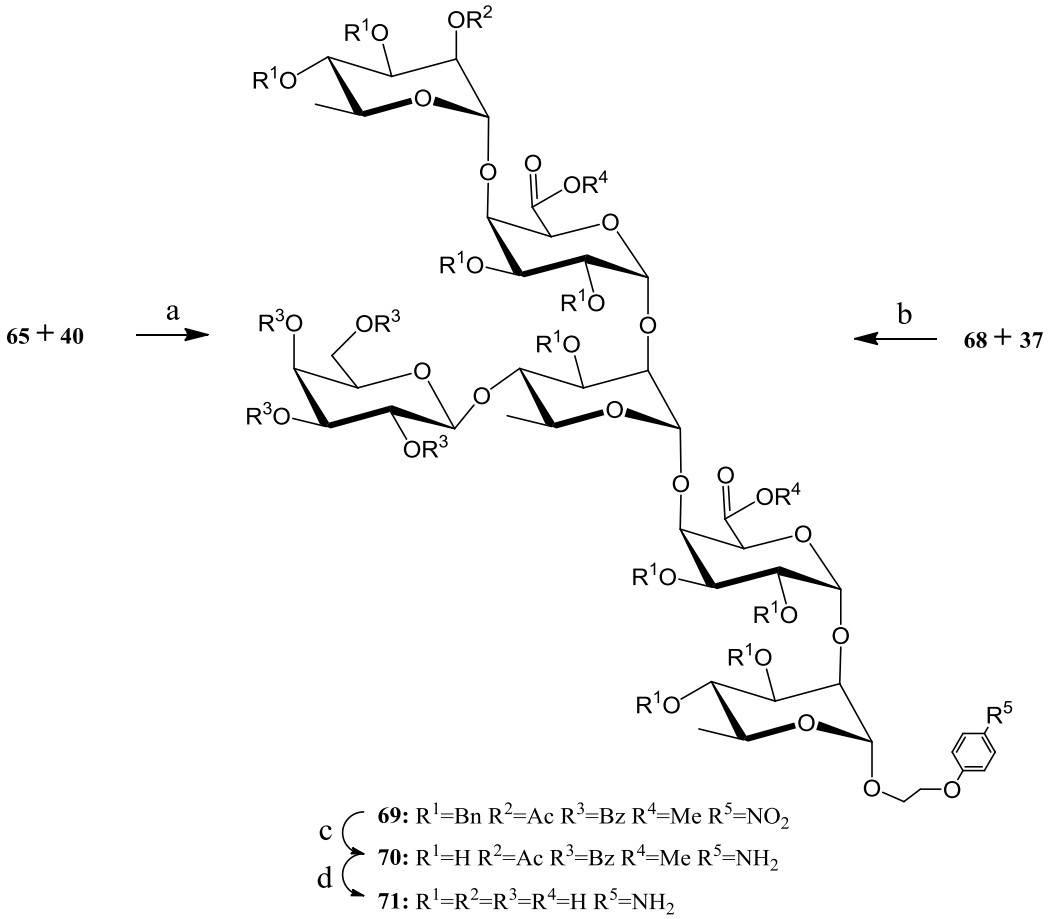
A special task of my PhD work was the synthesis of branched RG-I modules (**Scheme 27**).

- Starting from allyl 2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranoside (**53**), module **56** was synthesized under Helferich conditions. Module **56** was converted to bromide **60** which was then coupled with acceptor **37** to provide branched tetrasaccharide **64** with spacer. Alternatively, module **56** was transformed into derivatives **61** suitable as an acceptor for the glycosylation with glycosyl donor **40** to yield tetrasaccharide **66**. Both tetrasaccharides **64** and **66** are suitable modules for branched pectin fragments accessible by modular design principle.



Scheme 27. Synthesis of branched rhamnogalacturonan fragments **64** and **66**.

- To get a higher branched RG-I fragments with spacer the hexasaccharide **69** was synthesized by using modular design principle. The synthesis of RG-I **69** was achieved by glycosylation of the previously synthesized donor **40** and acceptors **65**. In parallel, RG-I **69** was synthesized *via* donor **68** and acceptor **37**. After deprotaction branched hexasaccharide **71** with spacer was obtained (**Scheme 28**).



Scheme 28. Synthesis of branched RG-I fragment with spacer.

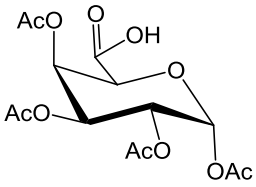
4. EXPERIMENTAL SECTION

4.1 GENERAL METHODS

Melting points were determined with a Boetius micro-heating plate BHMK 05 (Rapido, Dresden) and were not uncorrected. Optical rotation was measured for solutions in a 2-cm cell with an automatic polarimeter GYROMAT (Dr. Kernchen Co.). ^{1}H NMR spectra (500.13 MHz, 300.13 MHz and 250.13 MHz) and ^{13}C NMR spectra (125.8 MHz, 75.5 MHz and 62.9 MHz) were recorded using Bruker instruments AVANCE 500, ARX 300 and AVANCE 250, with $CDCl_3$ and DMSO-d_6 as solvents. NMR spectra were calibrated using solvent signals ($CDCl_3$: δ ^{1}H 7.25 and δ ^{13}C 77.0, DMSO-d_6: δ ^{1}H 2.49 and δ ^{13}C 39.50). The ^{1}H and ^{13}C NMR signals were assigned by DEPT and two-dimensional ^{1}H,^{1}H COSY, ^{1}H,^{1}H NOESY, and ^{1}H,^{13}C correlation spectra (HMBC and HSQC). Elemental analysis was performed on a CHNS-Flash-EA-1112 instrument (Thermoquest). All washing solutions were cooled to ~5 °C. The $NaHCO_3$ solution was saturated. Reactions were monitored by thin-layer chromatography (TLC, Silica Gel 60, F_{254}, 0.25 mm, Merck KGaA). The spots were made visible by spraying with ethanolic 10% H_2SO_4 solution and charring them for 10–30 sec with a heat gun. Detection of benzyl derivatives was effected by UV fluorescence. Preparative flash chromatography was performed by elution from columns of slurry-packed Silica gel 60 (Merck, 40–63 μm). All solvents and reagents were purified and dried according to standard procedures.[100] After classical work–up of the reaction mixtures, organic layers were dried over $MgSO_4$ and then concentrated under reduced pressure (rotary evaporator).

4.2. PREPARATIVE METHODS

1,2,3,4-tetra-*O*-acetyl-α-D-galactopyranuronic acid (1)



D-galacturonic acid monohydrate (40.32 g, 190.2 mmol) was added in small portions to a stirred solution of 70% perchloric acid (1.5 mL) in acetic anhydride (250 mL) at 5 °C. The reaction mixture was stirred for 30 min at that temperature, the cooling-bath was removed and stirring was continued for 3 h at ambient temperature (monitored by TLC). The mixture was cooled to 0 °C, and methanol (60 mL) was added dropwise. After stirring for 30 min, the solution was poured into ice-water (600 mL) and the aqueous layer was extracted with chloroform (3 × 100 mL). The combined organic solutions were washed with ice-water (3 × 25 mL), dried and concentrated. Heptane (20 mL) was added to a solution of the crude material in EtOAc (100 mL) and the precipitate was collected. A similar precipitation procedure was repeated with the mother liquor (3-4 times). Crystallization from diethyl tether gave compound **7** as colourless crystals.

Yield: 58.5 g (85%)

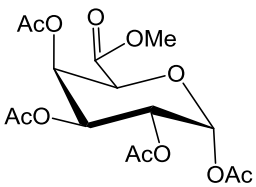
M.p.: 162 - 164 °C (from dietyl ether)

R_f : 0.25 (2 : 1 EtOAc - MeOH)

$[\alpha]_D^{21}$: +125 (*c* 1.0, $CHCl_3$)

NMR data an elemental analysis are published, yet.[53]

Methyl 1,2,3,4-tetra-*O*-acetyl-α-D-galactopyranuronate (2)



Compound **1** (7.25 g, 20.0 mmol) was dissolved in a minimum of chloroform and treated with ethereal diazomethane until yellow color persisted. The excess diazomethane was destroyed

with acetic acid. The solution was diluted with heptane (200 mL), washed with sat aq $NHCO_3$ (2 × 60 mL), ice-water (2 × 60 mL), dried and concentrated. Crystallization from Heptane - EtOAc gave compound **7** as colourless crystals.

Yield: 7.15 g (95%)

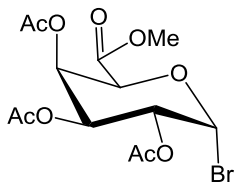
M.p.: 138 - 140 °C (from Heptane - EtOAc)

R_f: 0.35 (2 : 1 Toluene - EtOAc)

$[\alpha]_D^{23}$: +159.9 (*c* 1.0, $CHCl_3$)

NMR data an elemental analysis are published, yet.[53]

Methyl 2,3,4-tri-*O*-acetyl-α-D-galactopyranosyluronate bromide (3)



Foregoing 40% HBr solution in acetic acid (90 mL) was added to a solution of compound **2** (9.4 g, 25.0 mmol) in dry chloroform (80 mL) at 0 °C. After 15 min cooling-bath was removed, and the reaction mixture was stirred at ambient temperature. After 3 h (monitored by TLC) the solution was poured into ice-water (300 mL). The organic layer was separated and the aqueous layer was extracted with chloroform (3 × 75 mL). The combined organic layers were washed with ice-water (150 mL), sat aq $NHCO_3$ (2 × 150 mL), ice-water (2 × 150 mL), dried and concentrated. Obtained compound **3**, which was sufficiently pure (NMR) to be used in the next step without further purification. Crystallization gave an analytical sample as colourless crystals.

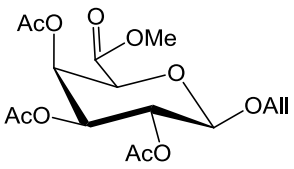
Yield: 8.7 g (90%)

M.p.: 128 - 130 °C (from dry diethyl ether)

R_f: 0.49 (2 : 1 toluene - EtOAc)

$[\alpha]_D^{20}$: +240 (*c* 1.0, $CHCl_3$)

Methyl (allyl 2,3,4-tri-*O*-acetyl-β-D-galactopyranosid)uronate (4)



Bromide **3** (12 g, 30.2 mmol), $Hg(CN)_2$ (5.88 g, 23.3 mmol), $HgBr_2$ (1 g, 2.8 mmol) and molecular sieves (3Å, 5 g) in dry allyl alcohol (100 mL) were stirred overnight at ambient temperature under an atmosphere of argon. The mixture was concentrated, diluted with chloroform (200 mL) and filtered. The filtrate was washed with aq 10% KBr (3 × 50 mL) and ice-water (2 × 25 mL), dried and concentrated. The crude product was purified by column chromatography (2 : 1 PE - EtOAc) to give compound **4** as colourless crystals.

Yeld: 10.33 g (91%)

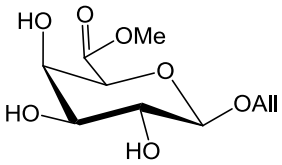
M.p.: 98 - 99 ^{o}C (from heptane - EtOAc)

R_f: 0.44 (1 : 1 PE - EtOAc)

$[\alpha]_D^{20}$: 0 (*c* 1.0, $CHCl_3$)

NMR data an elemental analysis are published, yet.[53]

Methyl (allyl β-D-galactopyranosid)uronate (10)



Compound **4** (3.74 g, 10 mmol) was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (7.3 mL) to ice-cold dry methanol (360 mL)] and the mixture was stirred for 24 h at ambient temperature under an atmosphere of argon (monitored by TLC). $PbCO_3$ x $Pb(OH)_2$ (30 g) was added and the reaction mixture was stirred for additional 2 h at ambient temperature. The salts were filtered off, washed with methanol (3 × 30 mL) and the combined organic solutions were concentrated. The purification of the residue by flash chromatography (3 : 1 $CHCl_3$ - MeOH) gave compound **10** as colourless crystals.

Yield: 2.22 g (90%)

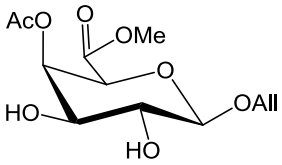
M.p.: 151 - 153 °C (from MeOH - EtOAc)

R_f: 0.3 (8 : 1 EtOAc - MeOH)

$[\alpha]_D^{22}$: –62.9 (*c* 1.0, acetone)

NMR data an elemental analysis are published, yet.[53]

Methyl (allyl 4-*O*-acetyl-β-D-galactopyranosid)uronate (12)



Triethyl orthoacetate (5 × 5.5 mL, 150 mmol) and anhydrous camphorsulfonic acid (2 × 400 mg, 3.4 mmol) were added in portions into a stirred solution of compound **10** (10.2 g, 41.1 mmol) in dry CH_2Cl_2 (300 mL) at amient temperature under an atmosphere of argon. After 1.5 h (monitored by TLC) the reaction was terminated by addition of triethylamine (20 mL, 144.5 mmol), and the mixture was diluted with $CHCl_3$ (500 mL). The organic phase was washed with ice-water (2 × 50 mL), dried and concentrated. The residue was immediately dissolved in aqueous 95% acetic acid (100 mL) and the solution was kept for 10 min in ambient temperature. After concentration, the residue was co-evaporated with toluene (4 × 50 mL) to remove traces of acetic acid. The purification of the crude product by flash chromatography (2 : 1 Toluene - EtOAc) gave compound **12** as colourless crystals.

Yield: 10.1 g (85%)

M.p.: 105 - 107 °C (from hot EtOAc)

R_f: 0.3 (EtOA)

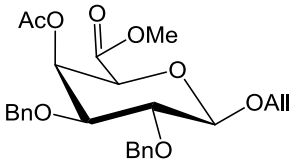
$[\alpha]_D^{23}$: +2.2 (*c*1.0, methanol)

^{1}H NMR (300 MHz, DMSO): δ 5.93 (m, 1H, CH_2CH=CH_2), 5.58 (dd,1H, $^3J_{4,5}$ 1.3 Hz, H-4), 5.32, 5.22 (2 × m, 2H, CH_2CH=CH_2), 4.46 (m, 1H,CH_2CH=CH_2), 4.35 (d, 1H, $^3J_{1,2}$ 7.7 Hz, H-l), 4.24 (m, 1H, H-5), 4.14 (m, 1H, CH_2CH=CH_2), 3.83 (m, 1H, H-2), 3.74 (s, 3H, OCH_3),

3.71 (dd, 1H, $^{3}J_{2,3}$ 9.4 Hz, H-3), 3.26 (bs, 1H, OH), 3.18 (bs, 1H, OH), 2.09 (s, 3H, CH_3CO); **^{13}C NMR (75.5 MHz, CDC1$_3$):** δ 169.4 (CH_3COO), 167.8 (COO), 134.6 ($OCH_2CH=CH_2$), 116.7 ($CH_2CH=CH_2$), 102.1 (C-l), 71.8 (C-3), 71.3 (C-2), 70.6 (C-4), 70.3 (C-5), 69.2 ($CH_2CH=CH_2$), 51.9 (OCH_3), 20.6 (CH_3COO).

Anal. Calcd for $C_{12}H_{18}O_8$ (290.27): C, 49.65; H, 6.25. Found: C, 49.54; H, 6.18.

Methyl (allyl 4-*O*-acetyl-2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (9)



Freshly distilled benzyl 2,2,2-trichloroacetimidate (12 mL, 64.3 mmol) was added to a solution of compound **12** (5 g, 17.2 mmol) in freshly distilled dioxane (130 mL) at 0 °C under an atmosphere of argon. The mixture was made strongly acidic by addition of trifluoromethanesulfonic acid (0.9 mL). After stirring for 15-30 min, the reaction mixture was passed through a layer of alkaline alumina and concentrated. The residue was suspended in Heptane - EtOAc (6 : 1 v/v, 300 mL), the carbohydrate-free precipitates were filtered off and washed with Heptane - EtOAc (6 : 1 v/v, 150 mL). The filtrate and washings were combined end concentrated. The purification of crude product by flash chromatography (2 : 1 PE - EtOAc) gave compound **9** as colourless crystals.

Yield: 7.15 g (89%)

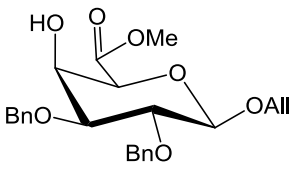
M.p.: 136 °C (from heptane-EtOAc)

R_f: 0.54 (1 : 1 PE - EtOA)

[α]$_D^{23}$: +35.8 (*c* 1.0, chloroform)

NMR data an elemental analysis are published, yet.[57]

Methyl (allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (8)



Compound **9** (428 mg, 1.0 mmol) was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (2 mL) to ice-cold dry methanol (100 mL)] and the mixture was stirred for 24 h at ambient temperature under an atmosphere of argon (monitored by TLC). The solution was filtered through a layer of alkaline alumina by elution with $CHCl_3$. The combined eluates (ca. 400 mL) were dried, concentrated and the crude product was chromatographed (3 : 1 Pet - EtOAc) to provide acceptor **8** as colourless crystals.

Yield: 430 mg (90%)

M.p.: 111 ^{o}C (EtOAc - heptane)

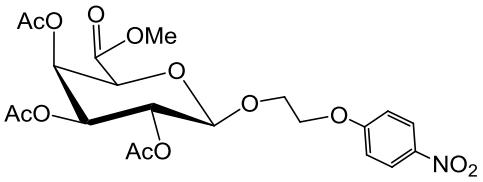
R_f: 0.45 (2 : 1 heptane - EtOAc)

$[\alpha]_D^{22}$: –4.7 (*c* 1.0, $CHCl_3$)

^{1}H NMR (300 MHz, $CDCl_3$): δ 7.40–7.23 (m, 10H, 2 × Ph), 5.95 (m, 1H, CH_2CH=CH_2), 5.33, 5.19 (2 × m, 2H, CH_2CH=CH_2), 4.92, 4.73 (2 × d, 2H, CH_2Ph), 4.73 (s, 2H, CH_2Ph), 4.48 (m, 1H,CH_2CH=CH_2), 4.41 (d, 1H, $^3J_{1,2}$ 7.6 Hz, H-l), 4.31 (m, 1H, H-4), 4.13 (m, 1H, CH_2CH=CH_2), 4.04 (m, 1H, H-5), 3.82 (s, 3H, OCH_3), 3.71 (dd, 1H, $^3J_{2,3}$ 9.5 Hz, H-2), 3.55 (dd, 1H, $^3J_{3,4}$ 3.5 Hz, H-3), 2.53 (m, 1H, 4-OH); **^{13}C NMR (75.5 MHz, $CDC1_3$):** δ 168.4 (COO), 133.9 (OCH_2CH=CH_2), 138.4, 137.6, 128.5, 128.3, 128.2, 128.00, 127.9, 127.7 (2 × Ph,), 117.4 (CH_2CH=CH_2), 102.3 (C-l), 79.8 (C-3), 78.3 (C-2), 73.7 (C-5), 75.2 (CH_2CH=CH_2), 72.6, 70.3 (2 x CH_2Ph,), 68.0 (C-4), 52.5 (OCH_3).

Anal. Calcd for $C_{24}H_{28}O_7$ (428.48): C, 67.28; H, 6.59. Found: C, 67.17; H, 6.62.

Methyl (2-(4-nitrophenoxy)ethyl 2,3,4-tri-*O*-acetyl-β-D-galactopyranosid)uronate (13)



Bromide **3** (1 g, 2.5 mmol), 2-(4-nitrophenoxy)ethanol (620 mg, 3.4 mmol), $Hg(CN)_2$ (255 mg, 1.0 mmol), $HgBr_2$ (110 mg, 0.3 mmol) and molecular sieves (3Å, 1 g) in dry acetonitrile (20 mL) were stirred overnight at ambient temperature under an atmosphere of argon(monitored by TLC). The mixture was concentrated and the residue was dissolved in chloroform (30 mL) and filtered. The filtrate was washed with aq 10% KBr (3 × 10 mL) and ice-water (2 × 10 mL), dried and concentrated. The crude product was purified by column chromatography (1 : 1 PE - EtOAc) to give compound **13** as foam.

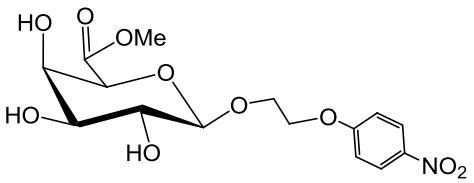
Yeld: 1.07 g (86%)

R_f: 0.2 (1 : 1 PE - EtOAc)

^{1}H NMR (300 MHz, DMSO): δ 8.18 (d, 2H, *J* 8.9 Hz, 2 × *m*-$OPhNO_2$), 6.95 (d, 2H, *J* 8.9 Hz, 2 × *o*-$OPhNO_2$), 5.70 (dd, 1H, $^3J_{3,4}$ 3.4 Hz, $^3J_{4,5}$ 1.3 Hz, H-4), 5.26 (dd, 1H, $^3J_{1,2}$ 7.9 Hz, $^3J_{2,3}$ 10.4 Hz, H-2), 5.07 (dd, 1H, $^3J_{3,4}$ 3.4 Hz, $^3J_{2,3}$ 10.4 Hz, H-3) 4.28-4.23 (m, 2H, C$H_2$$CH_2O$, CH_2CH_2O), 4.00 (m, 2H, CH_2CH_2O, C$H_2$$CH_2O$), 3.74 (s, 3H, OCH_3), 2.11 (s, 3H, CH_3), 1.98 (s, 3H, CH_3), 1.92 (s, 3H, CH_3); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 170.0 (*C*$OOCH_3$), 169.7, 169.2, 166.3 (3 × COO), 163.6 (*p*-$OPhNO_2$), 141.7 (*o*-$OPhNO_2$), 125.9 (*m*-$OPhNO_2$), 114.9 (*o*-$OPhNO_2$), 101.3 (C-1), 72.4 (C-3), 70.3 (C-4), 68.2 (C-5), 68.0 (C-2), 67.5 (*C*H_2CH_2O), 61.6 (CH_2*C*H_2O), 52.8 (O*C*H_3), 20.5 (3 × CH_3).

Anal. Calcd for $C_{21}H_{25}NO_{13}$ (499.42): C, 50.50; H, 5.05; N, 2.80 Found: C, 50.48; H, 5.08; N, 2.85.

Methyl (2-(4-nitrophenoxy)ethyl β-D-galactopyranosid)uronate (14)



Compound **13** (1.0 g, 2 mmol) was added to a stirred solution of methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (2.5 mL) to ice-cold dry methanol

(120 mL)] and the mixture was stirred for 24 h at ambient temperature under an atmosphere of argon (monitored by TLC). $PbCO_3$ x $Pb(OH)_2$ (10 g) was added and the reaction mixture was stirred for additional 2 h at ambient temperature. The salts were filtered off, washed with methanol (3 × 30 mL) and the combined organic solutions were concentrated. The purification of the residue by flash chromatography (7 : 1 EtOAc - MeOH) gave compound **14** as yellow foam.

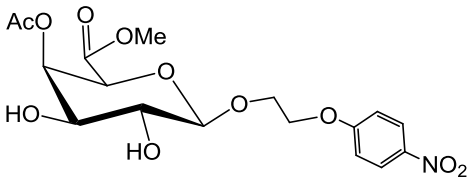
Yield: 555 mg (74%)

R_f: 0.35 (6 : 1 EtOAc - MeOH)

^{1}H NMR (300 MHz, DMSO): δ 8.25 (d, 2H, *J* 9.4 Hz, 2 × *m*-$OPhNO_2$), 7.24 (d, 2H, *J* 9.3 Hz, 2 × *p*-$OPhNO_2$), 5.07 (d,1H, *J* 4.5 Hz, OH), 4.93 (d, 1H, *J* 5.1 Hz, OH), 4.90 (d,1H, *J* 5.1 Hz, OH), 4.37 (t, 2H, C*H*$_2$$CH_2O$), 4.32 (d, 1H, $^3J_{1,2}$ 8.0 Hz, H-1), 4.30 (s, 1H, H-5), 4.13 (m, 1H, CH_2C*H*$_2$O), 3.96 (m, 1H, H-4), 3.90 (m, 1H, CH_2C*H*$_2$O), 3.67 (m, 1H, $^3J_{3,4}$ 3.6 Hz, H-3), 3.68 (s, 3H, OCH_3), 3.42 (m, 1H, H-3), 3.34 (s, 1H, H-2); **^{13}C NMR (75.5 MHz, DMSO):** δ 168.8 (COO), 163.8 (C-12), 140.3 (C-9), 125.9 (C-11, C-11´), 115.1 (C-10, C-10´), 103.4 (C-1), 73.4 (C-4), 72.6 (C-2), 69.9 (C-5), 69.7 (C-3), 68.4 (C-8), 67.2 (C-7), 51.6 (CH_3O).

Anal. Calcd for $C_{15}H_{19}NO_{10}$ (373.31): C, 48.26; H, 5.23; N, 3.75. Found: C, 48.32; H, 5.18; N, 3.85.

Methyl (2-(4-nitrophenoxy)ethyl 4-*O*-acetyl-β-D-galactopyranosid)uronate (15)



Triethyl orthoacetate (2 × 0.35 mL, 3.8 mmol) and anhydrous camphorsulfonic acid (15 mg, 0.064 mmol) were added in portions to a stirred solution of compound **14** (200 mg, 0.536 mmol) in dry CH_2Cl_2 (10 mL) at ambient temperature under an atmosphere of argon. After 1.5 h (monitored by TLC) the reaction was terminated by addition of triethylamine (2 mL, 0.022 mmol). The reaction mixture was then concentrated and the residue co-evaporated with toluene (3 × 2 mL). The residue was immediately dissolved in aqueous 95% acetic acid (5 mL) and the solution was kept for 10 min in ambient temperature. After concentration, the residue was co-evaporated with toluene (4 × 5 mL) to remove traces of acetic acid. The

purification of the crude product by flash chromatography (EtOAc) gave compound **15** as yellow foam.

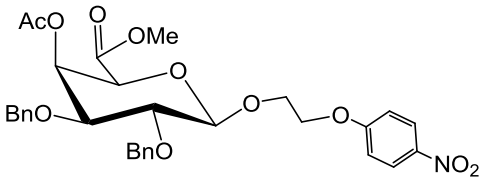
Yield: 205 mg (92%)

R_f: 0.2 (EtOA)

^{1}H NMR (300 MHz, DMSO): δ 8.25 (d, 2H, *J* 9.3 Hz, 2 × *m*-OPhNO_2), 7.23 (d, 2H, *J* 9.3 Hz, 2 × *p*-OPhNO_2), 5.34 (dd, 1H, $^3J_{4,5}$ 1.1 Hz, $^3J_{3,4}$ 3.6 Hz, H-4), 5.29 (d,1H, *J* 5.2 Hz, OH), 5.26 (d, 1H, *J* 6.4 Hz, OH), 4.56 (d,1H, $^3J_{4,5}$ 1.1 Hz, H-5), 4.42 (d, 1H, $^3J_{1,2}$ 7.7 Hz, H-1), 4.37 (t, 2H, C*H*$_2$CH_2O), 4.15 (m, 1H, CH_2C*H*$_2$O), 3.94 (m, 1H, CH_2C*H*$_2$O), 3.67 (m, 1H, $^3J_{3,4}$ 3.6 Hz, H-3), 3.63 (s, 3H, OCH_3), 3.36 (s, 2H), 3.30 (m, 1H, H-2) 2.01 (s, 3H, CH_3COO); **^{13}C NMR (75.5 MHz, DMSO):** δ 169.4 (CH_3*C*O), 167.7 (COO), 163.8 (C-12), 141.9 (C-9), 125.9 (C-11, C-11´), 115.1 (C-10, C-10´), 103.2 (C-1), 71.9 (C-4), 71.3 (C-2), 70.6 (C-5), 70.2 (C-3),68.3 (C-8), 67.4 (C-7), 51.9 (CH_3O), 20.6 (*C*H_3CO).

Anal. Calcd for $C_{17}H_{21}NO_{11}$ (415.16): C, 49.16; H, 5.10; N, 3.37. Found: C, 49.19; H, 5.08; N, 3.42.

Methyl (2-(4-nitrophenoxy)ethyl 4-*O*-acetyl-2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (16)



Freshly distilled benzyl 2,2,2-trichloroacetimidate (0.2 mL, 1.1 mmol) was added to a solution of compound **15** (180 mg, 0.43 mmol) in freshly distilled dioxane (1.5 mL) at 0 ^{o}C under an atmosphere of argon. The mixture was made strongly acidic by addition of trifluoromethanesulfonic acid (0.02 mL). After stirring for 15-30 min, the reaction mixture was passed through a layer of alkaline alumina and concentrated. The purification of crude product by flash chromatography (2 : 1 PE - EtOAc) gave compound **16** as yellow foam.

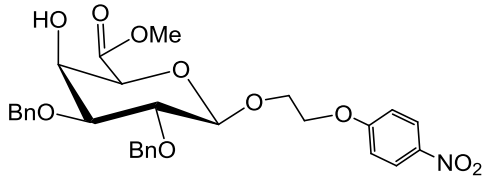
Yield: 185 mg (72%)

R_f: 0.27 (1 : 1 PE - EtOA)

^{1}H NMR (300 MHz, $CDCl_3$): δ 8.16 (d, 2H, *J* 8.9 Hz, 2 × *m*-$OPhNO_2$), 7.34–7.25 (m, 10H, 2×C_6H_5), 6.92 (d, 2H, *J* 8.9 Hz, 2 × *p*-$OPhNO_2$), 5.80 (q, 1H, $^3J_{4,5}$ 1.3 Hz, $^3J_{3,4}$ 2.8 Hz, H-4), 4.84 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.77 (d, 1H, ^2J 11.5 Hz, CH_2Ph), 4.71 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.56 (d, 1H, ^2J 11.5 Hz, CH_2Ph), 4.53 (d, 1H, $^3J_{1,2}$ 7.9 Hz, H-1), 4.37 (m, 1H, $^3J_{1,2}$ 7.9 Hz, $^3J_{2,3}$ 3.2 Hz, H-2), 4.32 (m, 1H, $^3J_{2,3}$ 3.2 Hz, $^3J_{3,4}$ 2.8 Hz, H-3), 4.25 (m, 2H, C$H_2$$CH_2$O), 4.24 (m, 1H, CH_2CH_2O), 4.20 (d, 1H, , $^3J_{4,5}$ 1.3 Hz, H-5), 3.99 (m, 1H, CH_2CH_2O), 3.77 (s, 3H, OCH_3), 2.12 (s, 3H, CH_3COO); **^{13}C NMR (62.9 MHz, $CDCl_3$):** δ 169.9 (CH_3*C*O), 167.2 (COO), 163.6 (C-12), 141.6 (C-9), 138.3, 137.4 (*i*-Ph), 128.3, 128.2, 128.0, 127.8 127.6, 127.4 (*o*-Ph, *m*-Ph, *p*-Ph), 125.8 (C-11, C-11´), 114.5 (C-10, C-10´), 103.7 (C-1), 78.4 (C-3), 78.0 (C-2), 75.2 (CH_2), 72.5 (C-5), 72.2 (CH_2), 68.2 (C-8), 67.8 (C-7), 67.4 (C-4), 52.6 (CH_3O), 20.7 (*C*H_3CO).

Anal. Calcd for $C_{24}H_{26}NO_{10}$ (488.46): C, 59.01; H, 5.37; N, 2.87. Found: C, 59.09; H, 5.28; N, 2.92.

Methyl (2-(4-nitrophenoxy)ethyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (17)



Compound **16** (750 mg, 1.26 mmol) was added to a stirring solution of methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (1 mL) to ice-cold dry methanol (50 mL)] and the mixture was stirred for 24 h at ambient temperature under an atmosphere of argon (monitored by TLC). The solution was filtered through a layer of alkaline alumina by elution with $CHCl_3$. The combined eluates (ca. 200 mL) were dried, concentrated and the crude product was chromatographed (1 : 1 PE- EtOAc) to provide acceptor **17** as yellow foam.

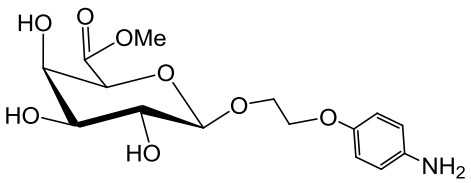
Yield: 592 mg (88%)

R_f: 0.15 (1 : 1 PE - EtOAc)

Anal. Calcd for $C_{22}H_{24}NO_{19}$ (446.43): C, 59.19; H, 5.42; N, 3.14. Found: C, 59.15; H, 5.35; N, 3.22.

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{29}H_{31}NO_{10}$ $[M+Na]^+$: 576.1840, found: 576.1846.

Methyl (2-(4-aminophenoxy)ethyl β-D-galactopyranosid)uronate (18)



10% Palladium on charcoal (30 mg) was added to a solution of compound **14** (150 mg, 0.4 mmol) in mixture of methanol and EtOAc (4 : 1, v/v,10 mL). The reaction mixture was stirred at ambient temperature under an atmosphere of hydrogen. After 1 h (monitored by TLC) the reaction mixture was filtered over celite by elution with methanol, and combined organic solutions were concentrated. The residue was purified by column chromatography (6 : 1 EtOAc - MeOH) to provide compound **18** as orange powder.

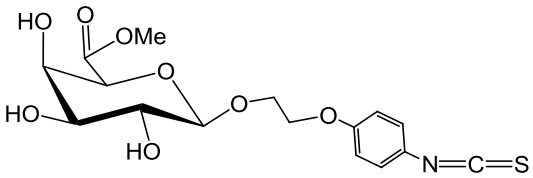
Yield: 125 mg (90%)

R_f: 0.26 (5 : 1 EtOAc - MeOH)

^{1}H NMR (300 MHz, DMSO): δ 6.67 (d, 2H, *J* 8.9 Hz, 2 × *o*-OPhNH_2), 6.51 (d, 2H, *J* 8.9 Hz, 2 × *m*-OPhNH_2), 5.01 (d, 1H, *J* 4.5 Hz, OH-2), 5.89 (d, 1H, *J* 5.1 Hz, OH-3), 4.85 (d, 1H, *J* 5.1 Hz, OH-4), 4.59 (bs, 2H, NH_2), 4.24 (s, 1H, H-5), 4.23 (d, 1H, $^3J_{1,2}$ 4.5 Hz, H-1), 4.05-3.95 (m, 3H, C*H*$_2$CH_2O, CH_2C*H*$_2$O), 3.91 (m, 1H, H-4), 3.75 (m, 1H, C*H*$_2$CH_2O), 3.65 (s, 3H, OCH_3), 3.44-3.28 (m, 2H, H-2, H-3); **^{13}C NMR (125.8 MHz, DMSO):** δ 168.9 (*C*OOCH_3), 149.7 (C-9), 142.5 (C-12), 115.4 (C-10, C-10´), 114.9 (C-11, C-11´), 103.3 (C-1), 73.9 (C-5), 72.6 (C-3), 69.9 (C-4), 69.8 (C-2), 67.6 (*C*H_2CH_2O), 67.5 (CH_2*C*H_2O), 51.6 (*C*H_3O).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{15}H_{21}NO_8$ $[M+H]^+$: 344.1340, found: 344.1342. calcd for $C_{15}H_{21}NO_8$ $[M+Na]^+$: 366.1160, found: 366.1163.

Methyl (2-(4-isothiocyanphenoxy)ethyl β-D-galactopyranosid)uronate (19)



Thiophosgen (1 ml, 5.8 mmol) was added to a solution of compound **18** (650 mg, 1.9 mmol) and $BaCO_3$ (100~200 mg, pH~8) in mixture of ethanol and water (4 : 1, v/v, 100 ml), and the

reaction mixture was stirred at ambient temperature. After 1 h (monitored by TLC) the reaction mixture was filtered over celite by elution with methanol. After concentration the residue was purified by column chromatography (6 : 1 EtOAc - MeOH) to provide compound **19** as read powder.

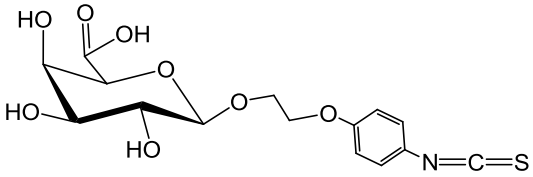
Yield: 560 mg (77%)

R_f: 0.45 (5 : 1 EtOAc - MeOH)

^{1}H NMR (300 MHz, DMSO): δ 7.41 (d, 2H, *J* 9.0 Hz, *m*-OPhNCS), 7.06 (d, 2H, *J* 8.9 Hz, *o*-OPhNCS), 5.54 (d, 1H, *J* 4.7 Hz, OH-2), 4.92 (d, 1H, *J* 5.1 Hz, OH-3), 4.89 (d, 1H, *J* 5.1 Hz, OH-4), 4.30 (d, 1H, $^3J_{1,2}$ 4.3 Hz, H-1), 4.28 (s, 1H, H-5), 4.22 (m, 2H, H-4, CH_2CH$_2$O), 4.09 (m, 1H, CH_2CH$_2$O), 3.98-3.93 (m, 1H, CH$_2$CH_2O), 3.91-3.80 (m, 1H, H- CH$_2$CH_2O), 3.68 (s, 3H, OCH$_3$), 3.44-3.29 (m, 1H, H-2), 3.39-3.33 (m, 1H, H-3); **^{13}C NMR (125.8 MHz, DMSO):** δ 168.9 (*C*OOCH$_3$), 157.8 (*p*-OPhNCS), 132.0 (*i*-OPhNCS), 127.3 (C-11, C-11´), 122.2 (C-13), 115.6 (C-10, C-10´), 103.3 (C-1), 73.9 (C-5), 72.5 (C-3), 69.8 (C-4), 69.7 (C-2), 67.7 (*C*H$_2$CH$_2$O), 67.2 (CH$_2$*C*H$_2$O), 51.5 (O*C*H$_3$).

Anal. Calcd for $C_{16}H_{19}NO_8S$ (385.39): C, 49.86; H, 4.97; N, 3.63, S, 8.32. Found: C, 49.80; H, 4.95; N, 3.68; S, 8.35.

2-(4-Isothiocyanphenoxy)ethyl β-D-galactopyranosiduronic acid (20)



Lithiumhydroxid (12 mg, 0.5 mmol) was added to a suspension of compound **19** (184 mg, 0.48 mmol) in a mixture of methanol and water (2 : 1, v/v, 40 ml). After stirring for 15 min at ambient temperature (monitored by TLC), the solution was passed through a column of Dowex-50 (H^+). Methanol was removed from solution by evaporation under reduced pressure and the residue was purified by column chromatography (1 : 1 $CHCl_3$ - MeOH) to provide compound **20** as read powder.

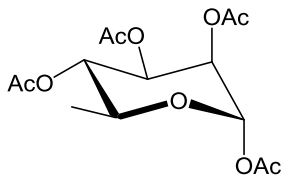
Yield: 63 mg (92%)

R_f: 0.3 (1 : 1 $CHCl_3$ - MeOH)

^{1}H NMR (300 MHz, DMSO-d_6): δ 7.40 (d, 2H, *J* 9.0 Hz, 2 × *m*-OPhNCS), 7.05 (d, 2H, *J* 8.9 Hz, 2 × *o*-OPhNCS), 5.54 (d, 1H, *J* 4.7 Hz, OH-2), 4.91 (d, 1H, *J* 5.1 Hz, OH-3), 4.89 (d, 1H, *J* 5.1 Hz, OH-4), 4.29 (d, 1H, $^{3}J_{1,2}$ 4.3 Hz, H-1), 4.27 (s, 1H, H-5), 4.22 (m, 2H, H-4, C*H*$_2$CH$_2$O), 4.09 (m, 1H, C*H*$_2$CH$_2$O), 3.98-3.93 (m, 1H, CH$_2$C*H*$_2$O), 3.91-3.80 (m, 1H, CH$_2$C*H*$_2$O), 3.44-3.29 (m, 1H, H-2), 3.39-3.33 (m, 1H, H-3); **^{13}C NMR (125.8 MHz, DMSO-d_6):** δ 172.0 (COOH), 157.8 (*p*-OPhNCS), 132.0 (*i*-OPhNCS), 127.3 (*m*-OPhNCS), 122.2 (NCS), 115.6 (*o*-OPhNCS), 103.3 (C-1), 73.9 (C-5), 72.5 (C-3), 69.8 (C-4), 69.7 (C-2), 67.7 (*C*H$_2$CH$_2$O), 67.2 (CH$_2$*C*H$_2$O).

Anal. Calcd for $C_{15}H_{17}NO_8S$ (371.36): C, 48.51; H, 4.61; N, 3.77, S, 8.63. Found: C, 48.49; H, 4.58; N, 3.78; S, 8.8.65.

1,2,3,4-Tetra-*O*-acetyl-α-L-rhamnose (21)[68]

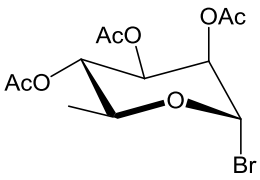


Perchloric acid (0.4 mL, 60%) was added to a fresh distilled acetic anhydride (36 mL) at 0 ^{o}C. After stirring for 30 min L-rhamnose monohydrate (5.0 g, 27.5 mmol) was added in portions (0.5 g, 2.75 mmol) to solution at that temperature, the cooling bath was removed and stirring was continued at ambient temperature. After 1.5 h (monitored by TLC) the reaction mixture was cooled to 0 ^{o}C and poured into ice-water (200 mL). The aqueous layer was extracted with chloroform (3 × 30 mL). The combined organic solutions were washed with ice-water (3 × 20 mL), sat aq $NHCO_3$ (3 × 30 mL), ice-water (2 × 30 mL), dried and concentrated. Drying under high vacuum gave compound **21** as a colourless syrup.

Yield: 8.96 g (98%)

R_f: 0.3 (3 : 1 PE - EtOAc)

2,3,4-Tri-*O*-acetyl-α-L-rhamnopyranosyl bromide (22)[68]



General procedure:

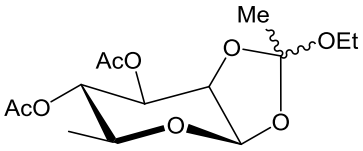
Water (33 mL) was added dropweise to a mixture of acetyl bromide (136 mL) and glacial acetic acid (100 mL) at –8 ^{o}C. At the end acetic anhydride (4 mL) was added to the solution. The resulting viscous mixture, which contains 40% (w/w) of hydrogen bromide and 1% (w/w) of acetic anhydride, can be safely kept in a refrigirator.

Foregoing solution (40 mL) was added to a solution of compound **21** (9.02 g, 28.0 mmol) in dry chloroform (50 mL) at 0 ^{o}C. The cooling-bath was then removed and the reaction mixture was stirred at ambient temperature. After 40 min (monitored by TLC) the reaction mixture was diluted with chloroform (20 mL), poured into ice-water (100 mL) and after 5 min organic layer was separated. The aqueous layer was extracted with chloroform (3 × 15 mL). The combined organic solutions were washed with ice-water (2 × 20 mL), sat aq $NHCO_3$ (3 × 30 mL), ice-water (2 × 10 mL), dried and concentrated. The residue was dried under high vacuum to give compound **22** as a yellow syrup. Bromide **22** was used for the next step directly without further purification.

Yield: 9.45 g (96%)

R_f: 0.45 (3 : 1 PE - EtOAc)

3,4-Di-*O*-acetyl-1,2-*O*-(1-*exo*-ethoxyethyliden)-β-L-rhamnopyranose (23)[68]



Bromide **22** (5.0 g, 14.1 mmol) and molecular sieves (4Å, 0.5 g) were stirred in dry dichlormethane (50 mL) for 20 min at ambient temperature in darkness. Dry ethanol (1.8 mL, 20.6 mmol), *sym*-collidine (2.5 mL, 19.1 mmol) and tetrabutylammonium bromide (2 g, 6.2 mmol) were added to the mixture. After stirring for 9 h (monitored by TLC) at ambient

temperature under an atmosphere of argon, the precipitated *sym*-collidine hydrobromide was filtered off and the filtrate was passed through a layer of silica gel. The solution was diluted with chloroform (50 mL) and heptane (150 mL), washed with ice-water (3 × 30 mL), dried end concentrated. The purification of the residue by column chromatography (2 : 1 PE - EtOAc with 1% Et_3N) gave compound **23** as a colourless syrup. Analytical sample was crystallized from diethyl ether to provide stereo structure.

Yield: 4.26 g (95%)

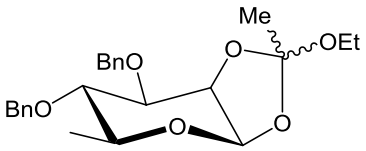
M.p.: 87 - 88 ^{o}C (from diethyl ether)

R_f: 0.3 (2 : 1 PE - EtOAc)

$[\alpha]_D^{23}$: +33.2 (*c* 1.0, $CHCl_3$)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 5.39 (d, 1H, $^3J_{1,2}$ 2.4 Hz, H-1), 5.06 (m, 2H, ^3J Hz, H-4, CH_2CH_3), 4.57 (dd, 1H, $^3J_{2,3}$ 3.6 Hz, $^3J_{1,2}$ 2.4 Hz, H-2), 3.54 (m, 2H, $^3J_{3,4}$ 9.1 Hz, $^3J_{2,3}$ 4.1 Hz, H-3, CH_2CH_3), 3.49 (m, 1H, $^3J_{4,5}$ 9.1 Hz, $^3J_{5,6}$ 6.0 Hz, H-5), 2.10 (s, 3H, CH_3CO), 2.05 (s, 3H, CH_3CO), 1.72 (s, 3H, CH_3), 1.22 (d, 3H, $^3J_{5,6}$ 6.0 Hz, H-6), 1.16 (t, 3H, ^3J 7.0 Hz, CH_2CH_3); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 170.5 (CH_3CO), 169.7 (CH_3CO), 124.8 (COC_2H_5), 97.2 (C1), 76.6 (C-2), 70.8 (C-3), 73.0 (C-4), 69.1 (C-5), 58.0 (CH_2CH_3), 24.9 (CH_3), 20.8 (CH_3CO), 20.7 (CH_3CO), 17.5 (C-6) 15.3 (CH_2CH_3).

2,3-Di-*O*-benzyl-1,2-*O*-(1-*exo*-ethoxyethyliden)-β-L-rhamnopyranose (25)[68]



Powdered potassium hydroxide (10.0 g, 178.6 mmol) was added to a solution of compound **23** (4.3 g, 13.5 mmol) in dry toluene (30 mL) and the mixture was heated under reflux. After 20 min benzyl chloride (15 mL, 130.3 mmol) was added dropwise. The reaction mixture was heated under reflux for 2.5 h (monitored by TLC), cooled to room temperature and diluted with toluene (30 mL). The salts were filtered off and washed with toluene (3 × 5 mL). The combined organic solutions were washed with ice-water (5 × 10 mL), dried and concentrated. The crude product was purified by column chromatography (4 : 1 PE - EtOAc with 1% Et_3N) to give colourless crystalline compound **25**.

Yield: 4.94 g (88%)

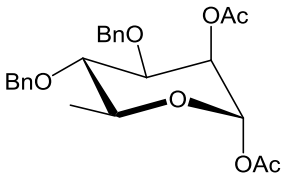
M.p.: 76 - 78 ^{o}C (from Hept - EtOAc, similar to litr.)

R_f: 0.6 (2 : 1 PE - EtOAc)

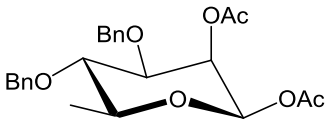
[α] $^{23}_{D}$**:** +3.3 (*c* 1.0, $CHCl_3$)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 7.42–7.30 (m, 10H, 2 × Ph), 5.27 (d, 1H, $^{3}J_{1,2}$ 2.3 Hz, H-1), 4.97 (d, ^{2}J 10.8 Hz, CH_2Ph), 4.78 (s, 2H, 2 × CH_2Ph), 4.68 (d, ^{2}J 10.8 Hz, CH_2Ph), 4.38 (dd, 1H, $^{3}J_{2,3}$ 4.1 Hz, $^{3}J_{1,2}$ 2.3 Hz, H-2), 3.69 (dd, 1H, $^{3}J_{3,4}$ 9.1 Hz, $^{3}J_{2,3}$ 4.1 Hz, H-3), 3.56 (m, 2H, ^{3}J 7.0 Hz, CH_2CH_3), 3.49 (t, 1H, $^{3}J_{3,4}$ 9.1 Hz, H-4), 3.33 (m, 1H, $^{3}J_{4,5}$ 9.1 Hz, $^{3}J_{5,6}$ 6.0 Hz, H-5), 1.73 (s, 3H, CH_3), 1.35 (d, 3H, $^{3}J_{5,6}$ 6.0 Hz, H-6), 1.22 (t, 3H, ^{3}J 7.0 Hz, CH_2CH_3); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 138.3 (*i*-Ph), 137.9 (*i*-Ph), 128.5, 128.4, 128.1, 128.0, 127.9, 127.8 (*m*-Ph, *p*-Ph, *o*-Ph), 123.6 (COC_2H_5), 97.3 (C-1), 79.5 (C-4), 79.0 (C-3), 77.0 (C-2), 75.5 (CH_2Ph), 72.3 (CH_2Ph), 70.0 (C-5), 58.0 (CH_2CH_3), 24.7 (CH_3), 17.9 (C-6) 15.2 (CH_2CH_3).

1,2-Di-*O*-acetyl-3,4-di-*O*-benzyl-α/β-L-rhamnopyranose (26)



α



β

Compound **25** (8.8 g, 21.2 mmol) was hydrolyzed by treatment with 70% aqueous acetic acid (60 mL) for 7 min at ambient temperature. The solution was concentrated and acetic acid was removed by co-evaporation with toluene (5 × 20 mL). Without further purification, the crude syrupy residue was dissolved in dry pyridine (220 mL). Acetic anhydride was added to the solution at 0 ^{o}C, cooling-bath was then removed and the reaction mixture was stirred at ambient temperature. After 1 h (monitored by TLC) the mixture was poured into ice-water and the aqueous layer was extracted with chloroform (3 × 100 mL). The combined organic solutions were washed with aq 1% HCl (3 × 50 mL), ice-water (3 × 30 mL), sat aq $NHCO_3$ (3 × 50 mL), ice-water (3 × 30 mL), dried and concentrated. The syrupy residue was purified by flash chromatography (3 : 1 PE - EtOAc) to give compound **26α** as a colourless solid and **26β** as a colourless syrup.

1,2-di-O-Acetyl-3,4-di-O-Benzyl-β-L-Rhamnopyranose colourless syrup.

Yield: 5α 6.28 g (69%) and **5β** 1.27 g (14%)

R_f : 0.5 (**5α);** 0.47 (**5β)** (2 : 1 PE - EtOAc)

(5α) **^{1}H NMR (500.13 MHz, $CDCl_3$):** δ 7.38–7.30 (m, 10H, 2×Ph), 6.02 (d, 1H, $^3J_{1,2}$ 2.0 Hz, H-1), 5.37 (dd, 1H, $^3J_{2,3}$ 3.4 Hz, $^3J_{1,2}$ 2.0 Hz, H-2), 4.94 (d, ^2J 10.7 Hz, CH_2Ph), 4.74 (d, ^2J 11.1 Hz, CH_2Ph), 4.64 (d, ^2J 10.7 Hz, CH_2Ph), 4.56 (d, ^2J 11.1 Hz, CH_2Ph), 3.94 (dd, 1H, $^3J_{3,4}$ 9.2 Hz, $^3J_{2,3}$ 3.4 Hz, H-3), 3.85–3.80 (m, 1H, H-5), 3.49 (t, 1H, $^3J_{3,4}$ 9.2 Hz, H-4), 2.18 (s, 3H, CH_3CO), 2.09 (s, 3H, CH_3CO), 1.35 (d, 3H, H-6).

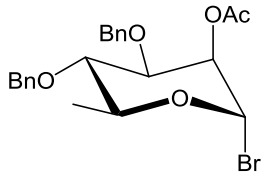
^{13}C NMR (125.8 MHz, $CDCl_3$): δ 170.0 (CH_3CO), 168.5 (CH_3CO), 138.2 (*i*-Ph), 137.7 (*i*-Ph), 128.4, 128.1, 128.0, 127.8, 127.8 (*m*-Ph, *p*-Ph, *o*-Ph), 91.1 (C-1), 79.5 (C-4), 77.57 (C-3), 75.59 (CH_2Ph), 71.88 (CH_2Ph), 69.99 (C-5), 67.76 (C-2), 20.93 (CH_3CO), 20.87 (CH_3CO), 17.98 (C6).

(5β) **^{1}H NMR (500.13 MHz, $CDCl_3$):** δ 7.37–7.30 (m, 10H, Ph), 5.74 (d, 1H, $^3J_{1,2}$ 1.0 Hz, H-1), 5.62 (dd, 1H, $^3J_{2,3}$ 3.4 Hz, $^3J_{1,2}$ 1.0 Hz, H-2), 4.94 (d, ^2J 10.8 Hz, CH_2Ph), 4.73 (d, ^2J 11.2 Hz, CH_2Ph), 4.64 (d, ^2J 10.8 Hz, CH_2Ph), 4.52 (d, ^2J 11.2 Hz, CH_2Ph), 3.71 (dd, 1H, $^3J_{3,4}$ 9.2 Hz, $^3J_{2,3}$ 3.4 Hz, H-3), 3.56–3.51 (m, 1H, $^3J_{4,5}$ 9.5 Hz, H-5), 3.49 (t, 1H, $^3J_{4,5}$ 9.5 Hz, $^3J_{3,4}$ 9.2 Hz, H-4), 2.23 (s, 3H, CH_3CO), 2.11 (s, 3H, CH_3CO), 1.39 (d, 3H, H-6).

^{13}C NMR (125.8 MHz, $CDCl_3$): δ 170.5 (CH_3CO), 168.7 (CH_3CO), 138.1 (*i*-Ph), 137.4 (*i*-Ph), 128.5, 128.4, 128.1, 128,0, 127.9, 127.8 (*m*-Ph, *p*-Ph, *o*-Ph), 91.1 (C-1), 79.7 (C-3), 79.2 (C-4), 75.5 (CH_2Ph), 72,7 (C-5), 71.6(CH_2Ph), 67.6 (C-2), 21.0 (CH_3CO), 20.8 (CH_3CO), 17.9 (C6).

Anal. Calcd for $C_{24}H_{28}O_7$ (428.47): C, 67.28; H, 6.59. Found: C, 67.29; H, 6.57.

2-*O*-Acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl bromide (27)



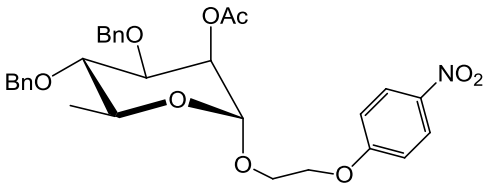
Oxalyl bromide (1.2 mL, 8.4 mmol) was added to solution of a compound **26** (1 g, 2.3 mmol) in dry dichloromethane (15 mL) under an atmosphere of argon at –40 °C. After stirring for 1 h

at that temperature, the cooling-bath was removed and stirring was continued for 4 h at ambient temperature (monitored by TLC). The mixture was concentrated and co-evaporated with toluene (3 × 5 mL). The residue was dried under high vacuum to give compound **27** as light-yellow syrup. Bromide **27** was used directly without further purification.

Yeld: 995 mg (~96%)

R_f : 0.55 (2 : 1 PE - EtOAc)

2(-4-Nitrophenoxy)ethyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranoside (28)



2-(4-Nitrophenoxy)ethanol (320 mg, 1.75 mmol) compound **27** (0.6 g, 1.33 mmol) and molecular sieves (4Å, 0.3 g) were dried for 2 h under high vacuum in darkness. The mixture was dissolved in dry acetonitrile (6 mL) and stirred at ambient temperature under an atmosphere of argon. After 20 min $Hg(CN)_2$ (0.2 g, 0.8 mmol), $HgBr_2$ (0.05 g, 0.15 mmol) were added and stirring was continued at ambient temperature. After 24 h (monitored by TLC) the mixture was diluted with chloroform (10 mL) and filtered over celite. The filtrate was extracted with ice-water (2 × 5 mL), aq 10% KI (3 × 5 mL), ice-water (2 × 5 mL), dried and concentrated. Purification of the residue by column chromatography (3 : 1 PE - EtOAc) gave compound **28** as a yellow syrup.

Yield: 704 mg (96%)

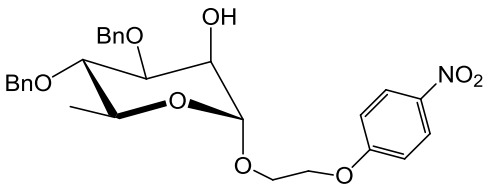
R_f: 0.4 (2 : 1 PE - EtOAc)

^{1}H NMR (300 MHz, $CDCl_3$): δ 8.17 (d, 2H, *m*-$OPhNO_2$), 7.30–7.23 (m, 10H, Ph), 6.94 (d, 2H, *o*-$OPhNO_2$), 5.38 (dd, 1H, $^3J_{2,3}$ 3.4 Hz, H-2), 4.89 (d, 1H, ^2J 10.9 Hz, CH_2Ph), 4.81 (d, 1H, $^3J_{1,2}$ 1.7 Hz, H-1), 4.66 (d, 1H, ^2J 11.2 Hz, CH_2Ph), 4.59 (d, 1H, ^2J 10.9 Hz, CH_2Ph), 4.49 (d, 1H, ^2J 11.2 Hz, CH_2Ph), 4.17 (t, 2H, CH_2CH_2O), 3.99 (m, 1H, CH_2CH_2O), 3.90 (dd, 1H, $^3J_{2,3}$ 3.4 Hz, H-3), 3.83 (m, 1H, CH_2CH_2O), 3.79 (m, 1H, H-5), 3.44 (t, 1H, $^3J_{4,5}$ 9.5 Hz, H-4), 2.14 (s, 3H, CH_3CO), 1.31 (d, 3H, H-6); **^{13}C NMR (75.5 MHz, $CDC1_3$):** δ 170.3 (CH_3CO), 163.6 (*p*-$OPhNO_2$), 141.7 (*i*-$OPhNO_2$), 138.3, 137.9 (*i*-Ph), 128.3–127.7 (*o-Ph,m-*

Ph,p-Ph), 125.9 (*m*-$OPhNO_2$), 114.5 (*o*-$OPhNO_2$), 97.9 (C-1), 79.8 (C-4), 77.8 (C-3), 75.4(*C*H_2Ph), 71.7 (*C*H_2Ph), 68.7 (C-2), 67.9 (C-5), 67.5 (CH_2*C*H_2O), 65.6 (*C*H_2CH_2O), 21.0 (*C*H_3CO), 17.9 (C-6).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{30}H_{34}NO_9$ $[M+H]^+$: 552.2228, found: 552.2223; calcd for $C_{30}H_{34}NO_9$ $[M+Na]^+$: 574.2048, found: 574.2064.

2-(4-Nitrophenoxy)ethyl 3,4-di-*O*-benzyl-α-L-rhamnopyranoside (29)



Compound **28** (600 mg, 1.09 mmol was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (1.1 mL) in ice-cold dry methanol (50 mL)] and the mixture was stirred at ambient temperature under an atmosphere of argon. After 24 h (monitored by TLC) $PbCO_3 \times Pb(OH)_2$ (5 g) was added to the reaction mixture and stirring was continued for additional 2 h at ambient temperature. Salts were filtered off by using glass sintered filter funnel with a layer of silica gel, washed with methanol (3 × 10 mL) and the combined organic solutions were concentrated. Purification of the residue by column chromatography (2 : 1 PE - EtOAc) gave compound **29** as a yellow syrup.

Yield: 530 mg (95%)

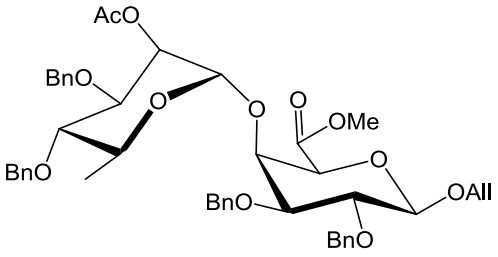
R_f: 0.2 (2 : 1 PE - EtOAc)

^{1}H NMR (300 MHz, $CDCl_3$): δ 8.21 (d, 2H, *m*-$OPhNO_2$), 7.37–7.31 (m, 10H, Ph), 6.98 (d, 2H, *o*-$OPhNO_2$), 4.92 (d, 1H, ^3J , 1.6 Hz, H-1), 4.70 (bs, 2H, H-2, C*H*$_2$Ph) 4.65 (d, 1H, ^2J 10.9 Hz, C*H*$_2$Ph), 4.21 (t, 2H, CH_2C*H*$_2$O), 4.07(dd, 1H, H-3), 4.02 (m, 1H, C*H*$_2CH_2O$), 3.89–3.81 (m, 2H, C*H*$_2CH_2O$, C*H*$_2$Ph),3.77 (m, 1H, $^3J_{4,5}$ 9.4 Hz, H-5), 3.48 (t, 1H, $^3J_{4,5}$ 9.4 Hz, H-4), 2.14 (s, 3H, CH_3CO), 1.31 (d, 3H, H-6); **^{13}C NMR (75.5 MHz, $CDC1_3$):** δ 163.7 (*p*-$OPhNO_2$), 141.7 (*i*-$OPhNO_2$), 138.2, 137.8 (*i*-Ph), 128.5, 128.4, 128.0, 127.8,127.7 (*o-Ph,m-Ph,p-Ph*), 125.9 (*m*-$OPhNO_2$), 114.5 (*o*-$OPhNO_2$), 99.3 (C-1), 79.9 (C-4), 79.7 (C-3),

75.4(CH_2Ph), 72.0 (CH_2Ph), 68.4 (C-2), 67.7 (CH_2CH_2O), 67.6 (C-5),65.5 (CH_2CH_2O), 17.9 (C-6).

Anal. Calcd for $C_{28}H_{31}NO_8$ (509.55): C, 66.00; H, 6.13; N, 2.75. Found: C, 66.03; H, 6.11; N, 2.74.

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (30)



Compound **27** (0.6 g, 1.3 mmol), compound **18** (0.43 g, 1.0 mmol) and molecular sieves (4Å, 0.4 g) were dried 2 h under high vacuum in darkness. The mixture was suspended in dry acetonitrile (15 mL) and stirred under an atmosphere of argon. After 20 min $Hg(CN)_2$ (0.2 g, 0.8 mmol) and $HgBr_2$ (0.05 g, 0.14 mmol) were added. The reaction mixture was continued to stirring under an atmosphere of argon. After 24 h the mixture was filtered over Celite and the filter was washed with chloroform (20 mL). Combined organic solution was extracted with ice-water (2 × 10 mL), aq 10% KI (3 × 10 mL) and ice-water (2 × 10 mL). The organic layer was then concentrated and the residue was purified by column chromatography (4 : 1 PE - EtOAc) to give compound **30** as colourless foam and corresponding β isomer in 20% yield.

Yield: 0.54 g (67%)

R_f: 0.43 (2 : 1 PE- EtOAc)

[α] $^{22}_{D}$ **:** +42.3 (*c* 1.0, $CHCl_3$)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 7.39–7.22 (m, 20H, Ph), 5.98 (dddd, 1H, *J* 17.3, 10.5, 6.2, 5.0 Hz, CH_2CH=CH_2), 5.55 (dd, 1H, $^3J_{2',3'}$ 3,3 Hz, $^3J_{1',2'}$ 1,9 Hz, H-2´), 5.37 (d'q', 1H, ^3J 17,3 Hz, ^2J 1.5 Hz, CH_2CH=CH_2), 5.23 (d'q', 1H, ^3J 10,5 Hz, ^2J 1.5 Hz, CH_2CH=CH_2), 5.22 (m, 1H, $^3J_{1',2'}$ 1,9 Hz, H-1´), 4.95 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.90 (d, 1H, ^2J 11.3 Hz, CH_2Ph), 4.80 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.78 (d, 1H, ^2J 11.8 Hz, CH_2Ph), 4.76 (d, 1H, ^2J 11.8 Hz, CH_2Ph), 4.69 (d, 1H, ^2J 10.9 Hz, CH_2Ph), 4.59 (d, 1H, ^2J 11.3 Hz, CH_2Ph), 4.52 (dd't', 1H, ^2J

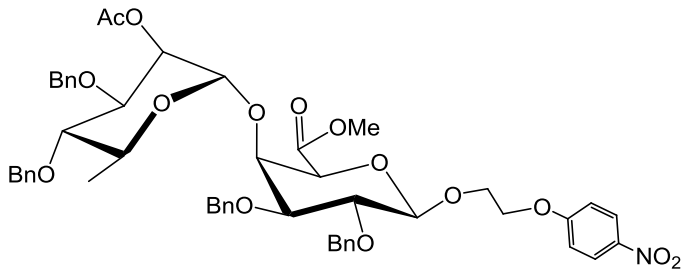
13.0 Hz, ^{3}J 5.0 Hz, ^{4}J 1.6 Hz, CH_2CH=CH_2), 4.48 (d, 1H, ^{2}J 10.9 Hz, CH_2Ph), 4.44 (dd, 1H, $^{3}J_{4,3}$ 3.0 Hz, $^{3}J_{4,5}$ 1.4 Hz, H-4), 4.41 (d, 1H, $^{3}J_{1,2}$ 7.8 Hz, H-1), 4.17 (dd't', 1H, ^{2}J 13.0 Hz, ^{3}J 6.2 Hz, ^{4}J 1.4 Hz, CH_2CH=CH_2), 4.04 (d, 1H, $^{3}J_{4,5}$ 1.4 Hz, H-5), 3.93 (dd, 1H, $^{3}J_{3',4'}$ 9.5 Hz, $^{3}J_{2',3'}$ 3.3 Hz, H-3´), 3.79 (s, 3H, OCH_3), 3.78 (dd, 1H, $^{3}J_{2,3}$ 9.7, $^{3}J_{1,2}$ 7.8 Hz, Hz, H-2), 3.65 (dq, 1H, $^{3}J_{4',5'}$ 9.5 Hz, $^{3}J_{5',6'}$ 6.2 Hz, H-5´), 3.56 (dd, 1H, $^{3}J_{2,3}$ 9.7 Hz, $^{3}J_{3,4}$ 3.0 Hz, H-3), 3.36 ('t', 1H, $^{3}J_{3',4'}$ = $^{3}J_{4',5'}$ 9.5 Hz, H-4´), 2.08 (s, 3H, CH_3CO), 1.29 (d, 3H, $^{3}J_{5',6'}$ 6.2 Hz, H-6´); **^{13}C NMR (125.8 MHz, CDCl$_3$):** δ 169.8 (CH$_3$*C*O), 168.0 (COO), 138.9, 138.4, 138.2, 137.9 (*i*-Ph), 133.9 (CH$_2$*C*H=CH$_2$), 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 127.6, 127.5 (*o-Ph*,*m-Ph*), 127.6,127.6, 127.5, 127.4 (*p-Ph*), 117.5 (CH$_2$CH=*C*H$_2$), 102.7 (C-1), 99.1 (C-1´), 80.8 (C-3), 79.7 (C-4´), 78.2 (C-2), 77.9 (C-3´), 75.1 (*C*H$_2$Ph), 74.8 (*C*H$_2$Ph), 73.7 (C-4), 73.7 (C-5), 73.1 (*C*H$_2$Ph), 71.8 (*C*H$_2$Ph), 70.6 (*C*H$_2$CH=CH$_2$), 68.8 (C-2´), 68.2 (C-5´), 52.4 (O*C*H$_3$), 21.0 (*C*H$_3$CO), 17.9 (C-6´).

β-isomer

^{1}H NMR (500.13 MHz, CDCl$_3$): δ 7.46–7.43 (m, 2H), 7.38–7.27 (m, 18H), (4 × Ph), 5.98 (dddd, 1H, *J* 17.3, 10.5, 6.1, 5.0 Hz, CH$_2$C*H*=CH$_2$), 5.58 (dd, 1H, $^{3}J_{2',3'}$ 3,3 Hz, $^{3}J_{1',2'}$ 1.0 Hz, H-2´), 5.36 (d'q', 1H, ^{3}J 17.3 Hz, , ^{2}J 1.6 Hz, CH$_2$CH=C*H*$_2$), 5.21 (d'q', 1H, ^{3}J 10.5 Hz, , ^{2}J 1.6 Hz, CH$_2$CH=C*H*$_2$), 4.94 (d, 1H, ^{2}J 10.9 Hz, C*H*$_2$Ph), 4.88 (d, 1H, ^{2}J 11.0 Hz, C*H*$_2$Ph), 4.85 (d, 1H, ^{2}J 11.6 Hz, C*H*$_2$Ph), 4.77 (d, 1H, ^{2}J 11.3 Hz, C*H*$_2$Ph), 4.76 (d, 1H, ^{2}J 11.0 Hz, C*H*$_2$Ph), 4.73 (dd, 1H, $^{3}J_{3,4}$ 3.2 Hz, $^{3}J_{4,5}$ 1.1 Hz, H-4), 4.63 (d, 1H, ^{2}J 10.9 Hz, C*H*$_2$Ph), 4.60 (d, 1H, $^{3}J_{1',2'}$ 1.0 Hz, H-1´), 4.59 (d, 1H, ^{2}J 11.5 Hz, C*H*$_2$Ph), 4.49 (dd't', 1H, ^{2}J 13.0 Hz, , ^{3}J 5.0 Hz, ^{4}J 1.6 Hz, C*H*$_2$CH=CH$_2$), 4.49 (d, 1H, ^{2}J 11.2 Hz, C*H*$_2$Ph), 4.41 (d, 1H, $^{3}J_{1,2}$ 7.7 Hz, H-1), 4.17 (dd't', 1H, ^{2}J 13.0 Hz, , ^{3}J 6.1 Hz, ^{4}J 1.4 Hz, C*H*$_2$CH=CH$_2$), 3.98 (d, 1H, $^{3}J_{4,5}$ 1.1 Hz, H-5), 3.82 (s, 3H, OCH_3), 3.75 (dd, 1H, $^{3}J_{1,2}$ 7.7 Hz, $^{3}J_{2,3}$ 9.7 Hz, H-2), 3.58 (dd, 1H, $^{3}J_{3',4'}$ 9.2 Hz, $^{3}J_{2',3'}$ 3.3 Hz, H-3´), 3.50 (dd, 1H, $^{3}J_{2,3}$ 9.7 Hz, $^{3}J_{3,4}$ 3.2 Hz, H-3), 3.46 ('t', 1H, $^{3}J_{4',5'}$ 9.3 Hz, $^{3}J_{3',4'}$ 9.2 Hz, H-4´), 3.32 (dq, 1H, $^{3}J_{4',5'}$ 9.3 Hz, $^{3}J_{5',6'}$ 6.2 Hz, H-5´), 2.03 (s, 3H, CH_3CO), 1.36 (d, 3H, $^{3}J_{5',6'}$ 6.2 Hz, H-6´); **^{13}C NMR (125.8 MHz, CDCl$_3$):** δ 170.4 (CH$_3$*C*O), 168.9 (COO), 138.7, 138.4, 138.4, 137.6 (*i*-Ph), 134.1 (CH$_2$*C*H=CH$_2$), 128.3, 128.3, 128.2,128.1,128.1,127.9,127.8 (*o-Ph*,*m-Ph*), 127.7, 127.7, 127.4, 127.4 (*p-Ph*), 117.1 (CH$_2$CH=*C*H$_2$), 102.6 (C-1), 97.8 (C-1´), 80.0 (C-3´), 79.7 (C-4´), 79.6 (C-3), 78.1(C-2), 75.3 (*C*H$_2$Ph), 75.2 (*C*H$_2$Ph), 73.1 (C-5), 71.9 (C-5´), 71.7 (C-4), 71.4 (*C*H$_2$Ph), 71.2 (*C*H$_2$Ph), 70.2 (*C*H$_2$CH=CH$_2$), 68.0 (C-2´), 52.4 (O*C*H$_3$), 20.9 (*C*H$_3$CO), 17.8 (C-6´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{46}H_{52}O_{12}$ $[M+Na]^+$: 819.3351, found: 819.3355.

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(2-(4-nitrophenoxy)ethyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (31)



Compound **27** (500 mg, 1.1 mmol), compound **17** (450 g, 0.8 mmol) and molecular sieves (4Å, 600 mg) were dried 2 h under high vacuum in darkness. The mixture was suspended in dry acetonitrile (15 mL) and stirred under an atmosphere of argon. After 20 min $Hg(CN)_2$ (300 mg, 1.2 mmol) and $HgBr_2$ (100 g, 0.28 mmol) were added and stirring was continued. After 30 h the mixture was filtered over Celite by elution with $CHCl_3$ (20 mL). Combined organic solution was extracted with ice-water (2 × 10 mL), aq 10% KI (3 × 10 mL) and ice-water (2 × 10 mL). The organic layer was dried, then concentrated and the residue was purified by column chromatography (2 : 1 PE - EtOAc) to give compound **31** as colourless foam and corresponding β isomer as yellow syrup in 15% yield.

Yield: 502 mg (68%)

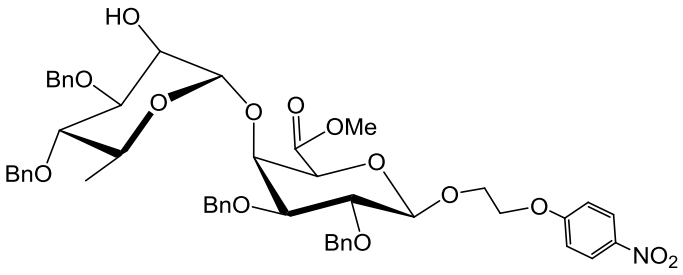
R_f: 0.33 (1 : 1 PE- EtOAc)

^{1}H NMR (300 MHz, $CDCl_3$): δ 8.17 (d, 2H, *m*-$OPhNO_2$), 7.33–7.19 (m, 20H, Ph), 6.93 (d, 2H, *o*-$OPhNO_2$), 5.54 (m, 1H, $^3J_{1',2'}$ 1.8 Hz, $^3J_{2',3'}$ 3,2 Hz, H-2´), 5.17 (d, 1H, $^3J_{1',2'}$ 1.6 Hz, H-1´), 4.88 (m, 2H, 2 × CH_2Ph), 4.76 (d, 2H, 2 × CH_2Ph), 4.67 (m, 1H, ^2J 11.0 Hz 2 × CH_2Ph), 4.57 (m, 1H, ^2J 11.0 Hz, CH_2Ph), 4.48 (d, 1H, CH_2Ph), 4.44 (m, 1H,H-1), 4.43 (dd, 1H, $^3J_{3,4}$ 2.8 Hz, H-4), 4.37-4.30 (m, 2H, C*H*$_2$$CH_2O$), 4.24 (m, 1H, CH_2C*H*$_2$O), 4.06 (d, 1H, ^3J 1.0 Hz, H-5), 3.99 (m, 1H, C*H*$_2$$CH_2O$), 3.90 (dd, 1H, $^3J_{2',3'}$ 3.4, $^3J_{3,4}$ 9.5 Hz, H-3´), 3.77 (s, 3H, OCH_3), 3.72 (dd, 1H, $^3J_{1,2}$ 7.6 Hz, $^3J_{2,3}$ 9.6 Hz, H-2), 3.65 (m, 1H, $^3J_{4''',5'''}$ 9.9 Hz, H-5´), 3.57 (dd, 1H, $^3J_{3,4}$ 2.8 Hz, $^3J_{2,3}$ 9.6 Hz, H-3), 3.36 (t, 1H, $^3J_{4',5'}$ 9.9 Hz, H-4´), 2.08 (s, 3H, CH_3CO), 1.29 (d, 3H, H-6´); **^{13}C NMR (62.9 MHz, $CDCl_3$):** δ 169.9 (CH_3*C*O), 167.8 (COO), 163.7 (*p*-$OPhNO_2$), 141.6 (*i*-$OPhNO_2$), 138.7, 138.2, 138.1, 137.7, (*i*-Ph), 129.0, 128.4,128.3, 128.2, 128.1, 128.0, 127.7, 127.7, 127.6, 127.4 (*o-Ph,m-Ph,p-Ph*), 125.9 (*m*-$OPhNO_2$), 114.5 (*o*-$OPhNO_2$), 104.0 (C-1) , 99.3 (C-1´), 80.4 (C-3), 79.7 (C-4´), 78.0 (C-2), 77.8 (C-3´), 75.0

(*C*H_2Ph), 74.9 (*C*H_2Ph), 73.9 (C-4), 73.6 (C-5), 73.0 (*C*H_2Ph), 71.8 (*C*H_2Ph), 68.8 (C-2´), 68.3 (C-5´), 68.1 (CH_2*C*H_2O), 67.8 (*C*$H_2$$CH_2$O), 52.5 (O*C*$H_3$), 21.1 (*C*$H_3$CO), 18.0 (C-6´).

Anal. Calcd for $C_{44}H_{48}NO_{14}$ (814.85): C, 64.85; H, 5.94; N, 1.72. Found: C, 64.88; H, 5.92; N, 1.71.

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(mthyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate Methyl 3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(2-(4-nitrophenoxy)ethyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (32)



Compound **31** (450 mg, 0.49 mmol) was added to stirred solution of methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (1 mL) to ice-cold dry methanol (50 mL)] and the mixture was stirred for 24 h at ambient temperature under an atmosphere of argon (monitored by TLC). The solution was filtered through a layer of alkaline alumina by elution with $CHCl_3$. The combined eluates (ca. 200 mL) were dried, concentrated and the crude product was purified by column chromatography (1 : 1 PE - EtOAc) to provide acceptor **32** as colourless foam.

Yield: 680 mg (87%)

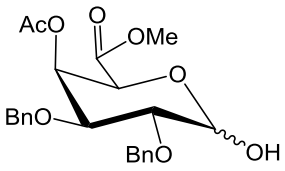
R_f: 0.27 (1 : 1 PE - EtOAc)

^{1}H NMR (300 MHz, $CDCl_3$): δ 8.17 (d, 2H, *m*-OPhNO_2), 7.33–7.17 (m, 20H, Ph), 6.92 (d, 2H, *o*-OPhNO_2), 5.17 (d, 1H, $^3J_{1´,2´}$ 1.7 Hz, H-1´), 4.88 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.86 (d, 1H, ^2J 11.3 Hz, CH_2Ph), 4.76 (d, 2H, 2 × CH_2Ph), 4.71 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.63 (m, 3H, ^2J 11.0 Hz 3 × CH_2Ph), 4.46 (m, 1H, , $^3J_{1,2}$ 7.6 Hz, H-1), 4.45 (dd, 1H, $^3J_{3,4}$ 2.8 Hz, H-4), 4.37-4.30 (m, 2H, C*H*$_2$$CH_2$O), 4.24 (m, 1H, CH_2C*H*$_2$O), 4.06 (d, 1H, ^3J 1.0 Hz, H-5), 4.00 (m, 1H, C*H*$_2$$CH_2$O), 3.83 (dd, 1H, $^3J_{2´,3´}$ 3.2, $^3J_{3,4}$ 9.5 Hz, H-3´), 3.79 (s, 3H, OCH_3), 3.71 (dd, 1H, $^3J_{1,2}$ 7.6 Hz, $^3J_{2,3}$ 9.6 Hz, H-2), 3.64 (m, 1H, $^3J_{4´,5´}$ 9.3 Hz, H-5´), 3.57 (dd, 1H, $^3J_{3,4}$ 2.8 Hz, $^3J_{2,3}$ 9.6 Hz, H-3), 3.42 (t, 1H, $^3J_{4´´´,5´´´}$ 9.3 Hz, H-4´), 2.36 (bs, 1H, OH), 1.28 (d, 3H, H-6´); **^{13}C**

NMR (125.8 MHz, $CDCl_3$): δ 167.8 (COO), 163.7 (*p*-$OPhNO_2$), 141.7 (*i*-$OPhNO_2$), 138.7, 138.3, 138.2, 137.6, (*i*-Ph), 129.0, 128.5,128.4, 128.2, 128.2, 127.9, 127.9, 127.8, 127.6, 127.4 (*o-Ph,m-Ph,p-Ph*), 125.9 (*m*-$OPhNO_2$), 114.5 (*o*-$OPhNO_2$), 104.0 (C-1) , 100.5 (C-1´), 80.4 (C-3), 79.7 (C-4´), 78.0 (C-2), 77.8 (C-3´), 75.0 (CH_2Ph), 74.9 (CH_2Ph), 73.9 (C-4), 73.6 (C-5), 73.0 (CH_2Ph), 71.8 (CH_2Ph), 68.8 (C-2´), 68.3 (C-5´), 68.1 (CH_2CH_2O), 67.8 (CH_2CH_2O), 52.2 (OCH_3), 17.9 (C-6´).

Anal. Calcd for $C_{42}H_{46}NO_{13}$ (772.81): C, 65.27; H, 6.00; N, 1.81. Found: C, 65.25; H, 5.99; N, 1.80.

Methyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-galactopyranuronate (33)



Methyl (allyl 4-*O*-acetyl-2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (470 mg, 1.0 mmol), palladium(II) chloride (180 mg, 1 mmol) and sodium acetate (656 mg, 8 mmol) were stirred in acetic acid (10 mL, 95%) for 3 h at 45 ^oC (monitored by TLC). The mixture was diluted with chloroform (20 mL), filtrated over celite, co-evaporated with toluene (3 × 10 mL) and concentrated. The residue was purified by column chromatography (1 : 1 PE - EtOAc) to give compound **33** as colourless syrup.

Yield: 323.4 mg (75%)

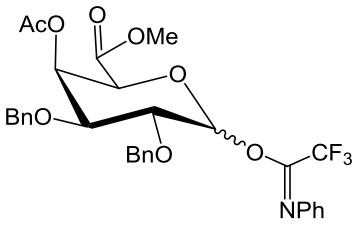
R_f: 0.2 (1 : 1 PE - EtOAc)

^{1}H NMR (500.13 MHz, $CDCl_3$, $\alpha:\beta$ = 4:1): δ 7.36–7.26 (m, 10H, Ph), 5.86 [dd, 1H, $^3J_{3,4}$ 3.5 Hz, $^3J_{4,5}$ 1.5 Hz, H-4(α)], 5.78 [dd, 1H, $^3J_{3,4}$ 3.2 Hz, $^3J_{4,5}$ 1.5 Hz, H-4(β)], 5.37 [d, 1H, $^3J_{1,2}$ 3.6 Hz, H-1(α)], 4.89 [d, 1H, ^2J 11.0 Hz, CH_2Ph(β)], 4.83 [d, 1H, ^2J 11.7 Hz, CH_2Ph(α)], 4.78 [d, 1H, ^2J 11.4 Hz, CH_2Ph(α)], 4.78 [d, 1H, ^2J 11.0 Hz, CH_2Ph(β)], 4.77 (d, 1H, ^2J 11.0 Hz, CH_2Ph(β)], 4.76 [d, 1H, $^3J_{4,5}$ 1.5 Hz, H-5(α)], 4.69 [d, 1H, $^3J_{1,2}$ 7.5 Hz, H-1(β)], 4.66 [d, 1H, ^2J 11.7 Hz, CH_2Ph(α)],4.57 [d, 1H, ^2J 11.4 Hz, CH_2Ph(α)], 4.54 [d, 1H, ^2J 11.0 Hz, CH_2Ph(β)],4.17 [d, 1H, $^3J_{4,5}$ 1.5 Hz, H-5(β)], 4.02 [dd, 1H, $^3J_{2,3}$ 9.8 Hz, $^3J_{3,4}$ 3.5 Hz, H-3(α)], 3.97 [br s, 1H, OH(β)], 3.83 [dd, 1H, $^3J_{2,3}$ 9.8 Hz, $^3J_{1,2}$ 3.6 Hz, H-2(α)], 3.76 [s, 3H,

$CH_3O(\beta)$], 3.74 [s, 3H, $CH_3O(\alpha)$], 3.64–3.57 [m, 2H, H-2(β), H-3(β)], 3.40 [br s, 1H, OH(α)], 2.10 [s, 3H, $CH_3CO(\beta)$], 2.08 [s, 3H, $CH_3CO(\alpha)$]. **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9, 168.3 [COO(α), $CH_3CO(\alpha)$], 169.9, 167.4 [COO(β), $CH_3CO(\beta)$], 138.3, 137.4 [*i*-Ph(β)], 137.9, 137.7 [*i*-Ph(α)], 128.4, 128.3, 128.0, 127.9 [*o*-Ph(α), *m*-Ph(α)], 128.3, 128.3, 128.0, 128.0 [*o*-Ph(β), *m*-Ph(β)], 127.9, 127.7 [*p*-Ph(α)], 127.8, 127.7 [*p*-Ph(β)], 97.4 [C-1(β)], 92.1 [C-1(α)], 79.2, 78.6 [C-2(β), C-3(β)], 75.2 [C-3(α)], 74.9 [C-2(α)], 73.8, 72.0 [CH_2Ph (α)], 72.5, 72.2 [CH_2Ph (β)], 68.5 [C-4(α)], 68.4 [C-5(α)], 67.6 [C-4(β)], 52.7 [$CH_3O(\beta)$], 52.5 [$CH_3O(\alpha)$], 20.7 [$CH_3CO(\alpha)$], 20.7 [$CH_3CO(\beta)$].

Anal. Calcd for $C_{23}H_{26}O_8$ (430.45): C, 64.18; H, 6.09. Found: C, 64.23; H, 6.04.

Methyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-galactopyranosyl uronat *N*-phenyl trifluoroacetimidate (42)[82]



Cs_2CO_3 (652 mg, 2.0 mmol) and 2,2,2-trifluoro-*N*-phenyl-acetimidoyl chloride (415 mg, 2.0 mmol) were consecutively added to compound **41** (430 mg, 1.0 mmol) in acetone (20 mL) at 0 ^oC. The cooling bath was removed, and reaction mixture was stirred at ambient temperature. After 3 h (monitored by TLC) reaction mixture was diluted with CH_2Cl_2 (20 mL). Salts were filtered off and washed with EtOAc (2 × 10 mL). The combined organic solutions were concentrated and the residue was purified by column chromatography (3 : 1 PE - EtOAc) to give compound **42** as a colourless amorphous.

Yield: 529 mg (88%)

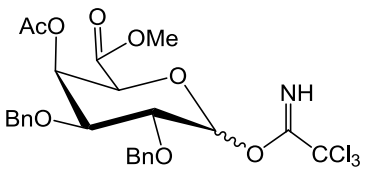
R_f: 0.59 (PE : EtOAc= 1 : 1)

^{1}H NMR (500.13 MHz, $CDCl_3$, α:β = 1:5): δ 7.36–7.24 (m, 12H, 2 Ph, *m*-NPh), 7.09 (m, 1H, *p*-NPh), 6.80 (d, 1H, *J* 7.9 Hz), 6.72 (d, 1H, *J* 7.9 Hz), (*o*-NPh), 5.91 [br s, 1H, H-4(α)], 5.79 [br s, 1H, H-4(β)], 5.68 (br, 1H, H-1), 4.81 [q_{AB}, 2H, ^2J 11.7 Hz, CH_2Ph(β)], 4.79 (d, 1H, ^2J 12.0 Hz), 4.73 [d, 1H, ^2J 12.0 Hz, CH_2Ph(α)], 4.79 (d, 1H, ^2J 11.3 Hz), 4.62 [d, 1H, ^2J 11.3

Hz, $CH_2Ph(\alpha)$], 4.79 (d, 1H, ^2J 11.3 Hz), 4.56 [d, 1H, ^2J 11.3 Hz, $CH_2Ph(\beta)$], 4.20 (br, 1H, H-5), 3.91 ('t', 1H, $^3J_{1,2} = {}^3J_{2,3}$ 8.5 Hz, H-2), 3.70 (br m, 1H, H-3), 3.78 [s, 3H, $CH_3O(\alpha)$], 3.78 [s, 3H, $CH_3O(\beta)$], 2.15 [s, 3H, $CH_3CO(\beta)$], 2.09 [s, 3H, $CH_3CO(\alpha)$]; **^{13}C** NMR (125.8 MHz, $CDCl_3$): δ 169.8 [$CH_3CO(\beta)$] , 169.7 [$CH_3CO(\alpha)$], 167.2 [$COO(\alpha)$], 166.4 [$COO(\beta)$], 143.2 [*i*-NPh(β)], 137.8, 137.5 [*i*-Ph(α)], 137.6, 137.2 [*i*-Ph(β)] , 128.7 [*m*-NPh(α)], 128.6 [*m*-NPh(β)], 128.5, 128.4, 128.2, 128.1 [*o*-Ph(β), *m*-Ph(β)], 128.4, 128.4, 127.8, 127.8 [*o*-Ph(α), *m*-Ph(α)], 128.0, 128.0 [*p*-Ph(β)], 127.5, 127.5 [*p*-Ph(α)], 124.3 [*p*-NPh(β)], 123.3 [*i*-NPh(α)], 119.4 [*o*-NPh(α)], 119.3 [*o*-NPh(β)], 96.4 [br, C-1(β)], 93.5 [br, C-1(α)], 78.7 [C-3(β)], 76.9 [C-2(β)], 75.7, 72.3 [Ph$CH_2(\beta)$], 73.7, 72.4 [Ph$CH_2(\alpha)$], 73.2 [C-5(β)], 68.2 [C-4(α)], 67.3 [C-4(β)], 52.7 [$CH_3O(\beta)$], 20.7 [$CH_3CO(\beta)$], 20.6 [$CH_3CO(\alpha)$].

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{31}H_{30}F_3NO_8$ $[M+Na]^+$: 624.1816, found: 624.1816.

Methyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α/β-D-galactopyranosyl uronat trichloroacetimidate (35)[67]



1,8-Diaazabicyclo[5.4.0]undec-7-en (23 μL, 0.15 mmol) was added to mixture of compound **33** (430 mg, 1.0 mmol) and trichloracetonitrile (2 mL, 9.6 mmol) in dry CH_2Cl_2 (8 ml) at –20 ^oC. After stirring for 1 h at –20 ^oC and an additional 1 h at room temperature (monitored by TLC) the reaction mixture was evaporated to dryness, dissolved in ethyl acetate (10 mL) and filtered over celite. Combined organic solutions were concentrated. Purification by column chromatography (2 : 1 PE - EtOAc) gave compound **35** as colourless foam.

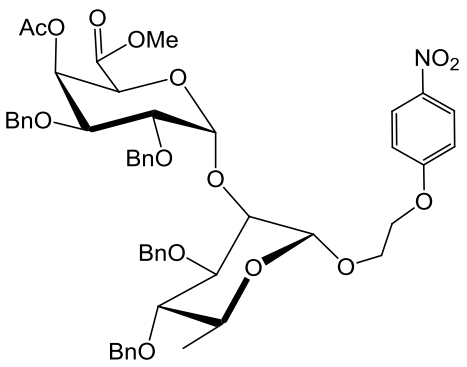
Yield: 430 mg (75%)

R_f: 0.37 (PE : EtOAc= 2 : 1)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.64 (s, 1H, NH), 7.32–7.27 (m, 10H, Ph), 6.66 (d, 1H, $^3J_{1,2}$ 3.1 Hz, H-1), 5.89 (dd, 1H, $^3J_{4,5}$ 1.5 Hz, H-4), 4.80 (d, 1H, ^2J 11.7 Hz, CH_2Ph), 4.79 (d, 1H, ^2J 12.0 Hz), 4.73 (d, 1H, ^2J 12.0 Hz, CH_2Ph), 4.62 (d, 1H, ^2J 11.3 Hz, CH_2Ph), 4.20 (br,

1H, H-5), 3.91 ('t', 1H, $^3J_{1,2} = {}^3J_{2,3}$ 8.5 Hz, H-2), 3.70 (brm, 1H, H-3), 3.75 (s, 3H, OCH_3), 2.10 (s, 3H, CH_3CO). **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.8 (CH_3CO), 167.3 (COO), 137.9, 137.4 (*i*-Ph), 128.5, 128.4, 128.2, 128.1 (*o*-Ph, *m*-Ph), 128.0, 128.0 (*p*-Ph), 93.5 (br, C-1), 74.4 (C-2), 74.2 (C-3), 73.7, 72.4 ($PhCH_2$), 73.2 (C-5), 68.2 (C-4), 52.7 (OCH_3), 20.7 (CH_3CO), 20.6 (CH_3CO).

2-(4-Nitrophenoxy)ethyl (methyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α-D-galactopyranosyl uronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranoside (36)



Via N-phenyltrifluoracetimidate. Compound **34** (700 mg, 1.16 mmol), compound **29** (770 mg, 1.5 mmol) and molecular sieves (4Å, 8 g) were dried for 2 h under high vacuum. The mixture was dissolved in dry CH_2Cl_2 (30 mL) and stirred at ambient temperature under an atmosphere of argon. After 30 min the mixture was cooled to –30 ^oC and $CF_3SO_3SiMe_3$ (60 μL, 0.33 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature, and stirring was continued for additional 2 h in ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 10 mL). The combined organic solutions were concentrated. Purification by column chromatography (3 : 1 PE - EtOAc) gave compound **36** as a colourless foam.

Yield: 908 mg (85%, α:β 20:1)

R_f: 0.45 (1 :1 PE - EtOAc)

Via Trichloracetimidate. Compound **35** (580 mg, 1.0 mmol), compound **29** (770 mg, 1.5 mmol) and molecular sieves (4Å, 4 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (10 mL) and stirred at ambient temperature under an atmosphere of argon. After 30 min the mixture was cooled to –70 ^oC and $CF_3SO_3SiMe_3$ (30 μL, 0.16 mmol)

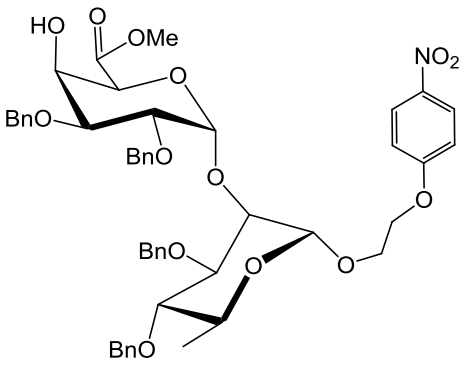
was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature and stirring was continued for additional 12 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 3 mL). The combined organic solutions were concentrated. Purification by column chromatography (3 : 1 PE - EtOAc) gave compound **36** as colourless foam.

Yield: 120 mg (67%, α:β 9:1)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.21 (d, 2H, *m*-$OPhNO_2$), 7.41–7.25 (m, 20H, Ph), 6.95 (d, 2H, *o*-$OPhNO_2$), 5.83 (dd, 1H, $^3J_{4',5'}$ 1.6 Hz, H-4´), 5.08 (d, 1H, $^3J_{1',2'}$ 3.6 Hz, H-1´), 4.98 (d, 1H, ^3J , 1.4 Hz, H-5´), 4.89 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.86 (d, 1H, ^2J 11.7 Hz, CH_2Ph), 4.83 (d, 1H, $^3J_{1,2}$ 1.7 Hz, H-1), 4.81 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.65 (m, 2H, ^2J 12.6 Hz, 2 × CH_2Ph), 4.60 (dd, 2H, ^2J 12.0 Hz, 2 × CH_2Ph), 4.19 (m, 2H, 2 × CH_2CH_2O), 4.10 (m, 1H, $^3J_{1,2}$ 1.7 Hz, $^3J_{2,3}$ 3.1 Hz, H-2), 4.08 (dd, 1H, $^3J_{2',3'}$ 10.1 Hz, H-3´), 4.00 (m, 1H, CH_2CH_2O), 3.89 (dd, 1H, $^3J_{2',3'}$ 10.1 Hz, $^3J_{1',2'}$ 3.6 Hz, H-2´), 3.84 (dd, 1H, $^3J_{3,4}$ 9.5 Hz, $^3J_{2,3}$ 3.1 Hz, H-3), 3.80 (m, 1H, CH_2CH_2O), 3.74 (m, 1H, $^3J_{4,5}$ 9.5 Hz, H-5), 3.50 (s, 3H, OCH_3), 3.48 (t, 1H, $^3J_{4,5}$ 9.5 Hz, H-4), 2.07 (s, 3H, CH_3CO), 1.35 (d, 3H, H-6); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9 (CH_3CO), 168.2 (COO), 163.7 (*p*-$OPhNO_2$), 141.7 (*i*-$OPhNO_2$), 138.8, 138.3, 138.1, 137.8 (*i*-Ph), 128.4, 128.3, 128.3, 128.0, 128.0, 127.8, 127.6, 127.6, 127.5 (*o-Ph,m-Ph,p-Ph*), 125.9 (*m*-$OPhNO_2$), 114.5 (*o*-$OPhNO_2$), 97.5 (C-1), 97.4 (C-1´), 80.0 (C-4), 78.9 (C-3), 75.3(*C*H_2Ph), 74.9 (C-3´), 74.7 (C-2´), 74.4 (C-2),72.7 (*C*H_2Ph), 72.1 (*C*H_2Ph), 71.9 (*C*H_2Ph), 69.4 (C-5´), 68.8 (C-4´), 68.5 (C-5), 67.7 (CH_2CH_2O), 65.4 (*C*H_2CH_2O), 52.2 (OCH_3), 20.4 (*C*H_3CO), 18.0 (C-6).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{51}H_{55}NO_{15}$ $[M+Na]^+$: 944.3464, found: 944.3464.

2-(4-Nitrophenoxy)ethyl (methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranoside (37)



Compound **36** (480 mg, 0.52 mmol) was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (1.1 mL) in ice-cold dry methanol (50 mL)] and the mixture was stirred at ambient temperature under argon atmosphere. After 24 h (monitored by TLC) $PbCO_3 \times Pb(OH)_2$ (5 g) was added to the reaction mixture and stirring was continued for additional 2 h. Salts were filtered off by using glass sintered filter funnel with layer of silica gel, washed with methanol (3 × 10 mL), and the combined organic solutions were concentrated. Purification of the residue by column chromatography (2 : 1 PE - EtOAc) gave compound **37** as a colourless foam.

Yield: 435 mg (95%)

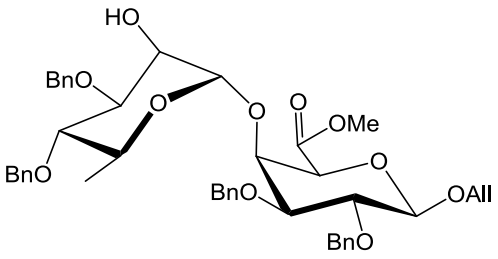
R_f: 0.3 (1 : 1 PE - EtOAc)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.20 (d, 2H, *m*-$OPhNO_2$), 7.42–7.27 (m, 20H, Ph), 6.95 (d, 2H, *o*-$OPhNO_2$), 5.05 (d, 1H, $^3J_{1',2'}$ 3.5 Hz, H-1´), 4.90 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.87 (d, 1H, H-5´), 4.81 (d, 1H, $^3J_{1,2}$ 2.8 Hz, H-1), 4.79 (d, 1H, ^2J 11.7 Hz, CH_2Ph), 4.77 (d, 1H, ^2J 11.4 Hz, CH_2Ph), 4.67 (d, 1H, ^2J 12.1 Hz, *C*H_2Ph), 4.66 (d, 1H, ^2J 11.7 Hz, CH_2Ph), 4.64 (d, 1H, ^2J 10.7 Hz, *C*H_2Ph), 4.59 (d, 1H, ^2J 12.1 Hz, *C*H_2Ph), 4.41 (m, 1H, $^3J_{3',4'}$ 3.5 Hz, H-4´), 4.19 (m, 2H, 2 × CH_2CH_2O), 4.12 (m, 1H, $^3J_{1,2}$ 2.8 Hz, $^3J_{2,3}$ 3.2 Hz, H-2), 4.03–3.98 (m, 2H, $^3J_{2',3'}$ 9.8 Hz, H-3´, CH_2CH_2O), 3.93 (dd, 1H, $^3J_{2',3'}$ 9.8 Hz, $^3J_{1',2'}$ 3.5 Hz, H-2´), 3.84 (dd, 1H, $^3J_{3,4}$ 9.5 Hz, $^3J_{2,3}$ 3.2 Hz, H-3), 3.82–3.79 (m, 2H, H-5, CH_2CH_2O), 3.60 (s, 3H, OCH_3), 3.52 (t, 1H, $^3J_{3,4}$ 9.5 Hz, H-4), 2.50 (bs, H, OH), 1.36 (d, 3H, H-6); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.1 (COO), 163.7 (*p*-$OPhNO_2$), 141.7 (*i*-$OPhNO_2$), 138.6, 138.3, 138.2, 137.8 (*i*-Ph), 128.5, 128.3, 128.3, 128.0, 128.0, 127.8, 127.6, 127.6, 127.00 (*o-Ph,m-Ph,p-Ph*), 125.9 (*m*-$OPhNO_2$), 114.5 (*o*-$OPhNO_2$), 97.4 (C-1), 96.7 (C-1´), 80.1 (C-4), 78.8 (C-3), 76.2 (C-3´),

75.2 (*C*H_2Ph), 75.0 (C-2´), 73.8 (C-2),72.8 (*C*H_2Ph), 72.5 (*C*H_2Ph), 72.0 (*C*H_2Ph), 70.1 (C-5´), 68.5 (C-4´), 68.4 (C-5), 67.7 (CH_2CH_2O), 65.5 (CH_2CH_2O), 52.2 (OCH_3), 18.0 (C-6).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{49}H_{53}NO_{14}$ $[M+Na]^+$: 902.9289, found: 902.9290.

Methyl 3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (38)



Compound **30** (820 mg, 1.03 mmol) was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (1 mL) to ice-cold dry methanol (50 mL)] and the mixture was stirred for 24 h at ambient temperature under an atmosphere of argon (monitored by TLC). The solution was filtered through a layer of alkaline alumina by elution with $CHCl_3$. The combined eluates (ca. 200 mL) were dried, concentrated and the crude product was purified by column chromatography (2 : 1 PE - EtOAc) to provide acceptor **38** as colourless foam.

Yield: 680 mg (87%)

R_f: 0.27 (2 : 1 PE - EtOAc)

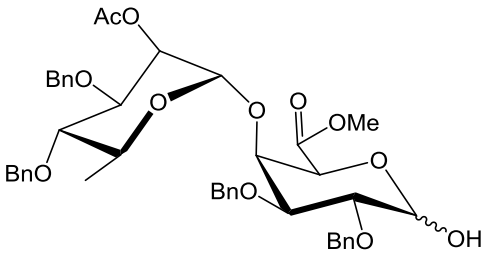
$[\alpha]_D^{22}$: +18.1 (*c* 1.0, $CHCl_3$)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 7.38–7.25 (m, 20H, Ph), 5.98 (dddd, 1H, *J* 17.3, 10.5, 6.2, 5.1 Hz, CH_2CH=CH_2), 5.36 (d'q', 1H, ^3J 17.3 Hz, ^2J 1.6 Hz, CH_2CH=CH_2), 5.35 (d, 1H, $^3J_{1',2'}$ 1.9 Hz, H-1´), 5.22 (d'q', 1H, ^3J 10.5 Hz, ^2J 1.6 Hz, CH_2CH=CH_2), 4.93 (d, 1H, ^2J 10.9 Hz, CH_2Ph), 4.86 (d, 1H, ^2J 11.5 Hz, CH_2Ph), 4.77 (d, 1H, ^2J 11.8 Hz, CH_2Ph), 4.75 (d, 1H, ^2J 10.9 Hz, CH_2Ph), 4.74 (d, 1H, ^2J 11.8 Hz, CH_2Ph), 4.66 (d, 1H, ^2J 11.4 Hz, CH_2Ph), 4.64 (d, 1H, ^2J 11.4 Hz, CH_2Ph), 4.62 (d, 1H, ^2J 11.5 Hz, CH_2Ph), 4.52 (dd't', 1H, ^2J 13.0 Hz, ^3J 5.1 Hz, ^4J 1.6 Hz, CH_2CH=CH_2), 4.46 (dd, 1H, $^3J_{4,3}$ 3.0 Hz, $^3J_{4,5}$ 1.3 Hz, H-4), 4.41 (d, 1H, $^3J_{1,2}$ 7.8 Hz, H-1), 4.17 (m, 1H, ^2J 13.0 Hz, ^3J 6.2 Hz, ^4J 1.4 Hz, CH_2CH=CH_2), 4.14 (dd't', 1H, H-

2´), 4.04 (d, 1H, $^{3}J_{4,5}$ 1.3 Hz, H-5), 3.85 (dd, 1H, $^{3}J_{3´,4´}$ 9.0 Hz, $^{3}J_{2´,3´}$ 3.3 Hz, H-3´), 3.79 (s, 3H, OCH_3), 3.72 (dd, 1H, $^{3}J_{2,3}$ 9.7 Hz, $^{3}J_{1,2}$ 7.8 Hz, H-2), 3.62 (dq, 1H, $^{3}J_{4´,5´}$ 9.6 Hz, $^{3}J_{5´,6´}$ 6.2 Hz, H-5´), 3.56 (dd, 1H, $^{3}J_{2,3}$ 9.7 Hz, $^{3}J_{3,4}$ 3.0 Hz, Hz, H-3), 3.42 ('t', 1H, $^{3}J_{4´,5´}$ 9.3 Hz, $^{3}J_{3´,4´}$ 9.0 Hz, H-4´), 2.40 (d, H, *J* 1.7 Hz, OH), 1.28 (d, 3H, $^{3}J_{5´,6´}$ 6.2 Hz, H-6´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 168.0 (COO), 138.8, 138.4, 138.1, 137.8 (*i*-Ph), 133.9 ($CH_2CH=CH_2$), 128.4, 128.4, 128.2, 128.2, 128.2, 127.8, 127.8, 127.6 (*o-Ph*,*m-Ph*), 127.8, 127.8, 127.6, 127.4 (*p-Ph*), 117.5 ($CH_2CH=CH_2$), 102.7 (C-1), 100.3 (C-1´), 81.1 (C-3), 79.8 (C-4´), 79.6 (C-3´), 78.3 (C-2), 75.2 (CH_2Ph), 74.8(CH_2Ph), 73.7 (C-5), 73.2 (C-4), 73.2 (CH_2Ph), 72.2 (CH_2Ph), 70.6 ($CH_2CH=CH_2$), 68.7 (C-2´), 67.9 (C-5´), 52.4 (OCH_3), 17.9 (C-6´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{44}H_{50}O_{11}$ $[M+Na]^+$: 777.2951 found: 777.2964.

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(2,3-di-*O*-benzyl-α/β-D-galactopyranose)uronate (39)



Compound **30** (840 mg, 1.05 mmol), palladium(II) chloride (360 mg, 2 mmol) and sodium acetate (1.2 g, 14.6 mmol) were stirred in acetic acid (20 mL, 95%) for 2.5 h at 45 ^{o}C (monitored by TLC). The mixture was diluted with chloroform (40 mL), filtered over celite and concentrated. The residue was co-evaporated with toluene (3 × 15 mL) and concentrated and was purified by column chromatography (1 : 1 PE - EtOAc) to give compound **39** as colourless syrup.

Yield: 602 mg (76%)

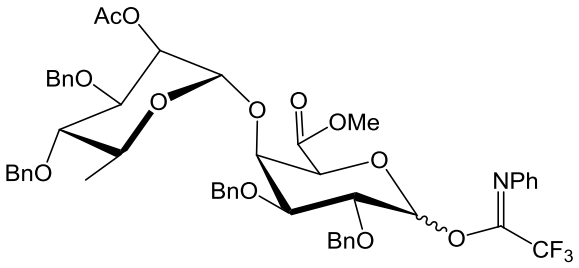
R_f: 0.27 (1 : 1 PE - EtOAc)

^{1}H NMR (250.13 MHz, $CDCl_3$): δ 7.40–7.25 (m, 20H, Ph), 5.53 (dd, 1H, $^{3}J_{2´,3´}$ 3,5 Hz, H-2´), 5.35 (t, 1H, H-1), 5.20 (m, 1H, H-1´), 4.89 (d, 1H, CH_2Ph), 4.84 (d, 1H, CH_2Ph), 4.80 (s, 2H, 2 × CH_2Ph), 4.76 (d, 1H, CH_2Ph), 4.67–4.55 (m, 2H, ^{2}J 10.9 Hz, CH_2Ph, H-4), 4.53 (t,

1H, H-3), 4.40 (d, 1H, CH_2Ph), 4.03–3.90 (m, 2H, H-5, H-2), 3.84 (dd, 1H, $^3J_{2',3'}$ 3.5 Hz, $^3J_{3',4'}$ 9.5 Hz, H-3′), 3.77 (s, 3H, OCH_3), 3.67–3.56 (m, 1H, $^3J_{4',5'}$ 9.5 Hz, H-5′), 3.36 (m, 1H, $^3J_{3',4'}$ 9.5 Hz, H-4′), 3.07 (d,1H, *J* 2.4 Hz, OH), 2.09 (s, 3H, CH_3CO), 1.29 (d, 3H, H-6′); **^{13}C NMR (62.9 MHz, $CDCl_3$):** δ 169.8 (CH_3CO), 168.0 (COO), 138.9, 138.4, 138.2, 137.7 (*i*-Ph), 133.9 ($CH_2CH=CH_2$), 128.3–127.3 (*o-Ph,m-Ph,p-Ph*), 117.5 ($CH_2CH=CH_2$), 102.7 (C-1), 99.1 (C-1′), 80.8 (C-3), 79.7 (C-4′), 78.2(C-2), 77.9 (C-3′), 75.1 (CH_2Ph), 74.8 (CH_2Ph), 73.7 (C-4), 73.7 (C-5), 73.1 (CH_2Ph), 71.8 (CH_2Ph), 70.6 ($CH_2CH=CH_2$), 68.9 (C-2′), 68.2 (C-5′), 52.5 (OCH_3), 20.9 (CH_3CO), 17.9 (C-6′).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{43}H_{48}O_{12}$ $[M+Na]^+$: 779.3038, found: 779.3042.

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(2,3-di-*O*-benzyl-α/β-D-galactopyranosyl)uronate *N*-phenyl trifluroacedimidate (40)



Cs_2CO_3 (600 mg, 1.8 mmol) and 2,2,2-trifluoro-*N*-phenyl-acetimidoyl chloride (570 mg, 2.8 mmol) were consecutively added to compound **39** (700 mg, 0.92 mmol) in acetone (20 mL) at 0 ^oC. The cooling bath was removed, and reaction mixture was stirred at ambient temperature. After 2 h (monitored by TLC) the reaction mixture was diluted with $CHCl_3$ (20 mL). Salts were filtered off and washed with EtOAc (2 × 10 mL). The combined organic solutions were concentrated and the residue was purified by column chromatography (3 : 1 PE - EtOAc) to give compound **40** as a yellow foam.

Yield: 774 mg (91%, α : β = 1 : 3)

R_f: 0.63 (1 : 1 PE - EtOAc)

α-$NPhCF_3$ compound

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 7.39–7.22 (m, 22H, Ph, *m*-NPh), 7.10 (m, 1H, *p*-NPh), 6.74 (m, 2H, *o*-NPh), 6.65 (br, 1H, H-1), 5.50 (dd, 1H, $^3J_{2',3'}$ 3.3 Hz, $^3J_{1',2'}$ 1.9 Hz, H-2′), 5.21

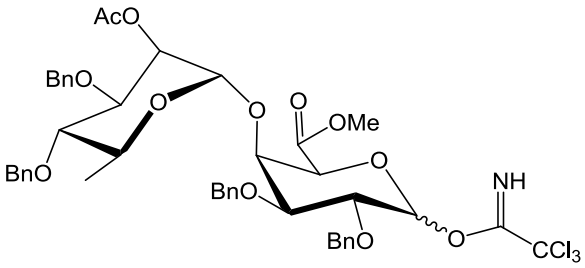
(d, 1H, $^{3}J_{1',2'}$ 1.9 Hz, H-1´), 4.87 (d, 1H, ^{2}J 11.2 Hz, CH_2Ph), 4.85 (d, 1H, ^{2}J 11.8 Hz, CH_2Ph), 4.79 (d, 1H, ^{2}J 11.8 Hz, CH_2Ph), 4.78 (qAB, 2H, CH_2Ph), 4.54 (br, 2H, H-4, H-5), 4.61 (d, 1H, ^{2}J 11.0 Hz, CH_2Ph), 4.57 (d, 1H, ^{2}J 11.2 Hz, CH_2Ph), 4.37 (d, 1H, ^{2}J 11.0 Hz, CH_2Ph), 4.09 (br dd, 1H, $^{3}J_{2,3}$ 10.0 Hz, $^{3}J_{1,2}$ 3.0 Hz, H-2), 4.01 (br dd, 1H, $^{3}J_{2,3}$ 10.0 Hz, $^{3}J_{3,4}$ 2.5 Hz, H-3), 3.80 (dd, 1H, $^{3}J_{3',4'}$ 9.5 Hz, $^{3}J_{2',3'}$ 3.3 Hz, H-3´), 3.79 (s, 3H, OCH_3), 3.60 (dq, 1H, $^{3}J_{4',5'}$ 9.5 Hz, $^{3}J_{5',6'}$ 6.2 Hz, H-5´), 3.35 (t, 1H, $^{3}J_{3',4'}$ 9.5 Hz, $^{3}J_{4',5'}$ 9.5 Hz, H-4´), 2.08 (s, 3H, CH_3CO), 1.28 (d, 3H, $^{3}J_{5',6'}$ 6.2 Hz, H-6´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.8 (CH_3CO), 167.7 (COO), 143.4 (*i*-NPh), 138.8, 138.1, 137.7, 137.6 (*i*-Ph), 128.7 (*m*-NPh), 128.5, 128.4, 128.3, 128.2, 128.1, 127.7, 127.5 (*o-Ph*,*m-Ph*),127.9, 127.8, 127.6,127.4 (*p*-Ph), 124.3 (*p*-NPh),119.4 (*o*-NPh), 99.2 (C-1´), 93.5 (br, C-1), 79.5 (C-4´), 77.9 (C-3´), 76.9 (C-3), 74.9 (CH_2Ph), 74.5 (C-4), 73.4 (CH_2Ph), 73.2 (CH_2Ph), 72.5 (C-2), 72.5 (C-5), 71.8 (CH_2Ph), 68.6 (C-2´), 68.4 (C-5´), 52.7 (OCH_3), 21.1 (CH_3CO), 18.0 (C-6´).

β-NPhCF_3 compound

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 7.35–7.24 (m, 22H, Ph, *m*-NPh), 7.08 (m, 1H, *p*-NPh), 6.81 (d, 2H, *o*-NPh), 5.60 (br, 1H, H-1) 5.53 (dd, 1H, $^{3}J_{2',3'}$ 3.3 Hz, $^{3}J_{1',2'}$ 1.8 Hz, H-2´), 5.20 (d, 1H, $^{3}J_{1',2'}$ 1.8 Hz, H-1´), 4.90 (d, 1H, ^{2}J 11.3 Hz, CH_2Ph), 4.84 (s, 2H, CH_2Ph), 4.77 (qAB, 2H, ^{2}J 11.8 Hz, CH_2Ph), 4.69 (d, 1H, ^{2}J 11.1 Hz, CH_2Ph), 4.59 (d, 1H, ^{2}J 11.3 Hz, CH_2Ph), 4.51 (d, 1H, ^{2}J 11.1 Hz, CH_2Ph), 4.43 (br, 1H, H-2), 4.04 (br, 1H, H-5), 3.95 (br, 1H, H-4), 3.91 (dd, 1H, $^{3}J_{3',4'}$ 9.4 Hz, $^{3}J_{2',3'}$ 3.2 Hz, H-3´), 3.78 (s, 3H, OCH_3), 3.63 (dq, 1H, $^{3}J_{4',5'}$ 9,5 Hz, $^{3}J_{5',6'}$ 6.2 Hz, H-5´), 3.61 (br, 1H, H-3), 3.38 ('t', 1H, $^{3}J_{4',5'}$ 9,5 Hz, $^{3}J_{3',4'}$ 9,4 Hz, H-4´), 2.09 (s, 3H, CH_3CO), 1.29 (d, 3H, $^{3}J_{5',6'}$ 6.2 Hz, H-6´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9 (CH_3CO), 167.1 (COO), 143.3 (*i*-NPh), 138.8, 138.1, 137.5, 137.4 (*i*-Ph), 128.6 (*m*-NPh), 128.5, 128.5, 128.4, 128.3, 128.2, 128.2, 127.7, 127.5 (*o*,*m*-Ph), 128.0, 127.9, 127.6, 127.4 (*p-Ph*), 124.2 (*p*-NPh),119.3 (*o*-NPh), 99.1 (C-1´), 96.9 (br, C-1), 80.8 (C-3), 79.6 (C-4´), 77.7 (C-3´), 76.9 (C-4), 75.5 (CH_2Ph), 74.9 (CH_2Ph), 74.3 (br, C-5), 73.2 (C-2), 73.0 (CH_2Ph), 71.9 (CH_2Ph), 68.9 (C-2´), 68.4 (C-5´), 52.6 (OCH_3), 21.1 (CH_3CO), 18.0 (C-6´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{51}H_{52}F_3NO_{16}$ $[M+Na]^+$: 950.3334, found: 950.3333.

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(2,3-di-*O*-benzyl-α/β-D-galactopyranosyl)uronate trichloracedimidate (41)



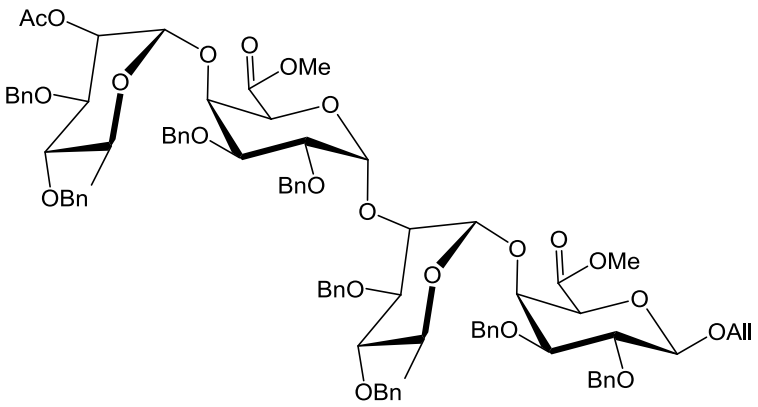
1,8-Diaazabicyclo[5.4.0]undec-7-en (15 μL, 0.1 mmol) was added to mixture of compound **39** (430 mg, 0.57 mmol) and trichloracetonitrile (2 mL, 9.6 mmol) in dry CH_2Cl_2 (8 ml) at –20 ^oC. After stirring for 1 h at –20 ^oC and an additional 1 h at room temperature (monitored by TLC) the reaction mixture was evaporated to dryness, dissolved in ethyl acetate (10 mL) and filtered over celite. Combined organic solutions were concentrated. Purification by column chromatography (2 : 1 PE - EtOAc) gave compound **41** as colourless foam.

Yield: 344 mg (67 %, α : β = 1.5 : 1)

R_f: 0.6 α and 0.5 β (1 : 1 PE - EtOAc)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.62 (s, 1H, NH), 7.34–7.21 (m, 20H, Ph,), 6.63 (d, 1H, $^3J_{1,2}$ 3.3 Hz, H-1) 5.51 ('t', 1H, $^3J_{2',3'}$ 3.2 Hz, H-2´), 5.22 (d, 1H, $^3J_{1',2'}$ 1.3 Hz, H-1´), 4.86 (d, 1H, *J* 11.2 Hz, CH_2Ph), 4.81 (d, 1H, *J* 12.0 Hz, CH_2Ph), 4.77–4.75 (ds, 2H, 2 × CH_2Ph), 4.72 (d, 1H, *J* 12.0 Hz, CH_2Ph), 4.61 (d, 1H, *J* 10.9 Hz, *C*H_2Ph) 4.58 (s, 1H, H-5), 4.55 (d, 1H, *J* 11.2 Hz, *C*H_2Ph) 4.53 (d, 1H, ^3J 1.7 Hz, H-4), 4.37 (d, 1H, *J* 10.9 Hz, *C*H_2Ph), 4.11 (dd, 1H, $^3J_{1,2}$ 3,3 Hz, $^3J_{2,3}$ 10,0 Hz, H-2), 4.03 (dd, $^3J_{2,3}$ 10,0 Hz, H-3), 3.80 (dd, 1H, $^3J_{2',3'}$ 3.2 Hz, $^3J_{3',4'}$ 9.4 Hz,H-3´), 3.74 (s, 3H, OCH_3), 3.61–3.51 (m, 1H, $^3J_{4',5'}$ 9,5 Hz, H-5´), 3.34 (t, 1H, $^3J_{4',5'}$ 9,5 Hz, H-4´), 2.07 (s, 3H, CH_3CO), 1.26 (d, 3H, H-6´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9 (CH_3CO), 167.9 (COO), 160.6 [*C*(=NH)CCl_3], 138.8, 138.1, 137.8, 137.7 (4 × *i*-Ph), 129.0–125.3 (*o-Ph,m-Ph,p-Ph*), 99.1 (C-1´), 94.5 (C-1), 91.0 [C(=NH)*C*Cl_3], 79.8 (C-4´), 77.9 (C-3´), 76.5 (C-3), 74.9 (*C*H_2Ph), 74.3 (C-4), 74.2 (C-2), 73.0 (*C*H_2Ph), 72.9 (*C*H_2Ph), 72.5 (C-5), 71.8 (*C*H_2Ph), 68.6 (C-2´), 68.4 (C-5´), 52.7 (O*C*H_3), 21.1 (*C*H_3CO), 18.0 (C-6´).

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (42)



Via N-phenyltrifluoracetimidate. Compound **40** (200 mg, 0.22 mmol), compound **38** (211 mg, 0.28 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (6 mL) and stirred at ambient temperature under an atmosphere of argon. After 30 min the mixture was cooled to –30 ^{o}C and $CF_3SO_3SiMe_3$ (30 μL, 0.16 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature and stirring was continued for additional 2 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 3 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 toluene - EtOAc) gave compound **42** as colourless foam.

It should be noted that traces of β-linked tetrasaccharide were observed by NMR investigations.

Yield: 295 mg (90%)

R_f: 0.4 (2 : 1 PE - EtOAc)

$[\alpha]_D^{22}$: +68.1 (*c* 1.0, $CHCl_3$)

Via Trichloracetimidate. Compound **41** (110 mg, 0.12 mmol), compound **38** (120 mg, 0.16 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was

suspended in dry CH_2Cl_2 (10 mL) and stirred at ambient temperature under an atmosphere of argon. After 30 min the mixture was cooled to –70 °C and $CF_3SO_3SiMe_3$ (30 μL, 0.16 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature and stirring was continued for additional 12 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 3 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 toluene - EtOAc) gave compound **42** as colourless foam.

Yield: 120 mg (67%)

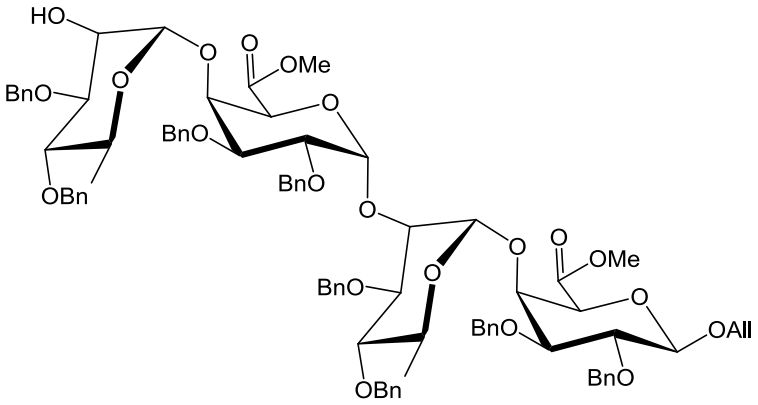
Only traces of β-linked tetrasaccharide were observed by NMR investigations.

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 7.41–7.16 (m, 40H, Ph), 5.96 (dddd, 1H, *J* 17.3, 10.4, 6.2, 5.1 Hz, CH_2CH=CH_2), 5.52 (m, 1H, $^3J_{2''',3'''}$ 3,3 Hz, $^3J_{1''',2'''}$ 2.0 Hz, H-2´´´), 5.39 (d, 1H, $^3J_{1',2'}$ 1.8 Hz, H-1´), 5.35 (d'q', 1H, ^3J 17.3 Hz, ^4J 1.6 Hz, CH_2CH=CH_2), 5.22 (d'q', 1H, ^3J 10.4 Hz, ^4J 1.5 Hz, CH_2CH=CH_2), 5.18 (d, 1H, $^3J_{1''',2'''}$ 2.0 Hz, H-1´´´), 4.98 (d, 1H, $^3J_{1'',2''}$ 3.6 Hz, H-1´´), 4.98 (d, 1H, ^2J 10.8 Hz, CH_2Ph), 4.88 (d, 1H, ^2J 11.1 Hz, CH_2Ph), 4.88 (d, 1H, ^2J 11.4 Hz, CH_2Ph), 4.87 (d, 1H, $^3J_{4'',5''}$ 1.2 Hz, H-5´´), 4.80 (d, 1H, ^2J 10.8 Hz, CH_2Ph), 4.74 (d, 1H, ^2J 12.0 Hz, CH_2Ph), 4.69 (d, 1H, ^2J 12.3 Hz, CH_2Ph), 4.68 (d, 2H, *J* 11.8 Hz, CH_2Ph), 4.64 (d, 1H, *J* 11.0 Hz, CH_2Ph), 4.62 (d, 1H, ^2J 11.1 Hz, CH_2Ph), 4.57 (m, 3H, CH_2Ph), 4.55 (d, 1H, ^2J 12.0 Hz, CH_2Ph), 4.51 (dd't', ^2J 12.9 Hz, ^3J 5.1 Hz, ^4J 1.6 Hz, CH_2CH=CH_2), 4.46 (d, 1H, ^2J 12.0 Hz, CH_2Ph), 4.45 (m, 2H, H-4, H-4´´), 4.40 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.37 (d, 1H, $^3J_{1,2}$ 7.7 Hz, H-1), 4.20 (dd, 1H, $^3J_{2',3'}$ 3.2 Hz, $^3J_{1',2'}$ 1.8 Hz, H-2´), 4.15 (dd, 1H, ^2J 12.9 Hz, ^3J 6.2 Hz, ^4J 1.4 Hz, CH_2CH=CH_2), 4.01 (d, 1H, $^3J_{4,5}$ 1.3 Hz, H-5), 3.99 (dd, 1H, $^3J_{2'',3''}$ 10.0 Hz, $^3J_{3'',4''}$ 2.8 Hz, H-3´´), 3.87 (dd, 1H, $^3J_{3',4'}$ 9.5 Hz, $^3J_{2',3'}$ 3.1 Hz, H-3´), 3.84 (dd, 1H, $^3J_{3''',4'''}$ 9.4 Hz, $^3J_{2''',3'''}$ 3.3 Hz, H-3´´´), 3.82 (dd, 1H, $^3J_{2'',3''}$ 10.0 Hz, $^3J_{1'',2''}$ 3.6 Hz, H-2´´), 3.78 (s, 3H, OCH_3), 3.73 (dd, 1H, $^3J_{1,2}$ 7.7 Hz, $^3J_{2,3}$ 9.7 Hz, H-2), 3.62 (dq, 1H, $^3J_{4''',5'''}$ 9.6 Hz, $^3J_{5''',6'''}$ 6.2 Hz, H-5´´´), 3.57 (dq, 1H, $^3J_{4',5'}$ 9.4 Hz, $^3J_{5',6'}$ 6.2 Hz, H-5´), 3.51 (dd, 1H, $^3J_{2,3}$ 9.7 Hz, $^3J_{3,4}$ 2.9 Hz, H-3), 3.48 (s, 3H, OCH_3), 3.43 ('t', 1H, $^3J_{4',5'}$ 9.5 Hz, $^3J_{3',4'}$ 9.5 Hz, H-4´), 3.35 ('t', 1H, $^3J_{4''',5'''}$ 9.6 Hz, $^3J_{3''',4'''}$ 9.4 Hz, H-4´´´), 2.08 (s, 3H, CH_3CO), 1.34 (d, 3H, $^3J_{5',6'}$ 6.2 Hz, H-6´), 1.27 (d, 3H, $^3J_{5''',6'''}$ 6.2 Hz, H-6´´´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9 (CH_3*C*O), 168.8,168.2 (2 × COO), 138.9, 138.9, 138.6, 138.4, 138.4, 138.1, 138.0, 137.6 (8 × *i*-Ph), 133.9 (CH_2*C*H=CH_2), 128.4, 128.3,128.2, 128.2, 128.2, 128.2, 128.1, 128.1, 128.1, 128.1, 127.7, 127.6, 127.5, 127.4, 127.4, 127.0 (*o-Ph,m-Ph*), 127.7, 127.7, 127.5, 127.4, 127.3, 127.3, 127.3, 127.1 (*p-Ph*), 117.5 (CH_2CH=*C*H_2), 102.7 (C-1) , 98.9 (C-1´´´), 97.96

(C-1´), 96.5 (C-1´´), 80.6 (C-3), 79.9 (C-4´), 79.6 (C-4´´´), 78.7 (C-3´), 78.6 (C-2), 78.0 (C-3´´´), 76.9 (C-3´´), 75.2 (*C*H_2Ph), 74.8 (*C*H_2Ph), 74.8 (C-4´´), 74.6 (*C*H_2Ph), 74.3 (C-2´´), 74.1 (C-2´), 73.7 (C-5), 73.1(*C*H_2Ph), 72.5 (C-4), 72.4 (*C*H_2Ph), 72.0 (*C*H_2Ph), 71.8 (*C*H_2Ph), 71.7 (*C*H_2Ph), 70.6 (*C*H_2CH=CH_2),70.5 (C-5´´), 68.7 (C-2´´´), 68.5 (C-5´), 68.2 (C-5´´´), 52.5 (O*C*H_3), 52.1 (O*C*H_3), 21.1 (*C*H_3CO), 18.1 (C-6´´´), 18.0 (C-6´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{87}H_{96}O_{22}$ $[M+Na]^+$: 1515.6286, found: 1515.6301.

Methyl 3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (43)



Compound **42** (240 mg, 0.16 mmol) was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (0.4 mL) to ice-cold dry methanol (20 mL)] and the mixture was stirred for 24 h at ambient temperature under an atmosphere of argon (monitored by TLC). The solution was filtered through a layer of alkaline alumina by elution with $CHCl_3$. The combined organic solution (ca. 100 mL) were dried, concentrated and the crude product was purified by column chromatography (2 : 1 PE - EtOAc) to provide acceptor **43** as colourless foam.

Yield: 199 mg (86%)

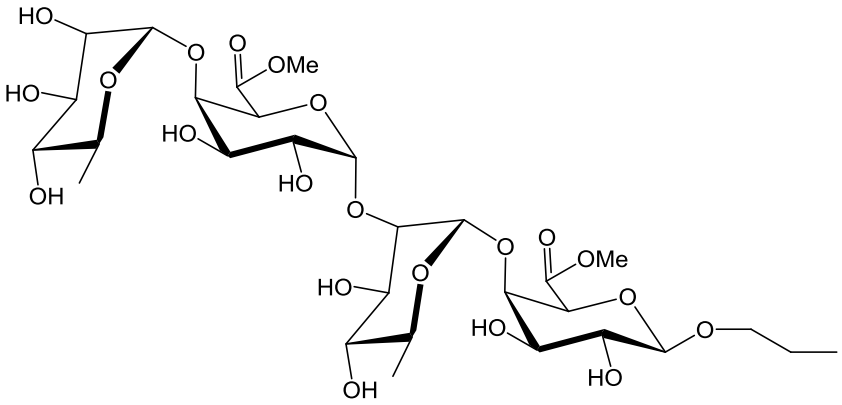
R_f: 0.24 (2 : 1 PE - EtOAc)

$[\alpha]_D^{22}$: +69.5 (*c* 1.0, $CHCl_3$)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 7.42–7.17 (m, 40H, Ph), 5.97 (dddd, 1H, ^{3}J 17.3, 10.4, 6.2, 5.1 Hz, CH_2CH=CH_2), 5.40 (d, 1H,$^{3}J_{1',2'}$ 1.8 Hz, H-1′), 5.36 (d'q', 1H, ^{3}J 17.3 Hz, J 1.6 Hz, CH_2CH=CH_2), 5.27 (d, 1H, $^{3}J_{1''',2'''}$ 2.0 Hz, H-1′′′), 5.22 (d'q', 1H, ^{3}J 10.5 Hz, J 1.5 Hz, CH_2CH=CH_2), 5.02 (d, 1H, $^{3}J_{1'',2''}$ 3.6 Hz, H-1′′), 4.99 (d, 1H, ^{2}J 10.7 Hz, CH_2Ph), 4.88 (d, 1H, ^{2}J 11.4 Hz, CH_2Ph), 4.87 (d, 1H, $^{3}J_{4'',5''}$ 1.4 Hz, H-5′′), 4.85 (m, 1H, ^{2}J 12.6 Hz, CH_2Ph), 4.81 (d, 1H, ^{2}J 10.7 Hz, CH_2Ph), 4.73 (d, 2H, ^{2}J 11.4 Hz, CH_2Ph), 4.68 (m, 1H, J 11.5 Hz, 2 × CH_2Ph), 4.68 (s, 2H, CH_2Ph), 4.62 (d,1H, ^{2}J 11.4 Hz, CH_2Ph), 4.61 (d, 1H, ^{2}J 11.5 Hz, CH_2Ph), 4.61 (d, 1H, ^{2}J 11.4 Hz, CH_2Ph), 4.59 (s,2H, CH_2Ph), 4.52 (d, 1H, ^{2}J 11.6 Hz, CH_2Ph), 4.51 (dd't', 1H, ^{2}J 12.9 Hz, ^{3}J 5.1 Hz, ^{4}J 1.6 Hz, CH_2CH=CH_2), 4.47 (dd, 1H, $^{3}J_{3'',4''}$ 2.8 Hz, $^{3}J_{4'',5''}$ 1.4 Hz, H-4′′), 4.45 (dd, 1H, $^{3}J_{3,4}$ 2.9 Hz, $^{3}J_{4,5}$ 1.3 Hz, H-4), 4.43 (d, 1H, ^{2}J 11.6 Hz, CH_2Ph), 4.38 (d, 1H, $^{3}J_{1,2}$ 7.7 Hz, H-1), 4.22 (dd, 1H, $^{3}J_{2',3'}$ 3.1 Hz, $^{3}J_{1',2'}$ 1.8 Hz, H-2′), 4.15 (dd't', 1H, ^{2}J 12.9 Hz, ^{3}J 6.2 Hz, ^{4}J· 1.4 Hz, CH_2CH=CH_2), 4.13 (m, 1H, H-2′′′), 4.02 (d, 1H, $^{3}J_{4,5}$ 1.3 Hz, H-5), 3.99 (dd, 1H, $^{3}J_{2'',3''}$ 10.1 Hz, $^{3}J_{3'',4''}$ 2.8 Hz, H-3′′), 3.88 (dd, 1H, $^{3}J_{3',4'}$ 9.6 Hz, $^{3}J_{2',3'}$ 3.1 Hz, H-3′), 3.80 (dd, 1H, $^{3}J_{2'',3''}$ 10.1 Hz, $^{3}J_{1'',2''}$ 3.6 Hz, H-2′′), 3.79 (s, 3H, O CH_3), 3.76 (dd. 1H, $^{3}J_{3''',4'''}$ 9.0 Hz, $^{3}J_{2''',3'''}$ 3.2 Hz, H-3′′′), 3.74 (dd, 1H, $^{3}J_{1,2}$ 7.7 Hz, $^{3}J_{2,3}$ 9.7 Hz, H-2), 3.61 (dq, 1H, $^{3}J_{4''',5'''}$ 9.6 Hz, $^{3}J_{5''',6'''}$ 6.2 Hz, H-5′′′), 3.57 (dq, 1H, $^{3}J_{4',5'}$ 9.5 Hz, $^{3}J_{5',6'}$ 6.2 Hz, H-5′), 3.52 (m, 1H, $^{3}J_{2,3}$ 9.7 Hz, $^{3}J_{3,4}$ 2.9 Hz, H-3), 3.50 (s, 3H, OCH_3), 3.43 ('t', 1H, $^{3}J_{3',4'}$ 9.6 Hz, $^{3}J_{4',5'}$ 9.5 Hz, H-4′), 3.41 ('t', 1H, $^{3}J_{4''',5'''}$ 9.6 Hz, $^{3}J_{3''',4'''}$ 9.0 Hz, H-4′′′), 2.37 (brd, 1H, $^{3}J_{2''',OH}$ 1.8 Hz, OH), 1.34 (d, 3H, $^{3}J_{5''',6'''}$ 6.2 Hz, H-6′′′), 1.27 (d, 3H, $^{3}J_{5',6'}$ 6.2 Hz, H-6′); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 168.7, 168.2 (COO), 138.9, 138.8, 138.7, 138.4, 138.4, 138.0, 138.0, 137.6 (*i*-Ph), 133.8 (CH_2CH=CH_2), 128.4, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.0, 127.8, 127.8, 127.5, 127.4, 127.4, 127,4, 127.0 (*o-Ph,m-Ph*), 127.7, 127.7, 127.6, 127.6, 127.3, 127.3, 127.2, 127.1 (*p-Ph*), 117.5(CH_2CH=CH_2), 102.7 (C-1) , 100.4 (C-1′′′), 97.9 (C-1′), 96.4 (C-1′′), 80.7 (C-3), 79.9 (C-4′), 79.7 (C-4′′′), 79.6 (C-3′′′), 78.7 (C-3′), 78.6 (C-2), 76.9 (C-3′′), 75.2 (CH_2Ph), 74.8 (C-4′′), 74.7 (CH_2Ph), 74.6 (CH_2Ph), 74.6 (C-2′′), 74.0 (C-2′), 73.7 (C-5), 73.0 (CH_2Ph), 72.4 (CH_2Ph), 72.4 (C-4), 72.0 (CH_2Ph), 71.9 (CH_2Ph), 71.6 (CH_2Ph), 70.6 (CH_2CH=CH_2), 70.5 (C-5′′), 68.5 (2)(C-2′′′, C-5′), 67.8 (C-5′′′), 52.5 (OCH_3), 52.0 (OCH_3), 18.0 (C-6′′′), 17.9 (C-6′).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{85}H_{94}O_{21}$ $[M+Na]^+$: 1473.6180, found: 1473.6178.

Methyl α-L-rhamnopyranosyl-(1→4)-(methyl α-D-galactopyranosyluronate)-(1→2) α-L-rhamnopyranosyl-(1→4)-(propyl β-D-galactopyranosid)uronate (44)

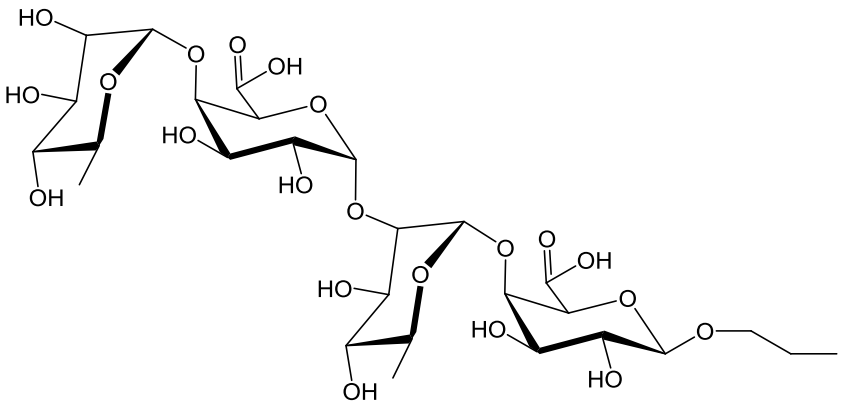


10% Palladium on charcoal (30 mg) was added to a solution of compound **43** (145 mg, 0.1 mmol) in methanol (10 mL), and the reaction mixture was stirred at ambient temperature under an atmosphere of hydrogen. After 24 h (monitored by TLC) the reaction mixture was filtered over celite by elution with methanol, and combined organic solutions were concentrated. The residue was dissolved in water and lyophilized to obtain compound **44** as a colourless foam. Compound **44** was used without further structural characterization for the next step.

Yield: 71 mg (97%)

R_f: 0.22 (2 : 1 $CHCl_3$ - MeOH), 0.81 (1 : 2 $CHCl_3$ - MeOH)

Propyl α-L-rhamnopyranosyl-(1→4)-α-D-galactopyranosyluronic acid-(1→2) α-L-rhamnopyranosyl-(1→4)- β-D-galactopyranosiduronic acid (45)



Lithiumhydroxid (5 mg, 0.2 mmol) was added to a suspension of tetrasaccharide **44** (71 mg, 0.097 mmol) in a mixture of methanol and water (2 : 1, v/v, 10 ml). After stirring for 15 min at ambient temperature (monitored by TLC), the solution was passed through a column of Dowex-50 (H^+). Methanol was removed from solution by evaporation under reduced pressure and the residue was repeatedly dissolved in water and lyophilized to obtain tetrasaccharid **45** as a colourless foam.

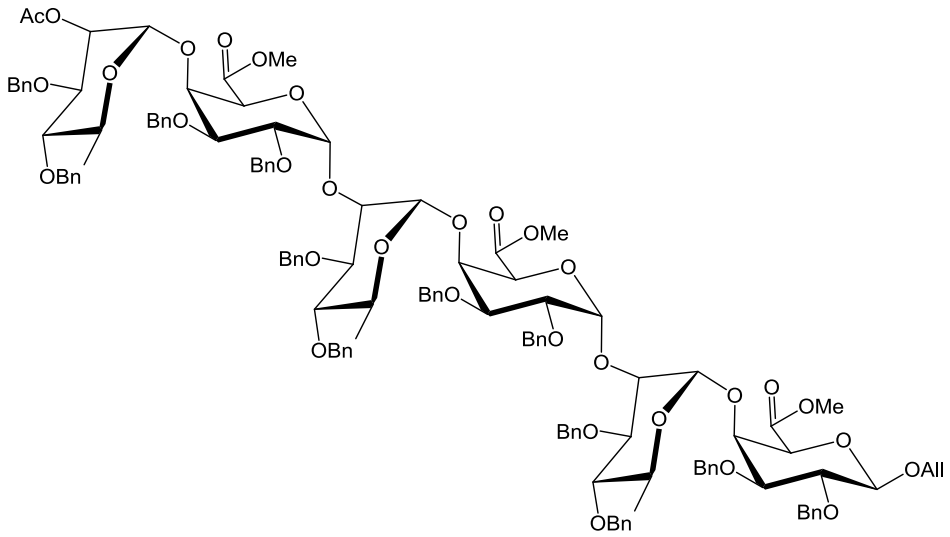
Yield: 63 mg (92%)

R_f: 0.22 (1 : 2 $CHCl_3$ - MeOH)

^{1}H NMR (500.13 MHz, DMSO-d_6): δ 5.15 (d, 1H, $^3J_{1´,2´}$ 1.4 Hz, H-1´), 5.13 (dd, 1H, $^3J_{1´´´,2´´´}$ 1.4 Hz, H-1´´´), 4.95 (d, 1H, $^3J_{1´´,2´´}$ 3.1 Hz, H-1´´), 4.33 (d, 1H, H-5´´), 4.31 (dd, 1H, $^3J_{4´´,5´´}$ 0.9 Hz, H-4´´), 4.26 (d, 1H, dd, $^3J_{1,2}$ 7.3 Hz, H-1), 4.22 (dd, 1H, $^3J_{4,5}$ 0.9 Hz, H-4), 3.92 (d, 1H, H-5), 4.02–3.40 (m,11H, H-2´, H-3, H-3´, H-4´, H-5´, H-2´´, H-3´´, H-2´´´, H-3´´´, H-4´´´, H-5´´´), 3.32 (dd, 1H, , $^3J_{2,3}$ 9.7 Hz, H-1), 3.24 (m, 2H, $CH_2CH_2CH_3$), 1.53 (dt, 2H, $CH_2CH_2CH_3$), 1.16, 1.14 (2d, 6H, H-6´, H-6´´´), 0.83 (t, 3H, $CH_2CH_2CH_3$); **NMR (125.8 MHz, DMSO-d_6):** δ 171.3, 170.4 (COO, C´´OO), 103.4 (C-1), 100.1 (C-1´), 99.7 (C-1´´´), 99.5 (C-1´´), 79.2, 78.7, 78.1, 75.0, 74.5, 73.8, 73.0, 72.1, 72.0, 71.8, 71.5, 71.0, 70.3 (C-2, C-3, C-4, C-5, C-2´, C-3´, C-4´, C-5´, C-2´´, C-3´´, C-4´´, C-5´´, C-2´´´, C-3´´´, C-4´´´, C-5´´´, , $CH_2CH_2CH_3$), 18.2, 18.1 (C-6´, C-6´´´), 10.8 ($CH_2CH_2CH_3$).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{27}H_{44}O_{21}$ $[M+Na]^+$: 727.2081, found: 727.2073.

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranosy-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (46)



Via N-phenyltrifluoracetimidate. Compound **40** (47 mg, 0.05 mmol), compound **43** (45 mg, 0.03 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (6 mL) and stirred at ambient temperature under an atmosphere of argon. After 30 min the mixture was cooled to –30 ^oC and $CF_3SO_3SiMe_3$ (30 μL, 0.16 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature, and stirring was continued for additional 3 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 3 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 Toluene - EtOAc) gave compound **46** as a colourless foam.

Yield: 52 mg (79%)

R_f: 0.55 (1 : 1 PE - EtOAc)

Only traces of β-linked tetrasaccharide were observed by NMR investigations.

Via Trichloracedimidate. Compound **41** (45 mg, 0.05 mmol), compound **43** (45 mg, 0.03 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (6 mL) and stirred at ambient temperature under an atmosphere of

argon. After 30 min the mixture was cooled to –70 °C and $CF_3SO_3SiMe_3$ (30 μL, 0.16 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature, and stirring was continued for additional 18 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 3 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 Toluene - EtOAc) gave compound **46** as a colourless foam.

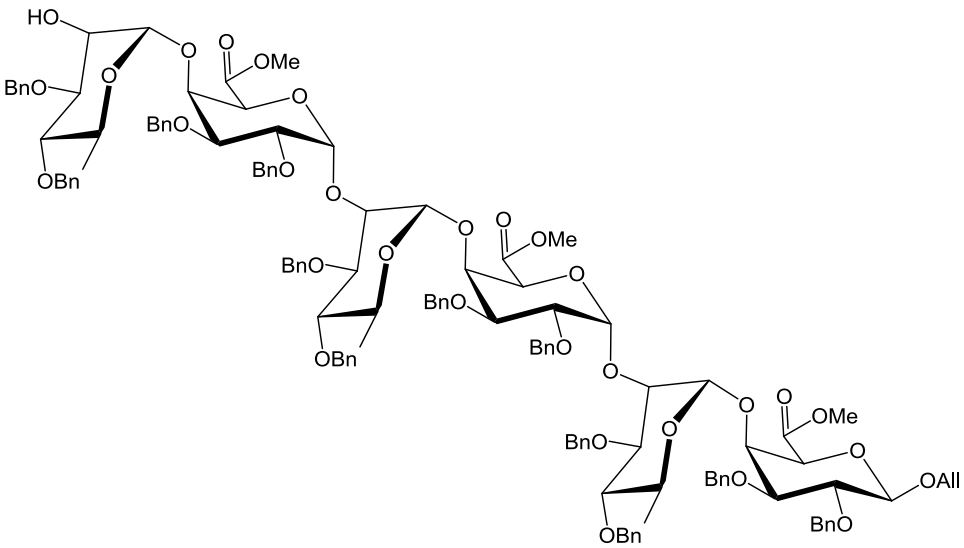
Yield: 33 mg (60%)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 7.44–7.17 (m, 60H, 12 × Ph), 5.96 (dddd, 1H, *J* 17.3, 10.4, 6.2, 5.1 Hz, CH_2CH=CH_2), 5.54 (’q’, 1H, $^3J_{1''''',2'''''}$ 1.9 Hz, $^3J_{2''''',3'''''}$ 3.2 Hz, H-2´´´´´), 5.39 (bs, 2H, H-1´, H-1´´´),5.35 (d’q’, 1H, ^3J 17.3 Hz, ^4J 1.6 Hz, CH_2CH=CH_2), 5.22 (d’q’, 1H, ^3J 10.4 Hz, ^4J 1.5 Hz, CH_2CH=CH_2), 5.19 (’d’,1H, $^3J_{1''''',2'''''}$ 1.9 Hz, H-1´´´´´), 5.03 (d, 1H, $^3J_{1'',2''}$ 3.5 Hz, H-1´´), 4.98 (m, 2H, *J* 10.7 Hz, CH_2Ph, H-1´´´´), 4.89 (m, 3H, CH_2Ph, H-5´´, H-5´´´´), 4.85 (d, 2H, CH_2Ph), 4.81 (m, 2H, CH_2Ph), 4.75 (s, 2H, CH_2Ph), 4.71 (m, 1H, CH_2Ph), 4.68 (d, 1H, CH_2Ph), 4.66 (m, 3H, CH_2Ph), 4.65 (d, 3H, CH_2Ph), 4.61 (m, 2H, CH_2Ph), 4.58 (m, 2H, CH_2Ph), 4.55 (m, 2H, CH_2Ph), 4.52 (m, 3H, *J* 12.9 Hz, CH_2CH=CH_2, 2 × CH_2Ph), 4.46 (m, 4H, CH_2Ph, H-4, H-4´´, H-4´´´´), 4.41 (m, 2H, CH_2Ph), 4.38 (d, 1H, $^3J_{1,2}$ 7.6 Hz, H-1), 4.21 (m, 1H, $^3J_{1',2'}$ 1.9 Hz, H-2´), 4.18 (m, 1H, $^3J_{1''',2'''}$ 1.9 Hz, H-2´´´), 4.15 (m, 1H, *J* 12.9 Hz, CH_2CH=CH_2), 4.02 (d, 1H, H-5), 3.98 (dd, 1H, ^3J 2.8 Hz, H-3´´´´), 3.95 (dd, 1H, ^3J 2.5 Hz, H-3´´), 3.86 (dd, 1H, $^3J_{2''''',3'''''}$ 3.2 Hz, H-3´´´´´), 3.84 (m, 2H, , H-2´´´´, H-3´´´), 3.82 (d, 1H, ^3J 3.7 Hz, H-2´´), 3.80 (m, 2H, H-3´, H-), 3.78 (s, 3H, OCH_3), 3.76 (m, 1H, ^3J 6.9 Hz, H-), 3.72 (dd, 1H, $^3J_{1,2}$ 7.6 Hz, H-2), 3.63 (m, 1H, ^3J 9.5 Hz, H-5´´´´´), 3.55 (m, 2H, H-5´´´), 3.52 (m, 2H, H-5´, H-3), 3.50 (s, 3H, OCH_3), 3.47 (s, 3H, OCH_3), 3.43 (m, 1H, ^3J 9.5 Hz, H-4´), 3.39 (m, 1H, ^3J 9.5 Hz, H-4´´´), 3.36 (m, 1H, ^3J 9.5 Hz, H-4´´´´´), 2.08 (s, 3H, CH_3CO), 1.34–1.27 (m, 9H, H-6´, H-6´´´, H-6´´´´´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9 (CH_3*C*O), 168.9,168.8, 168.2 (3 × COO), 138.9, 138.9, 138.9, 138.7, 138.6, 138.5, 138.4, 138.4, 138.1, 138.1, 137.8, 137.6 (12 × *i*-Ph), 133.9 (CH_2*C*H=CH_2), 128.4–1276.8 (*o-Ph,m-Ph,p-Ph*), 117.5 (CH_2CH=*C*H_2), 102.7 (C-1) , 98.9 (C-1´´´´´), 97.8 (C-1´´´), 97.7 (C-1´), 96.6 (C-1´´´´), 96.0 (C-1´´), 80.8 (C-3), 80.0 (C-4´´´´´), 79.8 (C-4´), 79.6 (C-4´´´), 79.0 (C-2´´´´), 78.6 (C-3´´´), 78.6 (C-2), 78.0 (C-3´´´´´), 76.8 (C-3´´´´), 76.6 (C-3´´), 75.2 (*C*H_2Ph), 75.0 (C-3´), 74.8 (C-4´´´´), 74.8 (*C*H_2Ph), 74.7 (*C*H_2Ph), 74.6 (*C*H_2Ph), 74.3 (C-2´´), 74.2 (C-2´), 73.7 (C-5), 73.7 (C-2´´´), 73.6 (C-4´´), 73.1(*C*H_2Ph), 72.6 (*C*H_2Ph), 72.5 (*C*H_2Ph), 72.2 (C-4), 72.0 (*C*H_2Ph), 71.9 (*C*H_2Ph), 71.8 (*C*H_2Ph), 71.7 (*C*H_2Ph), 71.6 (*C*H_2Ph),70.6 (*C*H_2CH=CH_2),70.6

(C-5´´), 70.4 (C-5´´´´), 68.7 (C-2´´´´´), 68.6 (C-5´), 68.5 (C-5´´´) 68.2 (C-5´´´´´), 52.5 (O*C*H$_3$), 52.0 (2 × O*C*H$_3$), 21.1 (*C*H$_3$CO), 18.1 (C-6´´´´), 18.0 (C-6´, C-6´´´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{128}H_{140}O_{32}$ $[M+Na]^+$: 2213.4492, found: 2213.4486.

Methyl 3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (47)



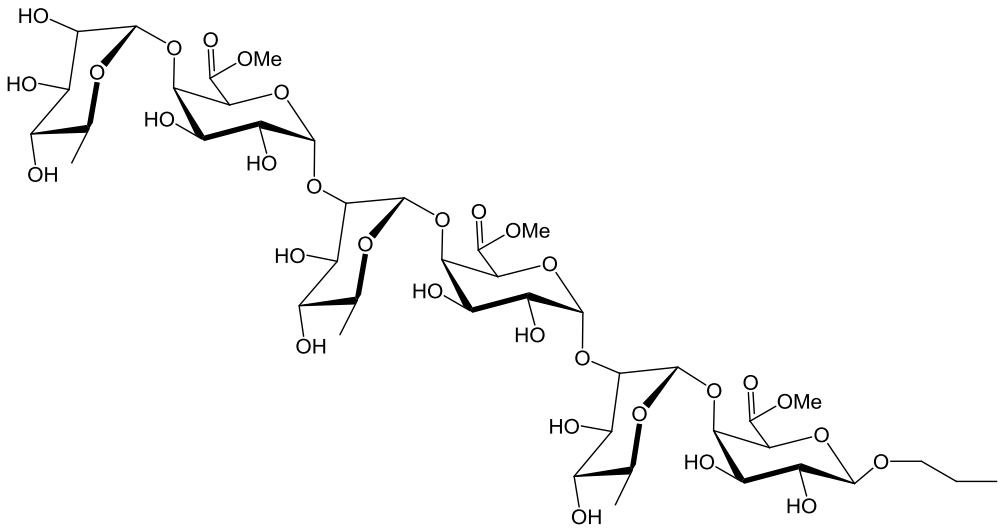
Compound **46** (85 mg, 0.04 mmol) was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (0.1 mL) to ice-cold dry methanol (5 mL)] and the mixture was stirred for 24 h at ambient temperature under an atmosphere of argon (monitored by TLC). The solution was filtered through a layer of alkaline alumina by elution with $CHCl_3$. The combined organic solutions (ca. 20 mL) were concentrated and the crude product was purified by column chromatography (2 : 1 PE- EtOAc) to provide compound **47** as a colourless foam.

Yield: 78 mg (93%)

R_f: 0.36 (1 : 1 PE - EtOAc)

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{126}H_{138}O_{31}$ $[M+Na]^+$: 2171.4494, found: 2171.4502.

Methyl α-L-rhamnopyranosyl-(1→4)-(methyl α-D-galactopyranosyluronate)-(1→2)-α-L-rhamnopyranosyl-(1→4)-(methyl α-D-galactopyranosyluronate)-(1→2)-α-L-rhamnopyranosyl-(1→4)-(propyl β-D-galactopyranosid)uronate (48)



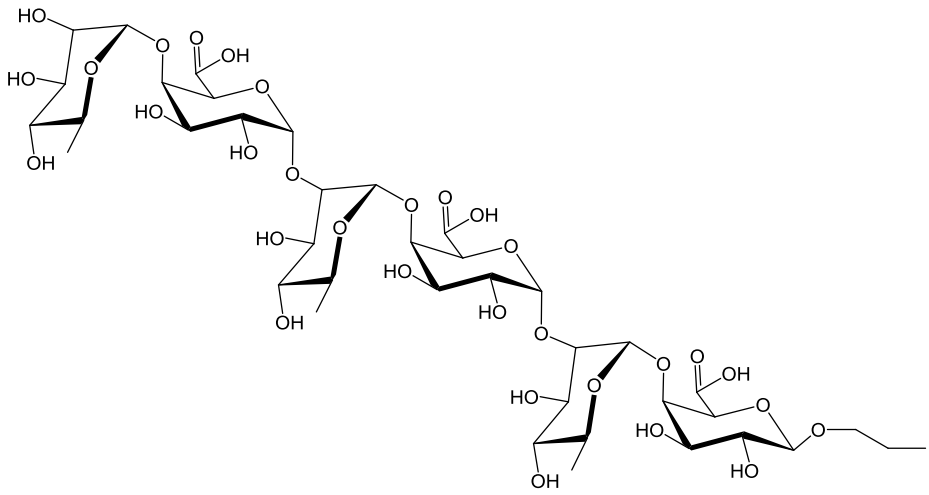
10% Palladium on charcoal (25 mg) was added to a solution of compound **47** (65 mg, 0.03 mmol) in methanol (10 mL) and the reaction mixture was stirred at ambient temperature under an atmosphere of hydrogen. After 28 h (monitored by TLC) the reaction mixture was filtered over celite by elution with with methanol and combined organic solutions were concentrated. The residue was dissolved in water and lyophilized to obtain compound **48** as a colourless foam. Compound **48** was used for the next step without structural characterization.

Yield: 33 mg (95%)

R_f: 0.27 (1 : 1 $CHCl_3$ - MeOH)

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{42}H_{68}O_{31}$ $[M+Na]^+$: 1091.3637, found: 1091.3652

Propyl α-L-rhamnopyranosyl-(1→4)-α-D-galactopyranosyluronic acid-(1→2)-α-L-rhamnopyranosyl-(1→4)-α-D-galactopyranosyluronic acid-(1→2)-α-L-rhamnopyranosyl-(1→4)-β-D-galactopyranosiduronic acid (49)



Lithiumhydroxid (4 mg, 0.17 mmol) was added to a suspension of compound **48** (33 mg, 0.029 mmol) in a mixture of methanol and water (2 : 1, v/v, 5 ml). After stirring for 15 min at ambient temperature (monitored by TLC) the solution was passed through a column of Dowex-50 (H^+). Methanol was removed from the solution by evaporation under reduced pressure and the residue was repeatedly dissolved in water and lyophilized to obtain tetrasaccharid **49** as a colourless foam.

Yield: 30 mg (93%)

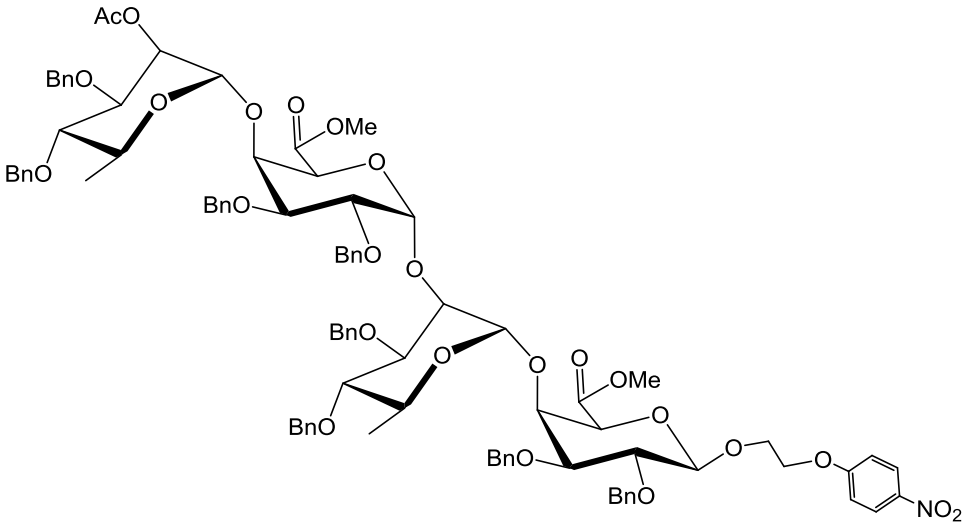
R_f: 0.2 (1 : 2 $CHCl_3$ - MeOH)

^{1}H NMR (500.13 MHz, DMSO-d_6): δ 5.28 (d, 1H, $^3J_{1‴,2‴}$ 1.3 Hz, H-1´´´), 5.24 (d, 2H, $^3J_{1,2}$ 1.5 Hz, H-1´´´´´, H-1´), 5.08 (dd, 1H, $^3J_{1‴,2‴}$ 2.2 Hz, H-1´´´), 5.02 (d, 1H, $^3J_{1″,2″}$ 3.5 Hz, H-1´´), 4.66 (dd,1H, ^3J 1.3 Hz, $^3J_{1,2}$ 7.9 Hz, H-2), 4.42 (m, 1H, ^3J 1.6 Hz, H-2´), 4.38 (d, 1H, $^3J_{1,2}$ 7.9 Hz, H-1), 4.33 (m, 1H, ^3J 2.2 Hz, ^3J 3.5 Hz, H-2´´´), 4.12 (m, 3H), 4.06 (q, 1H, ^3J 1.6 Hz, ^3J 3.5 Hz, H-3´), 4.02 (d,1H, H-5), 3.93 (m, 1H, $^3J_{1,2}$ 1.3 Hz, $^3J_{2‴,3‴}$ 5.4 Hz, H-2´´´), 3.91 (m, 2H, $^3J_{2‴,3‴}$ 5.4 Hz, $^3J_{2.3}$ 9.8 Hz, H-3´´´, H-3), 3.83 (m, 1H, ^3J 3.2 Hz, ^3J 1.0 Hz, H-4), 3.82 (m, 1H, H-5´´´), 3.80 (m, 1H, ^3J 3.8 Hz, ^3J 1.0 Hz, H-4´´´´), 3.79 (m, 1H, ^3J 3.5 Hz, H-), 3.78 (m, 1H, ^3J 3.2 Hz, ^3J 9.5 Hz, H-3´), 3.59 (m, 2H), 3.42 (m, 1H, $^3J_{2,3}$ 9.8, H-2), 3.36 (m, 2H, $CH_2CH_2CH_3$), 1.63 (m, 2H, $CH_2CH_2CH_3$),1.34-1.22 (m, 9H, H-6´, H-6´´´, H-6´´´´´), 0.93 (t, 3H, $CH_2CH_2CH_3$); **^{13}C NMR (125.8 MHz, DMSO-d_6):** δ 175.0, 174.2, 171.1 (3×COO),

102.1 (C-1), 100.5 (C-1´´´´´), 98.5 (C-1´, C-1´´´), 97.4 (C-1´´, C-1´´´´), 77.2, 76.8, 76.7, 76.3, 76.1, 74.5, 73.8, 72.2, 72.0, 70.4, 70.1, 69.4, 69.0, 68.7, 68.5, 67.9, 65.9 (C-2´, C-3´, C-4´, C-5´, C-2´´, C-3´´, C-4´´, C-5´´, C-2´´´, C-3´´´, C-4´´´, C-5´´´, C-2´´´´, C-3´´´´, C-4´´´´, C-5´´´´, C-2´´´´´, C-3´´´´´, C-4´´´´´, C-5´´´´´, 22.2, 20.1(CH_2), 16.8.16.7, 16.6 (C-6´, C-6´´´, C-6´´´´´), 9.7 ($CH_2CH_2CH_3$).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{39}H_{62}O_{31}$ $[M+Na]^+$: 1049.3541, found: 1049.3536

Methyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(2-(4-aminophenoxy)ethyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (50)



Compound **40** (100 mg, 0.11 mmol), compound **32** (130 mg, 0.15 mmol) and molecular sieves (4Å, 200 mg) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (3 mL) and stirred at ambient temperature under an atmosphere of argon. After 30 min the mixture was cooled to –30 ^oC and TMSOTf (20 μL, 0.11 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature and stirring was continued for additional 12 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 3 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 toluene - EtOAc) gave compound **50** as colourless foam.

It should be noted that traces of β-linked (~10%) tetrasaccharide were observed by NMR investigations.

Yield: 140 mg (77%)

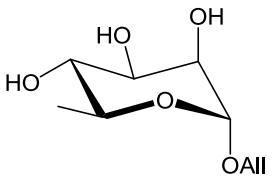
R_f: 0.36 (2 : 1 PE - EtOAc)

$[\alpha]_D^{22}$: +53.4 (*c* 1.0, $CHCl_3$)

^{1}H NMR (300 MHz, $CDCl_3$): δ 8.15 (d, 2H, *m*-$OPhNO_2$), 7.35–7.17 (m, 40H, Ph), 6.90 (d, 2H, *o*-$OPhNO_2$), 5.51 (m, 1H, $^3J_{1‴,2‴}$ 1.9 Hz, $^3J_{2‴,3‴}$ 3,2 Hz, H-2‴), 5.36 (d, 1H, , $^3J_{1′,2′}$ 1.9 H-1′), 5.17 (d, 1H, $^3J_{1‴,2‴}$ 1.6 Hz, H-1‴), 4.97 (d, 1H, $^3J_{1″,2″}$ 3.6 Hz H-1″), 4.92 (d, 1H, *J* 10.7 Hz, CH_2Ph), 4.88 (m, 3H, 2 × CH_2Ph, H-5), 4.75 (d, 2H, 2 × CH_2Ph), 4.68 (m, 2H, 2 × CH_2Ph), 4.66 (d,1H, *J* 11.0 Hz, CH_2Ph), 4.61 (bs, 1H, CH_2Ph), 4.57 (m, 3H, CH_2Ph), 4.46 (m, 3H, CH_2Ph, H-4, H-4″), 4.44 (m, 1H,H-1), 4.40 (dd, 1H, H-), 4.36 (m, 1H, CH_2Ph), 4.31 (m, 1H,), 4.24 (m, 2H, 2 × $CH_2C\mathit{H}_2O$), 4.19 (m, 1H, $^3J_{2′,3′}$ 3.1 Hz, H-2′), 4.03 (d, 1H, ^3J 1.3 Hz, H-5″), 3.99 (dd, 1H, $^3J_{2″,3″}$ 2.8 Hz, H-3″), 3.96 (m, 1H, $C\mathit{H}_2CH_2O$), 3.86 (dd, 1H, $^3J_{2′,3′}$ 3.0 Hz, H-3′), 3.81 (m, 2H, $^3J_{3‴,4‴}$ 9.5 Hz, H-3‴), 3.77 (s, 3H, CH_3OCO), 3.72 (dd, 1H, , $^3J_{1,2}$ 7.9 Hz, $^3J_{2,3}$ 9.8 Hz, H-2), 3.67 (m, 1H,)3.59 (m, 1H, $^3J_{4‴,5‴}$ 9.5 Hz, H-5‴), 3.54 (m, 1H, $^3J_{4′,5′}$ 9.5 Hz, H-5′), 3.51 (dd, 1H, $^3J_{2,3}$ 9.8 Hz, H-3), 3.46 (s, 3H, CH_3OCO), 3.41 (t, 1H, $^3J_{4′,5′}$ 9.5 Hz, H-4′), 3.33 (t, 1H, $^3J_{4‴,5‴}$ 9.5 Hz, H-4‴), 2.07 (s, 3H, CH_3CO), 1.32 (d, 3H, H-6‴), 1.26 (d, 3H, H-6′); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9 ($CH_3\mathit{C}O$), 168.8,168.2 (2 × COO), 163.7 (*p*-$OPhNO_2$), 141.7 (*i*-$OPhNO_2$), 138.8, 138.7, 138.4,138.3, 138.1, 138.1, 137.8, 137.6 (8 × *i*-Ph), 128.5–127.5 (*o-Ph,m-Ph,p-Ph*), 125.9 (2 × *m*-$OPhNO_2$), 114.5 (2 × *o*-$OPhNO_2$), 104.1 (C-1) , 98.9 (C-1‴), 98.2 (C-1′), 96.7 (C-1‴), 80.3 (C-3), 79.9 (C-4′), 79.6 (C-4‴), 78.2 (C-3′), 78.6 (C-2), 78.0 (C-3‴), 77.0 (C-3″), 75.1 ($\mathit{C}H_2Ph$), 74.8 (2 × $\mathit{C}H_2Ph$), 74.8 ($\mathit{C}H_2Ph$), 74.3 (C-2″), 74.1 (C-2′), 73.7 (C-5), 73.1($\mathit{C}H_2Ph$), 72.5 (C-4), 72.4 (C-4″), 72.0 ($\mathit{C}H_2Ph$), 71.8 ($\mathit{C}H_2Ph$), 71.7 ($\mathit{C}H_2Ph$), 70.5 (C-5″), 68.8 (C-2‴), 68.7 (C-5′), 68.2 (C-5‴),67.8 ($CH_2\mathit{C}H_2O$), 67.7 ($\mathit{C}H_2CH_2O$), 52.5 ($\mathit{C}H_3OCO$), 52.1 ($\mathit{C}H_3OCO$), 21.1 ($\mathit{C}H_3CO$), 18.1 (C-6‴), 18.0 (C-6′).

Anal. Calcd for $C_{78}H_{85}NO_{23}$ (1404.50): C, 66.70; H, 6.10; N, 1.00. Found: C, 66.74; H, 6.11; N, 0.98

Allyl α-L-rhamnopyranoside (51)[82]



Acetyl chloride (1.35 mL, 18.9 mmol) was added dropweise to allyl alcohol (20 mL) at 0 ^{o}C. After stirring for 20 min L-rhamnose monohydrate (2.5 g, 13.7 mmol) was added and the reaction mixture was heated under reflux. After 3 h (monitored by TLC) the reaction mixture was neutralized with $NaHCO_3$ (3 g). The salts were filtered off and then washed with chloroform (3 × 10 mL). The combined organic solutions were concentrated and the residue was purified by column chromatography (1 : 1→0 : 1 PE - EtOAc) to give compound **51** as a colourless syrup.

Yield: 2.27g (81%)

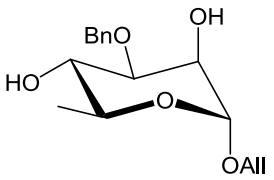
R_f: 0.25 (EtOAc)

$[\alpha]_D^{22}$: –123.8 (*c* 1.0, $CHCl_3$):

^{1}H NMR (300.13 MHz, $CDCl_3$): δ 5.87 (dddd, 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^3J_{7a,8}$ 5.2 Hz, $^3J_{7b,8}$ 6.0 Hz, $^3J_{8,9(E)}$ 10.4 Hz, H-8), 5.27 (d'q', 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^4J_{7,9} = {}^2J$ 1.5 Hz, H-9$_{(Z)}$), 5.18 (d'q', 1H, $^3J_{8,9(E)}$ 10.4 Hz, $^4J_{7,9} = {}^2J$ 1.5 Hz, H-9$_{(E)}$), 4.79 (d, 1H, $^3J_{1,2}$ 1.3 Hz, H-1), 4.66 (d, 1H, $^3J_{3,OH}$ 6.4 Hz, OH-3), 4.30 (d, 1H, $^3J_{4,OH}$ 4.7 Hz, OH-4), 4.22 (d, 1H, $^3J_{2,OH}$ 4.9 Hz, OH-2), 4.15 (dd't', 1H, $^2J_{7a,7b}$ 13.0 Hz, $^3J_{7a,8}$ 5.2 Hz, $^4J_{7a,9}$ 1.5 Hz, H-7a), 3.96 (dd't', 1H, $^2J_{7a,7b}$ 13.0 Hz, $^3J_{7b,8}$ 6.0 Hz, $^4J_{7b,9}$ 1.5 Hz, H-7b), 3.95–3.92 (m, 1H, H-2), 3.77 (ddd, 1H, $^3J_{3,4}$ 9.5 Hz, $^3J_{3,OH}$ 6.4 Hz, $^3J_{2,3}$ 3.2 Hz, H-3), 3.64 (dq, 1H, $^3J_{4,5}$ 9.5 Hz, $^3J_{5,6}$ 6.2 Hz, H-5), 3.46 (ddd, 1H, $^3J_{3,4} = {}^3J_{4,5}$ 9.5 Hz, $^3J_{4,OH}$ 4.7 Hz, H-4), 1.29 (d, 3H, $^3J_{5,6}$ 6.2 Hz, H-6); **^{13}C NMR (75.5 MHz, $CDCl_3$):** δ 133.6 (C-8), 117.6 (C-9), 98.9 (C-1), 72.8 (C-4), 71.7 (C-3), 71.0 (C-2), 68.2 (C-5), 68.0 (C-7), 17.5 (C-6).

Anal. Calcd for $C_9H_{16}O_5$ (204.22): C, 52.88; H, 7.83. Found: C, 52.84; H, 7.81.

Allyl 3-*O*-benzyl-α-L-rhamnopyranoside (52)



A mixture of allyl α-L-rhamnopyranoside (1.43 g, 7.0 mmol) and dibutyltin oxide (1.74 g, 7.0 mmol) in distilled toluene (35 mL) was refluxed for 3.5 h in a Dean-Stark apparatus. Powdered CsF (2.11 g, 14.0 mmol) was added before the mixture was concentrated. The residue was suspended in DMF (30 mL), benzyl bromide (1.2 mL, 14.0 mmol) was added and the resulting mixture was stirred overnight at room temperature and then concentrated. The residue was triturated with CH_2Cl_2 (30 mL), the mixture was filtered off, and the solids were repeatedly washed with CH_2Cl_2 (3 × 10 mL). The combined filtrates were washed with brine (3 mL) and the organic phase concentrated. The residue was purified by column chromatography (2 : 1 PE - EtOAc) to provide compound **52** as a colourless syrup.

Yield: 1.45 g (70%)

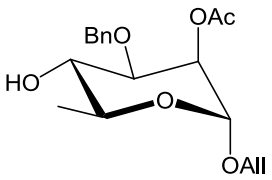
R_f: 0.33 (1 : 1 PE - EtOAc)

$[\alpha]_D^{22}$: –42.5 (*c* 1.0, $CHCl_3$)

^{1}H NMR (300.13 MHz, $CDCl_3$): δ 7.39–7.32 (m, 5H, Ph), 5.89 (dddd, 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^3J_{8,9(E)}$ 10.4 Hz, $^3J_{7b,8}$ 6.1 Hz, $^3J_{7a,8}$ 5.1 Hz, H-8), 5.28 (d'q', 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^4J_{7,9} = {}^2J$ 1.5 Hz, H-9$_{(Z)}$), 5.20 (d'q', 1H, $^3J_{8,9(E)}$ 10.4 Hz, $^4J_{7,9} = {}^2J$ 1.5 Hz, H-9$_{(E)}$), 4.86 (d, 1H, $^3J_{1,2}$ 1.6 Hz, H-1), 4.71 (d, 1H, ^2J 11.5 Hz, CH_2Ph), 4.57 (d, 1H, ^2J 11.5 Hz, CH_2Ph), 4.17 (dd't', 1H, $^2J_{7a,7b}$ 13.0 Hz, $^3J_{7a,8}$ 5.1 Hz, $^4J_{7a,9}$ 1.5 Hz, H-7a), 4.04 (m, 1H, H-2), 3.98 (dd't', 1H, $^2J_{7a,7b}$ 13.0 Hz, $^3J_{7b,8}$ 6.1 Hz, $^4J_{7b,9}$ 1.5 Hz, H-7b), 3.74–3.65 (m, 2H, H-3, H-5), 3.55 (ddd, 1H, $^3J_{3,4}$= $^3J_{4,5}$ 9.2 Hz, $^3J_{4,OH}$ 2.5 Hz, H-4), 2.43 (d, 1H, $^3J_{2,OH}$ 2.5 Hz, OH-2), 2.26 (d, 1H, $^3J_{4,OH}$ 2.5 Hz, OH-4), 1.30 (d, 3H, $^3J_{5,6}$ 6.1 Hz, H-6); **^{13}C NMR (75.5 MHz, $CDCl_3$):** δ 137.7 (*i*-Ph), 133.7 (C-8), 128.7, 127.9 (*o*-Ph, *m*-Ph), 128.2 (*p*-Ph), 117.4 (C-9), 98.4 (C-1), 79.9 (C-3), 71.6 (C-4), 71.6 (*C*H_2Ph), 67.9 (C-7), 67.8 (C-2), 67.7 (C-5), 17.6 (C-6).

Anal. Calcd for $C_{16}H_{22}O_5$ (294.34): C, 65.30; H, 7.47. Found: C, 65.33; H, 7.46.

Allyl 2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranoside (53)



A solution of acetyl chloride (0.64 mL, 8.9 mmol) in toluene (10 mL) was added dropwise to a solution of compound **52** (2.0 g, 6.8 mmol) in dry pyridine (50 mL) at –40 °C under atmosphere of argon. The mixture was stirred 2 h at –40 °C, 2 h at –20 °C and 12 h at –10 °C (monitored by TLC). After concentration the residue was co-evaporated with toluene (4 × 10 mL). Purification by column chromatography (4 : 1 PE - EtOAc) gave compound **53** (1.41 g, 60%) and allyl 2,4-di-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranoside (0.58 g, 14%) both as colourless syrup.

Yield: 1.41g (60%)

R_f: 0.36 (2 : 1 PE - EtOAc)

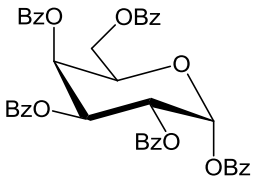
$[\alpha]_D^{23}$: –0.2 (*c* 1.0, $CHCl_3$)

^{1}H NMR (300.13 MHz, $CDCl_3$): δ 7.38–7.27 (m, 5H, Ph), 5.89 (dddd, 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^3J_{8,9(E)}$ 10.4 Hz, $^3J_{7b,8}$ 6.1 Hz, $^3J_{7a,8}$ 5.1 Hz, H-8), 5.38 (dd, 1H, $^3J_{2,3}$ 3.2 Hz, $^3J_{1,2}$ 1.8 Hz, H-2), 5.28 (d'q', 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^4J_{7,9} = {}^2J$ 1.5 Hz, H-$9_{(Z)}$), 5.21 (d'q', 1H, $^3J_{8,9(E)}$ 10.4 Hz, $^4J_{7,9} = {}^2J$ 1.5 Hz, H-$9_{(E)}$), 4.79 (d, 1H, $^3J_{1,2}$ 1.7 Hz, H-1), 4.72 (d, 1H, ^2J 11.1 Hz, CH_2Ph), 4.42 (d, 1H, ^2J 11.1 Hz, CH_2Ph), 4.17 (dd't', 1H, $^2J_{7a,7b}$ 13.0 Hz, $^3J_{7a,8}$ 5.1 Hz, $^4J_{7a,9}$ 1.5 Hz, H-7a), 3.98 (dd't', 1H, $^2J_{7a,7b}$ 13.0 Hz, $^3J_{7b,8}$ 6.1 Hz, $^4J_{7b,9}$ 1.5 Hz, H-7b), 3.77-3.68 (m, 2H, H-3, H-5), 3.55 ('t', 1H, $^3J_{3,4} = {}^3J_{4,5}$ 9.5 Hz, H-4), 2.35 (br s, 1H, OH), 2.12 (s, 3H, CH_3CO), 1.32 (d, 3H, ^3J 6.2 Hz, H-6); **^{13}C NMR (75.5 MHz, $CDCl_3$):** δ 170.3 (CH_3CO), 137.6 (*i*-Ph), 133.5 (C-8), 128.5, 128.1(*o*-Ph, *m*-Ph), 128.0 (*p*-Ph), 117.6 (C-9), 97.0 (C-1), 77.7 (C-3), 71.6 (C-4), 71.4 (CH_2Ph), 68.1 (C-5) 68.1 (C-2), 68.0 (C-7), 20.9 (CH_3CO), 17.7 (C-6).

Anal. Calcd for $C_{18}H_{24}O_6$ (336.38): C, 64.21; H, 7.14. Found: C, 64.27; H, 7.11.

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{18}H_{24}O_6$ $[M+Na]^+$: 359.2412, found: 359.2531.

1,2,3,4,6-Penta-*O*-benzoyl-D-galactopyranoside (54)



Molecular sieves (4Å, 200 mg) were added to a solution of D-galactose (2 g, 11.1 mmol) in dry pyridine (25 mL) and the mixture was stirred for 30 min under an atmosphere of argon. Benzoyl chloride (8.5 mL, 66.6 mmol) was added to them with intensive stirring at –7 ^{o}C. After stirring for 18 h at room temperature (monitored by TLC) the reaction mixture was cooled to 0 ^{o}C and excess of benzoyl chloride was destroyed with methanol (3 mL). The molecular sieves were filtrated off and washed with chloroform (2 × 10 mL). The combined filtrate and washings were concentrated, and the residue was co-evaporated with toluene/ethylacetat/ethanol (5 : 3 : 1, 4 × 3 mL). The crude product was dissolved in chloroform/heptane (1 : 2, 50 mL), washed with ice-water (2 × 10 mL), satd aq $NHCO_3$ (3 × 10 mL), ice-water (10 ml), filtered through cotton and concentrated. The purification of the residue by column chromatography (4 : 1 PE - EtOAc) gave a compound **54** as colourless crystals.

Yield: 7.7 g (99%)

M.p.: 158–159 ^{o}C, lit.[4]158–159 ^{o}C

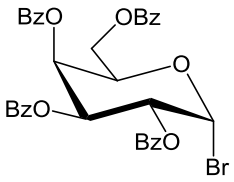
R_f: 0.35 (2 : 1 PE - EtOAc)

[α] $^{22}_{D}$**:**+187.1 (*c* 1.0, $CHCl_3$), lit.[4] +187.1

^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.15–7.81 (m, 10H, *o*-Ph), 7.68–7.24 (m, 15H, *m*-Ph, *p*-Ph), 6.97 (d, 1H, $^{3}J_{1,2}$ 3.6 Hz, H-1), 6.21 (dd, 1H, $^{3}J_{3,4}$ 3.2 Hz, $^{3}J_{4,5}$ 1.2 Hz, H-4), 6.15 (dd, 1H, $^{3}J_{2,3}$ 10.6 Hz, $^{3}J_{3,4}$ 3.2 Hz, H-3), 6.05 (dd, 1H, $^{3}J_{2,3}$ 10.6 Hz, $^{3}J_{1,2}$ 3.6 Hz, H-2), 4.85 (d't', 1H, $^{3}J_{5,6b}$ 7.0 Hz, $^{3}J_{5,6a}$ 6.5 Hz, $^{3}J_{4,5}$ 1.2 Hz, H-5), 4.65 (dd, 1H, ^{2}J 11.3 Hz, $^{3}J_{5,6a}$ 6.5 Hz, H-6a), 4.44 (dd, 1H, ^{2}J 11.3 Hz, $^{3}J_{5,6b}$ 7.0 Hz, H-6b); **^{13}C NMR (75.5 MHz, $CDCl_3$):** δ 165.9, 165.7, 165.5, 165.4, 164.5 (C=O), 133.9, 133.7, 133.4, 133.4 133.2 (*p*-Ph), 129.9, 129.9, 129.7 (*o*-Ph), 129.5, 129.3, 129.0, 128.9, 128.8 (*i*-Ph), 128.7, 128.7, 128.4, 128.4, 128.3 (*m*-Ph), 90.6 (C-1), 69.4 (C-5), 68.5 (C-3), 68.4 (C-4), 67.7 (C-2), 61.8 (C-6).

Anal. Calcd for $C_{41}H_{32}O_{11}$ (700.69): C, 70.18; H, 4.56. Found: C, 70.27; H, 4.48.

2,3,4,6-Tetra-*O*-benzoyl-α-D-galactopyranosyl bromide (55)



The foregoing 40% HBr solution in acetic acid (10 mL) was added to a solution of compound **54** (2.1 g, 3.0 mmol) in dry chloroform (10 mL) at 0 ^{o}C. The ice bath was removed and the reaction mixture was stirred 45 min at ambient temperature (monitored by TLC). After cooling to 5 ^{o}C and dilution with cold chloroform (20 mL), the mixture was poured into ice-water (30 mL). The organic layer was separated and the aqueous layer was extracted with chloroform (3 × 3 mL), the combined organic layers were washed with ice- water (2 × 10 mL), satd aq $NHCO_3$ (3 × 10 mL), ice-water (10 mL), filtered through cotton and concentrated. The residue was dried under high vacuum to give compound **55** as colourless foam. Bromide **55** was used for the next step directly without further purification.

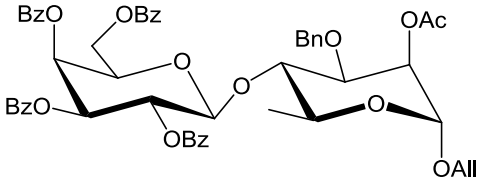
Yield: 1.93 g (97%)

[α] $^{23}_{D}$**:** +237.3 (*c* 1.0, $CHCl_3$)

R_f: 0.5 (2 : 1 PE - EtOAc)

^{1}H NMR (300.13 MHz, $CDCl_3$): δ 8.10–7.20 (m, 20H, 4×Ph), 6.00 (d, 1H, $^{3}J_{1,2}$ 4.0 Hz, H-1), 6.15 (dd, 1H, $^{3}J_{3,4}$ 3.2 Hz, $^{3}J_{4,5}$ 1.2 Hz, H-4), 6.07 (dd, 1H, $^{3}J_{2,3}$ 10.4 Hz, $^{3}J_{3,4}$ 3.2 Hz, H-3), 5.67 (dd, 1H, $^{3}J_{2,3}$ 10.4 Hz, $^{3}J_{1,2}$ 4.0 Hz, H-2), 4.95 (t, 1H, $^{3}J_{5,6b}$ 6.8 Hz,$^{3}J_{5,6a}$ 6.4 Hz, H-5), 4.66 (dd, 1H, ^{2}J 11.5 Hz, $^{3}J_{5,6a}$ 6.4 Hz, H-6a), 4.44 (dd, 1H, ^{2}J 11.5 Hz, $^{3}J_{5,6b}$ 6.8 Hz, H-6b); **^{13}C NMR (75.5 MHz, $CDCl_3$):** δ 165.9, 165.5, 165.3, 164.3 (C=O), 133.8, 133.8, 133.3, 133.3 (*p*-Ph), 130.0, 129.9, 129.8, 129.7 (*o*-Ph), 129.2, 128.8, 128.7, 128.7, (*i*-Ph), 128.5, 128.5, 128.4, 128.3 (*m*-Ph), 88.3 (C-1), 71.8 (C-5), 68.9 (C-3), 68.6 (C-4), 68.1 (C-2), 61.6 (C-6).

Allyl (2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)-2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranoside (56)



Compound **55** (1.05 g, 1.6 mmol), compound **53** (0.4 g, 1.2 mmol) and molecular sieves (4Å, 0.4 g) were dried for 2 h under high vacuum in darkness. The mixture was suspended in dry acetonitrile (8 mL) and stirred under an atmosphere of argon at ambient temperature. After 20 min $Hg(CN)_2$ (0.3 g, 1.2 mmol), $HgBr_2$ (0.2 g, 0.6 mmol) were added and stirring was continued at ambient temperature. After 24 h (monitored by TLC) the mixture was diluted with chloroform (40 mL) and filtrated over celite. The filtrate was extracted with ice-water (2 × 10 mL), aq 10% KI (3 × 10 mL), ice-water (2 × 10mL), dried and concentrated. Purification of the residue by column chromatography (4 : 1 PE - EtOAc) gave compound **56** (0.9 g, 82%) as a colourless foam.

Yield: 0.9 g (82%)

R_f: 0.43 (2 : 1 PE - EtOAc)

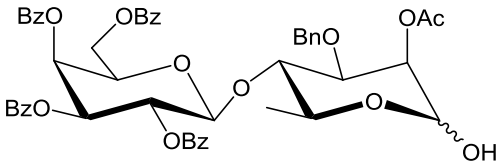
$[\alpha]_D^{23}$: +72.4 (*c* 1.0, $CHCl_3$)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.09 (m, 2H), 8.02 (m, 2H), 7.88 (m, 2H), 7.76 (m, 2H, *o*-Bz), 7.65–7.21 (m, 17H, *m*-Bz, *p*-Bz, Ph), 5.98 (dd, 1H, $^3J_{3',4'}$ 3.5 Hz, $^3J_{4',5'}$ 0.9 Hz, H-4´), 5.86 (m, 1H, H-8), 5.80 (dd, 1H, $^3J_{2',3'}$ 10.4 Hz, $^3J_{1',2'}$ 7.9 Hz, H-2´), 5.60 (dd, 1H, $^3J_{2',3'}$ 10.4 Hz, $^3J_{3',4'}$ 3.5 Hz, H-3´), 5.33 (d, 1H, $^3J_{1',2'}$ 7.9 Hz, H-1´), 5.28–5.18 (m, 3H, H-2, H-9), 4.73 (d, 1H, $^3J_{1,2}$ 1.6 Hz, H-1), 4.68 (dd, 1H, ^2J 11.1 Hz, $^3J_{5',6a'}$ 6.5 Hz, H-6a´), 4.42 (dd, 1H, ^2J 11.1 Hz, $^3J_{5',6b'}$ 6.8 Hz, H-6b´), 4.41 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.32 (d't', 1H, $^3J_{5',6b'}$ 6.8 Hz, $^3J_{5',6a'}$ 6.5 Hz, $^3J_{4',5'}$ 0.9 Hz, H-5´), 4.20 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.13 (dd't', 1H, $^2J_{7a,7b}$ 12.6 Hz, $^3J_{7a,8}$ 5.3 Hz, $^4J_{7a,9}$ 1.3 Hz, H-7a), 3.95 (dd't', 1H, $^2J_{7a,7b}$ 12.6 Hz, $^3J_{7b,8}$ 6.3 Hz, $^4J_{7b,9}$ 1.3 Hz, H-7b), 3.82–3.75 (m, 3H, H-3, H-4, H-5), 2.03 (s, 3H, CH_3CO), 1.43 (d, 3H, $^3J_{5,6}$ 5.7 Hz, H-6); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 170.2 (CH_3CO), 166.0, 165.6, 165.6, 165.4 (C=O), 137.8 (*i*-Ph), 133.4 (C-8), 133.5, 133.2, 133.2, 133.2 (*p*-Bz), 129.9, 129.7, 129.7, 129.6 (*o*-Bz), 129.4, 129.3, 129.2 128.8 (*i*-Bz), 128.7, 128.5, 128.5, 128.4, 128.3, 127.4 (*m*-Bz, *o*-Ph, *m*-Ph), 127.8 (*p*-Ph), 117.9 (C-9), 101.1 (C-1´), 96.6 (C-1), 77.8, 77.1 (C-3, C-4),

71.8 (C-3´), 71.5 (*C*H_2Ph), 70.8 (C-5´), 70.3 (C-2´), 68.5 (C-2), 68.3 (C-4´), 68.2 (C-7), 67.0 (C-5), 61.9 (C-6´), 20.9 (*C*H_3CO), 18.0 (C-6).

Anal. Calcd for $C_{52}H_{50}O_{15}$ (Mol.Wt.: 914.94): C, 68.20; H, 5.46. Found: C, 68.23; H, 5.49.

2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2-*O*-acetyl-3-*O*-benzyl-L-rhamnopyranose (57)



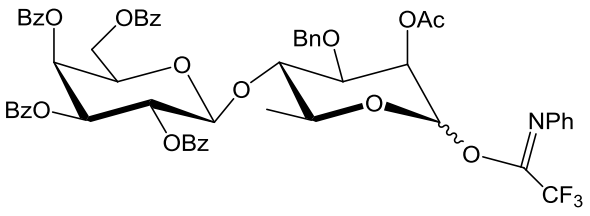
Compound **56** (460 mg, 0.5 mmol) was added to a solution of $PdCl_2$ (180 mg, 1 mmol) and sodium acetate (136 mg, 1mmol) in aq 90% acetic acid (6 ml). After stirring for 2 h at 45 ^oC (monitored by TLC) the reaction mixture was filtered through layer of silica, and the remaining salts were washed with methanol (2 × 3 mL). The combined organic solutions were concentrated to a half of the volume (~ 6 mL) and toluene (6 mL) was added. After concentration to the half of the volume toluene (6 mL) was added again. The procedure was repeated two times more. After concentration of the mixture to dryness the residue was purified by column chromatography (5 : 1 Toluene - EtOAc) gave compound **57** as a colorless foam.

Yield: 340 mg (77.8%)

R_f: 0.3 (4 : 1 Toluene - EtOAc) α and β

Anal. Calcd for $C_{49}H_{46}O_{15}$ (874.88): C, 67.27; H, 5.30. Found: C, 67.41; H, 5.42.

2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2-*O*-acetyl-3-*O*-benzyl-α/β-L-rhamnopyranoside *N*-phenyl trifluoroacetimidate (58)



Cs_2CO_3 (60 mg, 0.18 mmol) and 2,2,2-trifluoro-*N*-phenyl-acetimidoyl chloride (35 mg, 0.19 mmol) were consecutively added to compound **57** (200 mg, 0.23 mmol) in acetone (8 mL) at 0 ^oC. The cooling bath was removed, and the reaction mixture was stirred at ambient temperature. After 2 h (monitored by TLC) the reaction mixture was diluted with CH_2Cl_2 (5 mL), salts were filtered off and washed with EtOAc (2 × 3 mL). The combined organic solutions were concentrated and the residue was purified by column chromatography (3 : 1 PE - EtOAc) to give compound **58** as a colourless amorphous.

Yield: 190 mg (79%, α/β 1/10)

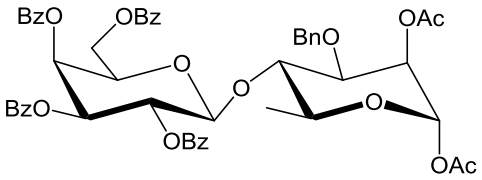
R_f: 0.36 α, 0.37 β (2 : 1 PE - EtOAc)

NMR -40 ^oC

^{1}H NMR (500.13 MHz, $CDCl_3$): 8.07 (m, 2H), 8.02 (m, 2H), 7.91 (m, 2H), 7.79 (m, 2H), (*o*-Bz), 7.63–7.10 (m, 20H, *m*-Bz, *p*-Bz, Bn), 6.80 (m, 2H, Ph), 6.15 (d, 1H, , $^3J_{1,2}$ 1.6 Hz, H-1), 6.01 (d, 1H, $^3J_{3,4}$ 3.5 Hz, H-4´), 5.83 (dd, 1H, $^3J_{2´,3´}$ 10.4 Hz, $^3J_{1´,2´}$ 8.0 Hz, H-2´), 5.59 (dd, 1H, $^3J_{2´,3´}$ 10.4 Hz, $^3J_{3´,4´}$ 3.5 Hz, H-3´), 5.29 (d, 1H, $^3J_{1´,2´}$ 8.0 Hz, H-1´), 5.24 (m, 1H, $^3J_{1,2}$ 1.6 Hz, H-2), 4.72 (dd, 1H, ^2J 13.0 Hz, H-6´), 4.41 (d, 1H, ^2J 11.1 Hz, CH_2Ph), 4.37 (m, 2H, ^2J 13.0 Hz, H-6´, H-5´), 4.28 (d, 1H, ^2J 11.1 Hz, CH_2Ph), 3.94 (m, 1H, $^3J_{4,5}$ 9.5 Hz, $^3J_{5,6}$ 6.0 Hz, H-5), 3.89 (t, 1H, $^3J_{4,5}$ 9.5 Hz, H-4), 3.78 (dd, 1H, $^3J_{2,3}$ 3.2 Hz, $^3J_{3,4}$ 9.5 Hz, H-3), 2.09 (s, 3H, CH_3CO), 1.50 (d, 3H, $^3J_{5,6}$ 6.0 Hz, H-6); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 170.2 (CH_3CO), 166.0, 165.5, 165.3, 165.3 (C=O), 14l.9 (C=N), 136.8 (*i*-Ph), 133.8, 133.5, 133.5, 133.5 (*p*-Bz), 129.8, 129.6, 129.6, 128.7 (*o*-Bz), 128.6, 128.6, 128.5, 128.4 (*i*-Bz), 128.3, 128.1, 127.9, 127.4, 124.2, 120.4. 119.1 (*m*-Bz, *o*-Ph, *m*-Ph, *p*-Ph, NPh), 100.8 (C-1´), 92.8 (C-1), 76.4 (C-3), 76.0 (C-4), 72.0 (CH_2Ph), 71.5 (C-3´), 70.2 (C-5´), 69.5 (C-5), 67.5 (C-4´), 67.0 (C-2), 61.0 (C-6´), 21.0 (CH_3CO), 18.0 (C-6).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{57}H_{50}F_3NO_{15}$ $[M+Na]^+$: 1068.3025, found: 1068.3028.

2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-1,2-di-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranoside (59)



Acetic anhydride (3 mL) was added to a solution of compound **57** (300 mg, 0.34 mmol) in dry pyridine (7 mL) at 0 ^{o}C and stirred for 24 h at ambient temperature (monitored by TLC). The reaction mixture was poured into ice-water (10 mL), the aq layer was extracted with chloroform (3 × 3 mL). The combined organic solutions were washed with ice-water (2 mL), satd aq $NHCO_3$ (3 × 2 mL), ice-water (2 mL), dried and concentrated. Purification of the residue by column chromatography (3 : 1 Toluene - EtOAc) gave compound **59** (240 mg, 77%) as a colourless foam.

Yield: 240 mg (77%)

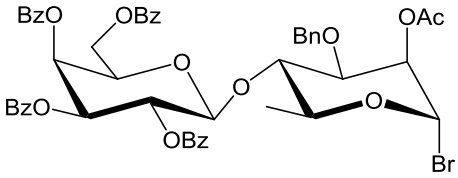
R_f : 0.55 (2 : 1 Toluen - EtOAc)

$[\alpha]_D^{23}$: +69.8 (*c* 1.0, $CHCl_3$)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.08 (m, 2H), 8.02 (m, 2H), 7.90 (m, 2H), 7.76 (m, 2H), (*o*-Bz), 7.65–7.17 (m, 17H, *m*-Bz, *p*-Bz, Bn), 5.98 (dd, 1H, $^3J_{3',4'}$ 3.5 Hz, $^3J_{4',5'}$ 0.9 Hz, H-4′), 5.96 (d, 1H, $^3J_{1,2}$ 1.9 Hz, H-1), 5.81 (dd, 1H, $^3J_{2',3'}$ 10.4 Hz, $^3J_{1',2'}$ 8.0 Hz, H-2′), 5.61 (dd, 1H, $^3J_{2',3'}$ 10.4 Hz, $^3J_{3',4'}$ 3.5 Hz, H-3′), 5.32 (d, 1H, $^3J_{1',2'}$ 8.0 Hz, H-1′), 5.18 (m, 1H , $^3J_{2,3}$ 3.5 Hz, $^3J_{1,2}$ 1.9 Hz, H-2), 4.68 (dd, 1H, ^2J 11.3 Hz, $^3J_{5',6a'}$ 6.6 Hz, H-6a′), 4.44 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.43 (dd, 1H, ^2J 11.3 Hz, $^3J_{5',6b'}$ 6.6 Hz, H-6b′), 4.33 (dt, 1H, $^3J_{5',6'}$ 6.6 Hz, $^3J_{4',5'}$ 0.9 Hz, H-5′), 4.25 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 3.88–3.82 (m, 2H, H-4, H-5), 3.73 (m, 1H, H-3), 2.07 (s, 3H, CH_3CO), 2.03 (s, 3H, CH_3CO), 1.44 (d, 3H, $^3J_{5,6}$ 5.7 Hz, H-6); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9, 168.5 (CH_3CO), 166.0, 165.5, 165.4, 165.4 (C=O), 137.4 (*i*-Ph), 133.6, 133.3, 133.3, 133.2 (*p*-Bz), 129.9, 129.7, 129.7, 129.6 (*o*-Bz), 129.4, 129.2, 129.1, 128.7 (*i*-Bz), 128.6, 128.5, 128.5, 128.4, 128.2, 127.8 (*m*-Bz, *o*-Ph, *m*-Ph), 128.2 (*p*-Ph), 101.1 (C-1′), 90.9 (C-1), 77.3 (C-3), 76.5 (C-4), 71.8 (C-3′), 71.7 (CH_2Ph), 70.9 (C-5′), 70.3 (C-2′), 69.3 (C-5), 68.2 (C-4′), 67.4 (C-2), 61.8 (C-6′), 20.9 (CH_3CO), 20.8 (CH_3CO), 18.0 (C-6). Anal. Calcd for $C_{51}H_{48}O_{16}$ (916.92): C, 66.75; H, 5.23. Found: C, 66.78; H, 5.24.

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{51}H_{48}O_{16}$ $[M+Na]^+$: 939.2834, found:939.2824.

2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranosyl bromide (60)

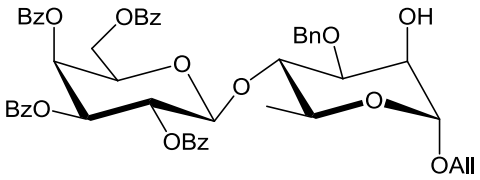


Oxalylbromide (0.38 mL, 2.7 mmol) was added to a solution of compound **59** (250 mg, 0.27 mmol) in dry CH_2Cl_2 (7 mL) at –40 ^oC under an atmosphere of argon. After stirring for 1h the cooling bath was removed and stirring was continued for 4 h at ambient temperature (monitored by TLC). The reaction mixture diluted with toluene (10 mL), the organic solution was concentrated to a half of the volume (~ 8 mL) and toluene (8 mL) was added. After concentration to the half of the volume toluene (8 mL) was added again and concentrated. Obtained syrup of compound **60** was unstable for storage and was used for the next step directly without further purification.

Yield: 215 mg (85%)

R_f: 0.4 (2 : 1 PE - EtOAc).

Allyl 2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-3-*O*-benzyl-α-L-rhamnopyranoside (61)



Compound **56** (3.4 g, 3.7 mmol) was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (2 mL) in ice-cold dry methanol (110 mL)] and the mixture was stirred at ambient temperature under an atmosphere of argon. After 24 h (monitored by TLC) $PbCO_3 \times Pb(OH)_2$ (10 g) was added to the reaction mixture and stirring

was continued for additional 2 h to neutralize hydrochloric acid. Salts were filtered off by using glass sintered filter funnel with layer of silica gel, washed with methanol (3 × 30 mL) and the combined organic solutions were concentrated. Purification of the residue by column chromatography (3 : 1 PE - EtOAc) gave compound **61** as a colourless foam.

Yield: 2.04 g (63%)

$[\alpha]_D^{23}$: + 49.4 (*c* 1.0, $CHCl_3$)

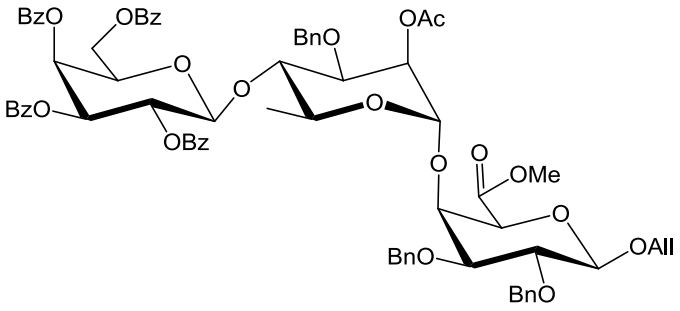
R_f : 0.3 (2 : 1 PE - EtOAc)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.08 (m, 2H), 8.01 (m, 2H), 7.87 (m, 2H), 7.77 (m, 2H, *o*-Bz), 7.65–7.16 (m, 17H, *m*-Bz, *p*-Bz, Bn), 5.99 (dd, 1H, $^3J_{3',4'}$ 3.5 Hz, $^3J_{4',5'}$ 0.9 Hz, H-4′), 5.87 (dddd, 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^3J_{8,9(E)}$ 10.4 Hz, $^3J_{7b,8}$ 6.0 Hz, $^3J_{7a,8}$ 5.2 Hz, H-8), 5.81 (dd, 1H, $^3J_{2',3'}$ 10.4 Hz, $^3J_{1',2'}$ 8.0 Hz, H-2′), 5.63 (dd, 1H, $^3J_{2',3'}$ 10.4 Hz, $^3J_{3',4'}$ 3.5 Hz, H-3′), 5.30 (d, 1H, $^3J_{1',2'}$ 8.0 Hz, H-1′), 5.25 (d'q', 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^4J_{7,9}$ = ^2J 1.5 Hz, H-9$_{(Z)}$), 5.19 (d'q', 1H, $^3J_{8,9(E)}$ 10.4 Hz, $^4J_{7,9}$ = ^2J 1.5 Hz, H-9$_{(E)}$), 4.81 (d, 1H, $^3J_{1,2}$ 1.6 Hz, H-1), 4.63 (dd, 1H, ^2J 11.3 Hz, $^3J_{5',6a'}$ 6.5 Hz, H-6a′), 4.43 (d, 1H, ^2J 11.3 Hz, $^3J_{5',6b'}$ 6.9 Hz, H-6b′), 4.35 (center of AB spectrum, 2H, ^2J 12.5 Hz, CH_2Ph), 4.30 (ddd, 1H, $^3J_{5',6b'}$ 6.9 Hz, $^3J_{5',6a'}$ 6.5 Hz, $^3J_{4',5'}$ 0.9 Hz, H-5′), 4.14 (dd't', 1H, $^2J_{7a,7b}$ 12.9 Hz, $^3J_{7a,8}$ 5.4 Hz, $^4J_{7a,9}$ 1.5 Hz, H-7a), 3.96 (dd't', 1H, $^2J_{7a,7b}$ 12.9 Hz, $^3J_{7b,8}$ 6.3 Hz, $^4J_{7b,9}$ 1.5 Hz, H-7b), 3.88 (m, 1H, H-2), 3.86-3.76 (m, 2H, H-4, H-5), 3.67 (dd, 1H, $^3J_{3,4}$ 8.8 Hz, $^3J_{2,3}$ 3.5 Hz, H-3), 2.27 (d, 1H, $^3J_{2,OH}$ 2.2 Hz, OH), 1.42 (d, 3H, $^3J_{5,6}$ 6.0 Hz, H-6); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 166.0, 165.6, 165.5, 165.3 (C=O), 137.8 (*i*-Ph), 133.7 (C-8), 133.5, 133.2, 133.2, 133.2 (*p*-Bz), 129.9, 129.7, 129.7, 129.6 (*o*-Bz), 129.4, 129.3, 129.2, 128.8 (*i*-Bz), 128.6, 128.6, 128.4, 128.3, 128.2, 127.2 (*m*-Bz, *o*-Ph, *m*-Ph), 128.0 (*p*-Ph), 117.7 (C-9), 101.3 (C-1′), 98.1 (C-1), 80.1 (C-3), 77.3 (C-4), 71.8 (*C*H_2Ph), 71.8 (C-3′), 71.0 (C-5′), 70.3 (C-2′), 68.3 (C-4′), 68.0 (C-7), 68.0 (C-2), 66.6 (C-5), 61.9 (C-6′), 17.9 (C-6).

Anal. Calcd for $C_{50}H_{48}O_{14}$ (872.91): C, 68.80; H, 5.50. Found: C, 68.81; H, 5.48.

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{50}H_{48}O_{14}$ $[M+Na]^+$: 895.2936, found: 895.2937.

Methyl (2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)-(2-*O*-acetyl-3-*O*-benzyl-α-rhamnopyranosyl)-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (62)



Compound **60** (250 mg, 0.25 mmol), compound **8** (94 mg, 0.22 mmol) and molecular sieves (4Å, 300 mg) were dried for 2 h under high vacuum in darkness. The mixture was suspended in dry acetonitrile (4 mL) and stirred at ambient temperature under an atmosphere of argon. After 20 min $Hg(CN)_2$ (60 mg, 0.24 mmol) and $HgBr_2$ (50 mg, 0.14 mmol) were added and stirring was continued. After 24 h (monitored by TLC) the mixture was diluted with chloroform (20 mL) and filtered through a layer of celite. The filtrate was extracted with ice-water (2 × 5 mL), aq 10% KI (3 × 5 mL), ice-water (2 × 5 mL), dried and concentrated. The residue was purified by column chromatography (2 : 2 PE - EtOAc) to give compound **62** (186 mg, 65%) as colourless foam.

Yield: 186 mg (65%)

R_f: 0.27 (2 : 1 PE - EtOAc)

$[\alpha]_D^{24}$: + 71.4 (*c* 1.0, $CHCl_3$)

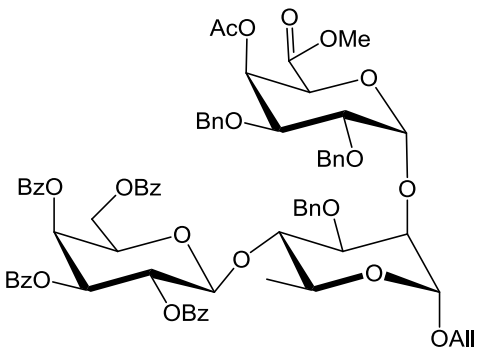
^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.07 (m, 2H), 8.01 (m, 2H), 7.87 (m, 2H), 7.77 (m, 2H, *o*-Bz), 7.63–7.20 (m, 27H, *m*-Bz, *p*-Bz, Bn), 5.97 (dd, 1H, $^3J_{3'',4''}$ 3.5 Hz, $^3J_{4'',5''}$ 0.9 Hz, H-4´´), 5.94 (m, 1H, H-8), 5.77 (dd, 1H, $^3J_{2'',3''}$ 10.4 Hz, $^3J_{1'',2''}$ 8.0 Hz, H-2´´), 5.56 (dd, 1H, $^3J_{2'',3''}$ 10.4 Hz, $^3J_{3'',4''}$ 3.5 Hz, H-3´´), 5.42 (dd, 1H, $^3J_{2',3'}$ 3.2 Hz, $^3J_{1',2'}$ 1.9 Hz, H-2´), 5.35 (m, 1H, H-1´), 5.33 (m, 1H, H-$9_{(Z)}$), 5.31 (d, 1H, $^3J_{1'',2''}$ 8.0 Hz, H-1´´), 5.20 (m, 1H, H-$9_{(E)}$), 4.89 (d, 1H, ^2J 11.9 Hz, CH_2Ph), 4.73 (d, 1H, ^2J 11.9 Hz, CH_2Ph), 4.73 (br s, 2H, CH_2Ph), 4.66 (dd, 1H, ^2J 11.2 Hz, $^3J_{5'',6a''}$ 6.5 Hz, H-6a´´), 4.51–4.46 (m, 2H, H-4, H-7a), 4.50 (d, 1H, ^2J 10.7 Hz, CH_2Ph), 4.41 (dd, 1H, ^2J 11.2 Hz, $^3J_{5'',6b''}$ 6.9 Hz, H-6b´´), 4.37 (d, 1H, $^3J_{1,2}$ 7.8 Hz, H-1), 4.29 (d't', 1H, $^3J_{5'',6b''}$ 6.9 Hz, $^3J_{5'',6a''}$ 6.5 Hz, $^3J_{4'',5''}$ 0.9 Hz, H-5´´), 4.18 (d, 1H, ^2J 10.7 Hz, CH_2Ph), 4.13 (m, 1H, H-7b), 4.06 (d, 1H, $^3J_{4,5}$ 1.3 Hz, H-5), 3.79 (s, 3H, OCH_3), 3.78–3.72 (m, 3H, H-2, H-3´, H-4´), 3.59 (dq, 1H, $^3J_{4',5'}$ 9.5 Hz, $^3J_{5',6'}$ 6.2 Hz, H-5´), 3.55 (dd, 1H, $^3J_{2,3}$

9.8 Hz, $^{3}J_{3,4}$ 2.8 Hz, H-3), 1.95 (s, 3H, CH_3CO), 1.42 (d, 3H, $^{3}J_{5',6'}$ 6.2 Hz, H-6′); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.6 (CH_3CO), 168.3 (COO), 166.0, 165.5, 165.5, 165.3 (C=O), 138.3, 138.0, 137.8 (*i*-Ph), 133.7 (C-8), 133.5, 133.2, 133.2, 133.2 (*p*-Bz), 129.9, 129.8, 129.7, 129.7 (*o*-Bz), 129.5, 129.3, 129.2, 128.8 (*i*-Bz), 128.7, 128.5, 128.4, 128.4, 128.3, 128.3, 128.2, 127.6, 127.6, 127.5 (*m*-Bz, *o*-Ph, *m*-Ph), 128.3. 127.7, 127.6 (*p*-Ph), 117.6 (C-9), 102.7 (C-1), 100.8 (C-1′′), 98.2 (C-1′), 81.0 (C-3), 78.1 (C-2), 77.4, 76.3 (C-3′, C-4′), 75.2 (CH_2Ph), 73.8 (C-5), 73.0 (CH_2Ph), 71.8 (C-4), 71.8 (C-3′′), 71.5 (CH_2Ph), 70.8 (C-5′′), 70.7 (C-7), 70.1 (C-2′′), 68.3 (C-4′′), 68.1 (C-2′), 67.3 (C-5′), 61.8 (C-6′′), 52.8 (OCH_3), 20.9 (CH_3CO), 17.9 (C-6′).

Anal. Calcd for $C_{73}H_{72}O_{21}$ (1285.34): C, 68.21; H, 5.65. Found: C, 68.29; H, 5.58.

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{73}H_{72}O_{21}$ $[M+Na]^+$: 1307.4458, found:1307.4477, calcd for $C_{73}H_{72}O_{21}$ $[M+K]^+$: 1323.4198, found:1323.4204.

Allyl (methyl 4-*O*-acetyl-2,3-di-*O*-benzyl-α-D-galactopyranosyluronat)-(1→2)-[2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl]-(1→4)-3-*O*-benzyl-α-L-rhamnopyranoside (63)



Compound **61** (235 mg, 0.27 mmol), compound **34** (120 mg, 0.2 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (20 mL). After 20 min the mixture was cooled to –30 ^{o}C and $CF_3SO_3SiMe_3$ (25 μL, 0.14 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature, and stirring was continued for additional 2 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 3 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 Toluene - EtOAc) gave compound **63** as colourless foam.

Yield: 170 mg (66%), colourless foam

R_f: 0.45 (4 : 1 Toluene - EtOAc)

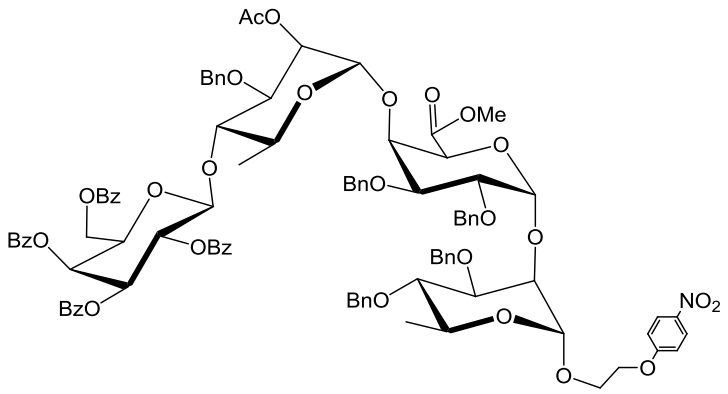
$[\alpha]_D^{24}$: +111.85 (*c* 1.0, $CHCl_3$)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.08 (m, 2H), 8.01 (m, 2H), 7.73 (m, 2H), 7.61 (m, 2H, *o*-Bz), 7.50–7.03 (m, 27H, *m*-Bz, *p*-Bz, Bn), 6.02 (d, 1H, $^3J_{3'',4''}$ 3.5 Hz, H-4´´), 5.86 (m, 1H, H-8), 5.81 (dd, 1H, $^3J_{2'',3''}$ 10.4 Hz, $^3J_{1'',2''}$ 8.0 Hz, H-2´´), 5.80 (dd, 1H, $^3J_{2,3}$ 3.5 Hz, $^3J_{1,2}$ 1.5 Hz, H-2), 5.60 (dd, 1H, $^3J_{2'',3''}$ 10.4 Hz, $^3J_{3'',4''}$ 3.5 Hz, H-3´´), 5.41 (d, 1H, $^3J_{1'',2''}$ 8.0 Hz, H-1´´), 5.23 (d'q', 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^4J_{7,9} = {}^2J$ 1.5 Hz, H-$9_{(Z)}$), 5.18 (d'q', 1H, $^3J_{8,9(E)}$ 10.4 Hz, $^4J_{7,9} = {}^2J$ 1.5 Hz, H-$9_{(E)}$), 4.97 (d, 1H, $^3J_{1',2'}$ 3.8 Hz, H-1´), 4.83 (d, 1H, ^2J 11.8 Hz), 4.61 (d, 1H, ^2J 11.8 Hz), (CH_2Ph), 4.71 (d, 1H, ^2J 11.0 Hz), 4.44 (d, 1H, ^2J 11.0 Hz), (CH_2Ph), 4.54 (d, 1H, ^2J 12.3 Hz), 4.18 (d, 1H, ^2J 12.3 Hz), (CH_2Ph), 4.80 (br s, 2H, H-1, H-5´), 4.65 (m, 1H, H-6a´´), 4.47 (m, 1H, H-6b´´), 4.45 (m, 1H, H-5´´), 4.04 (dd, 1H, $^3J_{3,4}$ 10.1 Hz, $^3J_{2,3}$ 3.5 Hz, H-3), 4.00 (dd, 1H, $^3J_{3',4'}$ 3.5 Hz, $^3J_{4',5'}$ 1.8 Hz, H-4´), 4.13 (m, 1H, H-7a), 3.92 (m, 1H, H-7b), 3.85–3.75 (m, 3H, H-2´, H-4, H-5), 3.29 (s, 3H, OCH_3), 2.01 (s, 3H, CH_3CO), 1.45 (d, 3H, $^3J_{5,6}$ 6.0 Hz, H-6); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.7 (CH_3CO), 167.9 (COO), 166.1, 165.5, 165.5, 165.4 (C=O), 138.6, 137.9, 137.9 (*i*-Ph), 133.7 (C-8), 133.5, 133.3, 133.2, 132.9 (*p*-Bz), 129.9, 129.7, 129.7, 129.5 (*o*-Bz), 129.3, 129.2, 129.0, 128.7 (*i*-Bz), 128.7, 128.6, 128.4, 128.3, 128.2, 128.2, 127.9, 127.7, 127.6, 125.9 (*m*-Bz, *o*-Ph, *m*-Ph), 128.3. 127.6, 127.3 (*p*-Ph), 117.6 (C-9), 101.3 (C-1´´), 98.1 (C-1´), 96.4 (C-1), 78.9 (C-3´), 77.8 (C-4), 75.2 (C-3), 74.5 (C-2´), 74.4 (C-4´), 72.9 (CH_2Ph), 71.9 (CH_2Ph), 71.8 (C-3´´), 71.1 (CH_2Ph), 70.8 (C-5´´), 70.1 (C-2´´), 69.4 (C-5´), 68.7 (C-2), 68.2 (C-4´´), 67.9 (C-7), 67.2 (C-5), 61.8 (C-6´´), 52.1 (OCH_3), 20.7 (CH_3CO), 18.1 (C-6).

Anal. Calcd for $C_{73}H_{72}O_{21}$ (Mol.Wt.: 1285.34): C, 68.21; H, 5.65. Found: C, 68.24; H, 5.61.

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{73}H_{72}O_{21}$ $[M+Na]^+$: 1307.4458, found:1307.4436.

2-(4-Nitrophenoxy)ethyl (2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)-2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranoside (64)



Compound **58** (190 mg, 0.18 mmol), compound **32** (180 mg, 0.2 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (10 mL). After 20 min the mixture was cooled to –25 ^oC and $CF_3SO_3SiMe_3$ (25 μL, 0.14 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature, and stirring was continued for additional 2 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.15 mL, 1.1 mmol), molecular sieves were filtered off and washed with chloroform (3 × 5 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 toluene - EtOAc) gave compound **64** as colourless foam.

Yield: 240 mg (77%)

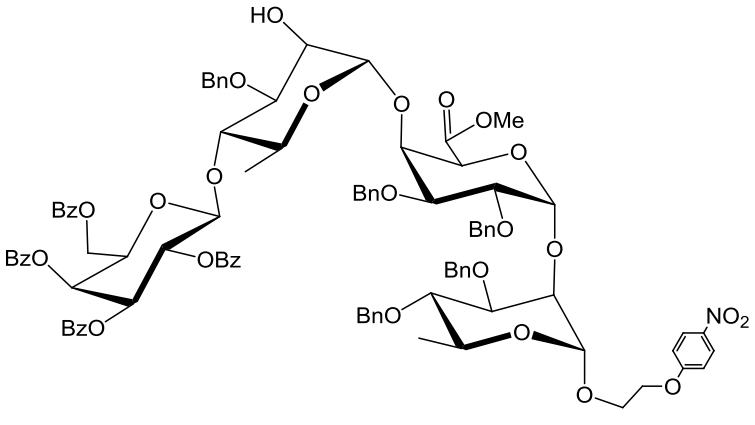
R_f: 0.15 (2 : 1 PE - EtOA)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.19 (m, 2H, *m*-$OPhNO_2$), 8.07 (m, 2H), 8.01 (m, 2H), 7.83 (m, 2H), 7.75 (m, 2H), (*o*-Bz), 7.63–7.20 (m, 37H, *m*-Bz, *p*-Bz, Bn), 6.94 (m, 2H, *o*-$OPhNO_2$), 5.97 (d, 1H, $^3J_{3''',4'''}$ 3.5 Hz, H-4´´´), 5.74 (dd, 1H, $^3J_{2''',3'''}$ 10.4 Hz, $^3J_{1''',2'''}$ 8.0 Hz, H-2´´´), 5.54 (dd, 1H, $^3J_{2''',3'''}$ 10.4 Hz, $^3J_{3''',4'''}$ 3.5 Hz, H-3´´´), 5.38 (m, 1H, $^3J_{1'',2''}$ 1.7 Hz, $^3J_{2'',3''}$ 3.2 Hz, H-2´´), 5.36 (d, 1H, $^3J_{1'',2''}$ 1.7 Hz, H-1´´), 5.29 (d, 1H, $^3J_{1''',2'''}$ 8.0 Hz, H-1´´´), 4.97 (d, 1H, $^3J_{1',2'}$ 3.5 Hz, H-1´), 4.87 (d, 1H, ^2J 10.7 Hz, CH_2Ph), 4.83 (d, 1H, ^3J 1.0 Hz, H-5´), 4.80 (d, 1H, $^3J_{1,2}$ 1.0 Hz, H-1), 4.78 (m, 2H, ^2J 12.0 Hz, CH_2Ph, H-4´), 4.74 (d, 1H, ^2J 12.0 Hz, CH_2Ph), 4.66 (d, 1H, ^2J 11.0 Hz, H-6´´´), 4.65 (d, 1H, ^2J 11.2 Hz, CH_2Ph), 4.62 (d, 1H, ^2J 12.0 Hz, CH_2Ph), 4.61 (d, 1H, ^2J 10.7 Hz, CH_2Ph), 4.53 (m, 2H, ^2J 12.3 Hz, CH_2Ph), 4.45 (d, 1H, ^2J 10.7 Hz, CH_2Ph), 4.40 (dd, 1H, $^3J_{5''',6'''}$ 6.9 Hz, H-6´´´), 4.29 (t, 1H, $^3J_{5''',6'''}$

6.9 Hz, H-5´´´), 4.15 (m, 3H, ^{2}J 11.0 Hz, CH_2CH$_2$O, CH$_2$Ph), 4.02 (m, 2H, $^{3}J_{2,3}$ 3.2 Hz, $^{3}J_{2',3'}$ 10.1 Hz, H-2, H-3´), 3.97 (m, 1H, ^{2}J 6.6 Hz, CH$_2$CH$_2$O), 3.80 (m, 1H, $^{3}J_{2,3}$ 3.2 Hz, H-3), 3.79 (m, 1H, ^{2}J 6.6 Hz, CH$_2$CH$_2$O), 3.77 (m, 1H, $^{3}J_{3'',4''}$ 9.5 Hz, H-4´´), 3.72 (m, 1H, $^{3}J_{4,5}$ 9.5 Hz, $^{3}J_{5,6}$ 6.3 Hz, H-5), 3.62 (dd, 1H, $^{3}J_{2'',3''}$ 3.5 Hz, $^{3}J_{3'',4''}$ 9.5 Hz, H-3´´), 3.55(m, 1H, $^{3}J_{4'',5''}$ 9.5 Hz, $^{3}J_{5'',6''}$ 6.3 Hz, H-5´´), 3.51 (s, 3H, OCH$_3$), 3.43 (t, 1H, $^{3}J_{4,5}$ 9.5 Hz, H-4), 1.96 (s, 3H, CH$_3$CO), 1.40 (d, 3H, $^{3}J_{5'',6''}$ 6.3 Hz, H-6´´), 1.34 (d, 3H, $^{3}J_{5,6}$ 6.0 Hz, H-6); **^{13}C NMR (125.8 MHz, CDCl$_3$):** δ 169.8 (CH$_3$CO), 168.8 (COO), 166.0, 165.5, 165.5, 165.2 (C=O), 163.7 (*p*-OPhNO$_2$), 141.7 (*i*-OPhNO$_2$), 138.5, 138.3, 138.2, 138.0, 137.9 (*i*-Ph), 133.5, 133.2, 133.2, 133.2 (*p*-Bz), 129.9, 129.7, 129.7, 129.6 (*o*-Bz), 129.4, 129.2, 128.8, 128.7 (*i*-Bz), 128.4, 128.4, 128.3, 128.2, 128.0, 127.8, 127.8, 127.7, 127.6, 127.6, 127,3, 126.9, (*m*-Bz, *o*-Ph, *m*-Ph, *p*-Ph), 125.9 (*m*-OPhNO$_2$), 114.5 (*o*-OPhNO$_2$), 100.8 (C-1´´´), 97.8 (C-1´´), 97.6 (C-1, C-1´), 80.1 (C-4), 78.8 (C-3), 77.7 (C-3´´), 77.1 (C-3´), 76.3 (C-4´´), 75.3 (*C*H$_2$Ph), 74.6 (C-2), 74.4 (C-2´), 72.8 (*C*H$_2$Ph), 72.6 (C-4´), 72.4 (*C*H$_2$Ph), 71.8 (C-3´´), 71.8 (*C*H$_2$Ph), 71.5 (*C*H$_2$Ph), 70.9 (C-5´), 70.8 (C-5´´´), 70.1 (C-2´´´), 68.4 (C-4´´´), 68.3 (C-5), 68.1 (C-4´´´´´, C-5´´´´), 67.8 (C-2´´), 67.7 (CH$_2$*C*H$_2$O), 67.5 (C-5´´), 65.4 (*C*H$_2$CH$_2$O), 61.8 (C-6´´´), 52.5 (OCH$_3$), 20.9 (CH$_3$CO), 18.0 (C-6), 18.0 (C-6´´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{98}H_{97}NO_{28}$ $[M+Na]^+$: 1758.6089, found: 1758.6099.

2-(4-nitrophenoxy)ethyl (2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranoside (65)



Compound **64** (200 mg, 0.115 mmol) was added with stirring to methanolic 0.28 M hydrochloric acid [prepared by adding of acetyl chloride (0.4 mL) in ice-cold dry methanol

(18 mL)] and the mixture was stirred at ambient temperature under an atmosphere of argon. After 20 h (monitored by TLC) $PbCO_3 \times Pb(OH)_2$ (2 g) was added to the reaction mixture and stirring was continued for additional 2 h. Salts were filtered off by using glass sintered filter funnel, with a layer of silica gel, washed with methanol (3 × 5 mL) and the combined organic solutions were concentrated. Purification of the residue by column chromatography (2 : 1 PE - EtOAc) gave compound **65** as a colourless foam.

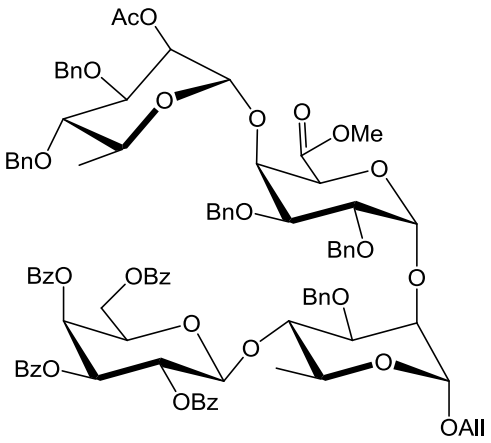
Yield: 160 mg (82%)

R_f: 0.46 (1 : 1 PE - EtOAc)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.19 (m, 2H, *m*-$OPhNO_2$), 8.06 (m, 2H), 8.01 (m, 2H), 7.85 (m, 2H), 7.76 (m, 2H), (*o*-Bz), 7.63–7.20 (m, 37H, *m*-Bz, *p*-Bz, Bn), 6.93 (m, 2H, *o*-$OPhNO_2$), 5.98 (d, 1H, $^3J_{3''',4'''}$ 3.5 Hz, H-4´´´), 5.75 (dd, 1H, $^3J_{2''',3'''}$ 10.4 Hz, $^3J_{1''',2'''}$ 8.0 Hz, H-2´´´), 5.58 (dd, 1H, $^3J_{2''',3'''}$ 10.4 Hz, $^3J_{3''',4'''}$ 3.5 Hz, H-3´´´), 5.41 (d, 1H, $^3J_{1'',2''}$ 1.5 Hz, H-1´´), 5.26 (d, 1H, $^3J_{1''',2'''}$ 8.0 Hz, H-1´´´), 5.00 (d, 1H, $^3J_{1',2'}$ 3.6 Hz, H-1´), 4.87 (d, 1H, ^2J 10.7 Hz, CH_2Ph), 4.82 (d, 1H, ^3J 1.1 Hz, H-5´), 4.79 (m, 2H, $^3J_{1,2}$ 1.0 Hz, ^2J 10.7 Hz, CH_2Ph, H-1), 4.73 (m, 2H, ^2J 12.0 Hz, 2 × CH_2Ph), 4.65 (d, 1H, ^2J 12.3 Hz, CH_2Ph), 4.63 (d, 1H, ^2J 10.2 Hz, CH_2Ph), 4.60 (m, 2H, ^2J 10.7 Hz, CH_2Ph, C-6´´´), 4.58 (m, 1H, ^2J 10.7 Hz, CH_2Ph), 4.53 (d, 1H, ^2J 12.3 Hz, CH_2Ph), 4.51 (m, 1H, $^3J_{4',5'}$ 1.7 Hz, H-4´), 4.41 (dd, 1H, $^3J_{5''',6'''}$ 6.9 Hz, H-6´´´), 4.32 (s, 2H, 2 × CH_2Ph), 4.27 (t, 1H, $^3J_{5''',6'''}$ 6.9 Hz, H-5´´´), 4.15 (m, 2H, ^2J 11.0 Hz, C$H_2$$CH_2$O), 4.02 (m, 2H, $^3J_{2,3}$ 3.2 Hz, $^3J_{2',3'}$ 10.1 Hz, H-2, H-3´), 3.97 (m, 2H, ^2J 6.6 Hz, CH_2CH_2O, H-2´´), 3.87 (dd, 1H, $^3J_{1',2'}$ 3.6 Hz, H-2´), 3.83 (d, 1H, $^3J_{3'',4''}$ 9.5 Hz, H-4´´), 3.80 (dd, 1H, $^3J_{2,3}$ 3.2 Hz, $^3J_{3,4}$ 9.5 Hz, H-3), 3.79 (m, 1H, ^2J 12.3 Hz, ^2J 6.60 Hz, CH_2CH_2O), 3.72 (m, 1H, $^3J_{4,5}$ 9.5 Hz, $^3J_{5,6}$ 5.99 Hz, H-5), 3.55 (dd, 1H, $^3J_{2'',3''}$ 3.5 Hz, Hz, H-3´´), 3.52 (bs, 4H, H-5´´, OCH_3), 3.43 (t, 1H, $^3J_{4,5}$ 9.5 Hz, H-4), 1,39 (d, 3H, $^3J_{5'',6''}$ 6.3 Hz, H-6´´), 1.34 (d, 3H, $^3J_{5,6}$ 5.99 Hz, H-6); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 168.8 (COO), 166.0, 165.5, 165.5, 165.1 (C=O), 163.6 (*p*-$OPhNO_2$), 141.7 (*i*-$OPhNO_2$), 138.6, 138.3, 138.2, 137.9, 137.9 (*i*-Ph), 133.5, 133.2, 133.2, 133.1 (*p*-Bz), 129.9, 129.8, 129.7, 129.6 (*o*-Bz), 129.4, 129.2, 128.8, 128.6 (*i*-Bz), 128.5, 128.4, 128.4, 128.3, 128.2, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127,4, 127.1, 126.9, (*m*-Bz, *o*-Ph, *m*-Ph, *p*-Ph), 125.9 (*m*-$OPhNO_2$), 114.5 (*o*-$OPhNO_2$), 101.1 (C-1´´´), 99.4 (C-1´´), 97.6 (C-1), 97.4 (C-1´), 80.0 (C-4), 79.7 (C-3´´), 78.8 (C-3), 77.2 (C-3´), 76.6 (C-4´´), 75.3 (*C*H_2Ph), 74.8 (C-2´), 74.5 (C-2), 72.9 (C-4´), 72.6 (*C*H_2Ph), 72.5 (*C*H_2Ph), 71.8 (C-3´´), 71.8 (*C*H_2Ph), 71.7 (*C*H_2Ph), 71.0 (C-5´´´), 70.8 (C-5´), 70.1 (C-2´´´), 68.4 (C-5), 68.2 (C-4´´´), 68.0 (C-2´´), 67.7 (CH_2*C*H_2O), 67.1 (C-5´´), 65.4 (*C*$H_2$$CH_2$O), 61.9 (C-6´´´), 52.5 (OCH_3), 18.0 (C-6), 17.9 (C-6´´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{96}H_{95}NO_{27}$ $[M+Na]^+$: 1716.5984, found: 1716.5979.

Allyl 2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-[2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl]-(1→4)-3-*O*-benzyl-α-L-rhamnopyranoside (66)



Compound **61** (220 mg, 0.25 mmol), compound **40** (180 mg, 0.19 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (15 mL). After 20 min the mixture was cooled to –25 ^oC and $CF_3SO_3SiMe_3$ (30 μL, 0.16 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature, and stirring was continued for additional 2 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.25 mL, 1.8 mmol), molecular sieves were filtered off and washed with chloroform (3 × 5 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 toluene - EtOAc) gave compound **66** as colourless foam.

Yield: 245 mg (80%)

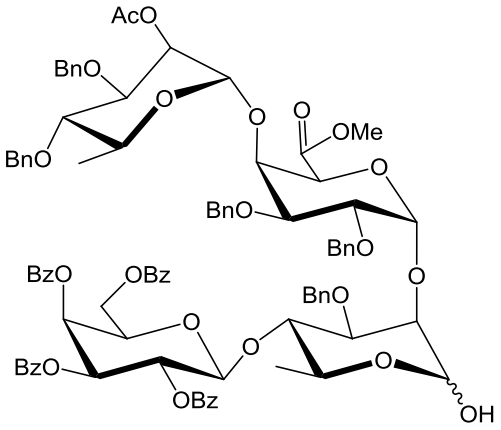
R_f: 0.36 (2 : 1 PE - EtOA)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.08 (m, 2H), 8.01 (m, 2H), 7.73 (m, 2H), 7.62 (m, 2H, *o*-Bz), 7.56 (m, 2H), 7.49–7.04 (m, 35H, *m*-Bz, *p*-Bz, Bn), 6.02 (d, 1H, $^3J_{3''',4'''}$ 3.5 Hz, H-4´´´), 5.87 (m, 1H, CH_2CH=CH_2), 5.80 (dd, 1H, $^3J_{2''',3'''}$ 10.4 Hz, $^3J_{1''',2'''}$ 8.0 Hz, H-2´´´), 5.58 (dd, 1H, $^3J_{2''',3'''}$ 10.4 Hz, $^3J_{3''',4'''}$ 3.5 Hz, H-3´´´), 5.47 (m, 1H, $^3J_{1'',2''}$ 1,9 Hz, $^3J_{2'',3''}$ 3.2 Hz, H-2´´) 5.41 (d, 1H, $^3J_{1''',2'''}$ 8.0 Hz, H-1´´´), 5.23 (d'q', 1H, $^3J_{8,9(Z)}$ 17.2 Hz, $^4J_{7,9}$ = ^2J 1.5 Hz, H-CH_2CH=CH_2), 5.20 (d'q', 1H, $^3J_{8,9(E)}$ 10.4 Hz, $^4J_{7,9}$ = ^2J 1.5 Hz, CH_2CH=CH_2), 5.13 (d, 1H,

$^{3}J_{1'',2''}$ 1.9 Hz, H-1´´), 4.91 (d, 1H, $^{3}J_{1',2'}$ 3.7 Hz, H-1´), 4.83 (d, 1H, ^{2}J 11.4 Hz, CH_2Ph), 4.82 (d, 1H, $^{3}J_{1,2}$ 1.7 Hz, H-1), 4.80 (d, 1H, ^{2}J 12.3 Hz, CH_2Ph), 4.68 (d, 2H, CH_2Ph), 4.66 (m, 3H, CH_2Ph, H-6´´´, H-5´), 4.59 (d, 1H, ^{2}J 10.8 Hz, CH_2Ph), 4.58 (d, 1H, ^{2}J 12.5 Hz, CH_2Ph), 4.53 (d, 1H, ^{2}J 11.4 Hz, CH_2Ph), 4.48–4.42 (m, 3H, H-6´´´, H-5´´´, H-4´), 4.33 (d, 1H, ^{2}J 10.9 Hz, CH_2Ph), 4.14 (m, 2H, ^{2}J 12.9 Hz, CH_2Ph, CH_2CH=CH$_2$), 4.00 (dd, 1H, $^{3}J_{3',4'}$ 10.1 Hz, $^{3}J_{2',3'}$ 3.6 Hz, H-3´), 3.98 (m, 1H, $^{3}J_{1,2}$ 1.9 Hz, H-2), 3.96 (m, 1H, CH_2CH=CH$_2$), 3.90 (dd, 1H, $^{3}J_{1',2'}$ 3.7 Hz, H-2´), 3.83 (m, 1H, $^{3}J_{3,4}$ 9.1 Hz, H-4), 3.78 (m, 1H, H-5) 3.75 (dd, 1H, $^{3}J_{2'',3''}$ 3.2 Hz, H-3´´), 3.70 (dd, 1H, $^{3}J_{2,3}$ 3.5 Hz, $^{3}J_{3,4}$ 9.1 Hz, H-3), 3.51 (m, 1H, $^{3}J_{4'',5''}$ 9.5 Hz, H-5´´), 3.29 (t, 1H, $^{3}J_{4'',5''}$ 9.5 Hz, H-4´´), 3.26 (s, 3H, OCH$_3$), 2.03 (s, 3H, CH$_3$CO), 1.45 (d, 3H, $^{3}J_{5,6}$ 6.0 Hz, H-6), 1.20 (d, 3H, H-6´´); **^{13}C NMR (125.8 MHz, CDCl$_3$):** δ 169.8 (CH$_3$*C*O), 168.4 (COO), 166.1, 165.5, 165.5, 165.4 (C=O), 138.9, 138.4, 138.2, 138.1, 138.1 (*i*-Ph), 133.7 (CH$_2$*C*H=CH$_2$), 133.5, 133.3, 133.2, 132.9 (*p*-Bz), 129.9, 129.7, 129.7, 129.5 (*o*-Bz), 129.3, 129.2, 129.0, 128.7 (*i*-Bz), 128.7, 128.6, 128.4, 128.3,128.3, 128.2, 128.2, 127.9, 127.9, 127.7, 127.6, 127.6, 127.2, 125.7 (*m*-Bz, *o*-Ph, *m*-Ph), 128.3. 127.6, 127.5, 127.4,127.3 (*p*-Ph), 117.6 (CH$_2$CH=*C*H$_2$), 101.3 (C-1´´´), 98.8 (C-1´´), 98.2 (C-1´), 96.5 (C-1), 79.6 (C-4´´), 79.0 (C-3), 78.0 (C-3´´), 77.7 (C-4), 77.3 (C-3´),74.7 (*C*H$_2$Ph), 74.6 (C-4´), 74.4 (C-2), 74.1 (C-2´), 72.9 (*C*H$_2$Ph), 72.5 (*C*H$_2$Ph), 71.9 (C-3´´´), 71.7 (*C*H$_2$Ph), 70.8 (C-5´´´), 70.7 (*C*H$_2$Ph), 70.6 (C-5´), 70.0 (C-2´´´), 68.7 (C-2´´), 68.2 (C-4´´´), 67.9 (*C*H$_2$CH=CH$_2$), 67.1 (C-5), 61.8 (C-6´´´), 52.0 (OCH$_3$), 21.0 (CH$_3$CO), 18.1 (C-6), 18.0 (C-6´´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{93}H_{94}O_{25}$ $[M+Na]^+$: 1633.5976, found: 1633.5965.

2-*O*-Acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate-(1→2)-[2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl]-(1→4)-3-*O*-benzyl-α/β-L-rhamnopyranose (46)



$PdCl_2$ (10 mg, 0.056 mmol) was added to a solution of compound **66** (240 mg, 0.15 mmol) in methanol-CH_2Cl_2 (1.6 : 1 v/v, 10 mL). After stirring for 16 h at ambient temperature (monitored by TLC) the reaction mixture was filtered through layer of silica by elution with methanol (2 × 3 mL). The combined organic solutions were concentrated and the residue was purified by column chromatography (5 : 1 Toluene - EtOAc) gave compound **67** as a colourless foam.

Yield: 208 mg (88%)

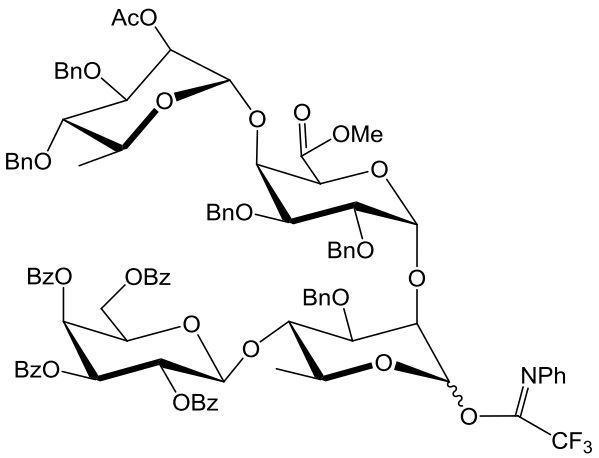
R_f: 0.3 α, 0.2 β (6 : 1 toluene - EtOAc)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.08 (m, 2H), 8.01 (m, 2H), 7.97 (m, 2H), 7.76 (m, 2H, *o*-Bz), 7.63–7.10 (m, 37H, *m*-Bz, *p*-Bz, Bn), 6.01 (d, 1H, $^3J_{3''',4'''}$ 3.5 Hz, H-4´´´), 5.82 (dd, 1H, $^3J_{2''',3'''}$ 10.4 Hz, $^3J_{1''',2'''}$ 8.0 Hz, H-2´´´), 5.65 (dd, 1H, $^3J_{2''',3'''}$ 10.4 Hz, $^3J_{3''',4'''}$ 3.5 Hz, H-3´´´), 5.49 (m, 1H, $^3J_{1'',2''}$ 1,9 Hz, $^3J_{2'',3''}$ 3.2 Hz, H-2´´), 5.34 (d, 1H, $^3J_{1''',2'''}$ 8.0 Hz, H-1´´´), 5.13 (d, 1H, $^3J_{1'',2''}$ 1.9 Hz, H-1´´), 4.98 (d, 1H, $^3J_{1',2'}$ 3.7 Hz, H-1´), 4.88 (d, 1H, ^2J 11.4 Hz, CH_2Ph), 4.78 (d, 1H, ^2J 10.7 Hz, H-6´´´), 4.77 (d, 1H, ^2J 11.3 Hz, CH_2Ph), 4.67 (d, 1H, ^2J 11.3 Hz, CH_2Ph), 4.64 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.59 (d, 1H, H-5´), 4.57 (d, 1H, ^2J 11.4 Hz, CH_2Ph), 4.54 (d, 1H, ^2J 12.3 Hz, CH_2Ph), 4.51 (bs, 1H, H-1), 4.44 (m, 1H, H-4´), 4.32 (m, 2H, ^2J 11.0 Hz, CH_2Ph, H-3´), 4.40–4.31(m, 2H, H-6´´´, H-5´´´), 4.21 (d, 1H, ^2J 12.3 Hz, CH_2Ph), 3.98 (dd, 1H, $^3J_{1',2'}$ 3.7 Hz, H-2´), 3.82 (dd, 1H, $^3J_{2'',3''}$ 3.2 Hz, H-3´´), 3.78 (m, 1H, $^3J_{3,4}$ 9.5 Hz, H-4), 3.78 (s, 3H, OCH_3), 3.67 (d, 1H, $^3J_{2,3}$ 3.8 Hz, H-2), 3.61 (m, 1H, $^3J_{4'',5''}$ 9.5 Hz, H-5´´), 3.41 (dd, 1H, $^3J_{2,3}$ 3.8 Hz, $^3J_{3,4}$ 9.5 Hz, H-3), 3.36 (m, 1H, $^3J_{4,5}$ 9.5 Hz, H-5), 3.34 (t, 1H, $^3J_{4'',5''}$ 9.5 Hz, H-4´´), 2.05 (s, 3H, CH_3CO), 1.43 (d, 3H, $^3J_{5,6}$ 6.0 Hz, H-6), 1.30 (d,

3H, H-6´´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.7 (CH_3CO), 168.0 (COO), 165.8, 165.5, 165.5, 165.4 (C=O), 138.9, 138.5, 138.2, 138.1, 137.5 (*i*-Ph), 133.6, 133.4, 133.3, 133.3, (*p*-Bz), 129.9, 129.7, 129.4, 129.3 (*o*-Bz), 129.3, 129.2, 129.0, 128.7 (*i*-Bz), 128.7, 128.6, 128.4, 128.3,128.3, 128.2, 128.2, 127.9, 127.9, 127.7, 127.6, 127.6, 127.2, (*m*-Bz, *o*-Ph, *m*-Ph), 128.3. 127.6, 127.5, 127.4,127.3 (*p*-Ph), 101.1 (C-1´´´), 99.1 (C-1´´), 95.7 (C-1´), 91.6 (C-1), 80.2 (C-3), 79.5 (C-4´´), 77.7 (C-3´´),77.5 (C-4´), 76.5 (C-4), 74.8 (CH_2Ph), 74.5 (C-3´), 73.8 (C-2), 73.0 (2 × CH_2Ph), 72.5 (C-5´), 71.7 (C-3´´´, CH_2Ph), 71.0 (C-5), 70.9 (C-5´´´), 70.3 (C-2´, C-2´´´), 68.6 (C-2´´), 68.3 (C-4´´´, C-5´´), 61.7 (C-6´´´), 52.4 (OCH_3), 21.0 (CH_3CO), 18.5 (C-6), 18.0 (C-6´´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{90}H_{90}O_{25}$ $[M+Na]^+$: 1593.5663, found: 1593.5661

2-*O*-Acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-[2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl]-(1→4)-3-*O*-benzyl-α/β-L-rhamnopyranoside *N*-phenyl trifluoroacetimidate (68)



Cs_2CO_3 (45 mg, 0.14 mmol) and 2,2,2-trifluoro-*N*-phenyl-acetimidoyl chloride (30 mg, 0.14 mmol) were consecutively added to compound **67** (160 mg, 0.1 mmol) in acetone (5 mL) at 0 ^{o}C. The cooling bath was removed, and the reaction mixture was stirred at ambient temperature. After 2 h (monitored by TLC) the reaction mixture was diluted with CH_2Cl_2 (5 mL), salts were filtered off and washed with EtOAc (2 × 3 mL). The combined organic solutions were concentrated and the residue was purified by column chromatography (3 : 1 PE - EtOAc) to give compound **68** as a colourless amorphous.

Yield: 150 mg (86%)

R_f: 0.39 (2 : 1 PE - EtOAc)

NMR at RT

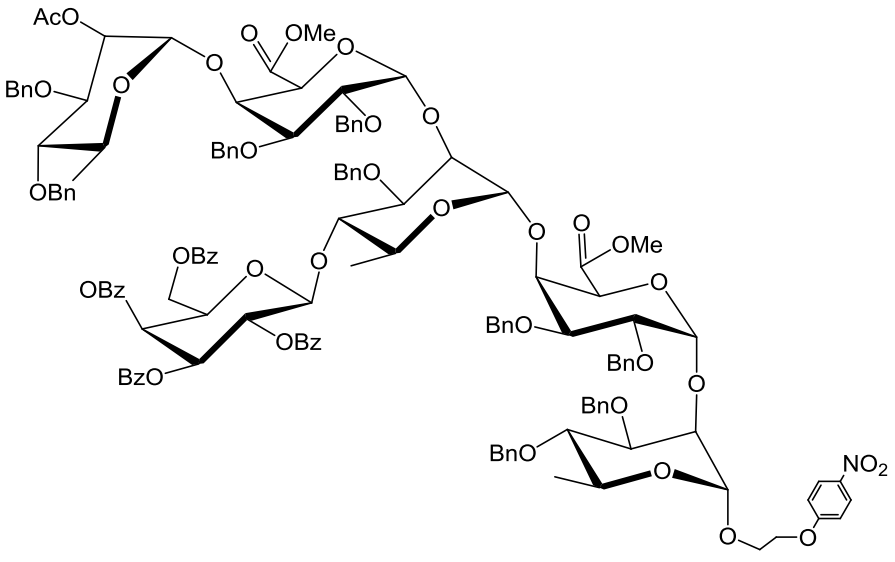
^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.07 (m, 2H), 7.98 (m, 2H), 7.72 (m, 2H, *o*-Bz), 7.62–7.07 (m, 44H, *m*-Bz, *p*-Bz, Bn, NPh), 6.80 (m, 2H, *m*-Bz), 6.01 (d, 1H, $^3J_{3‴,4‴}$ 3.4 Hz, $^3J_{4‴,5‴}$ 0.8 Hz, H-4‴´), 5.80 (dd, 1H, $^3J_{2‴,3‴}$ 10.4 Hz, $^3J_{1‴,2‴}$ 7.9 Hz, H-2‴´), 5.75 (bs, 1H, H-1), 5.65 (d, 1H, $^3J_{1´,2´}$ 3.2 Hz, H-1´), 5.60 (dd, 1H, $^3J_{2‴,3‴}$ 10.4 Hz, $^3J_{3‴,4‴}$ 3.4 Hz, H-3‴´), 5.46 (m, 1H, $^3J_{1´´,2´´}$ 2,0 Hz, H-2´´), 5.39 (d, 1H, $^3J_{1‴,2‴}$ 7.9 Hz, H-1‴´), 5.10 (d, 1H, $^3J_{1´´,2´´}$ 2.0 Hz, H-1´´), 4.90 (d, 1H, ^2J 11.7 Hz, CH_2Ph), 4.85 (d, 2H, ^2J 11.4 Hz, CH_2Ph), 4.77 (d, 1H, $^3J_{4‴,5‴}$ 0.8 Hz, H-5‴´), 4.72 (d, 1H, ^2J 11.6 Hz, CH_2Ph), 4.66 (d, 2H, ^2J 11.7 Hz, CH_2Ph), 4.63 (m, 1H, ^2J 11.0 Hz, CH_2Ph), 4.61 (d, 1H, ^2J 8.8 Hz, H-6‴´), 4.57 (d, 2H, CH_2Ph), 4.53 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.48 (d, 1H, ^2J 11.0 Hz, H-6‴´), 4.44 (m, 3H, H-2, H-3´, H-5‴´), 4.32 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.22 (d, 1H, ^2J 12.6 Hz, CH_2Ph), 3.99 (m, 2H, H-2´), 3.92 (m, 1H, $^3J_{3,4}$ 9.2 Hz, H-4), 3.78 (dd, 1H, $^3J_{2´´,3´´}$ 3.2 Hz, $^3J_{3´´,4´´}$ 9.2 Hz, H-3´´), 3.55 (m, 1H, $^3J_{4´´,5´´}$ 9.5 H-5´´), 3.52 (m, 1H, H-5), 3.47 (m, 1H, Hz, H-3), 3.30 (t, 1H, $^3J_{4´´,5´´}$ 9.5 Hz, H-4´´), 3.28 (s, 3H, OCH_3), 2.04 (s, 3H, CH_3CO), 1.54 (d, 3H, $^3J_{5,6}$ 6.0 Hz, H-6), 1.20 (d, 3H, H-6´´);
^{13}C NMR (125.8 MHz, $CDCl_3$): δ 169.7 (CH_3CO), 168.5 (COO), 166.1, 165.5, 165.5, 165.2 (C=O), 143.2 (*i*-NPh),138.9, 138.6, 138.3, 138.1, 137.2 (*i*-Ph), 133.6, 133.3, 133.2, 133.0, (*p*-Bz), 129.9, 129.7, 129.4, 129.3 (*o*-Bz), 129.3, 129.2, 129.0, 128.7 (*i*-Bz), 128.7, 128.6, 128.4, 128.3,128.3, 128.2, 128.2, 127.9, 127.8, 127.8, 127.6, 127.6, 127.2, (*m*-Bz, *o*-Ph, *m*-Ph), 128.3. 127.6, 127.5, 127.4, 127.3, 119.2 (*p*-Ph), 101.3 (C-1‴´), 99.2 (C-1´´), 97.4 (C-1´), 95.3 (C-1), 81.4 (C-3),79.6 (C-4´´), 77.8 (C-3´´), 77.4 (C-4), 76.9 (C-4´), 75,3 (C-3´),74.6 (CH$_2$Ph), 74.6 (C-2´), 72.9 (CH$_2$Ph), 72.5 (C-5), 71.7 (C-3‴´), 71.6 (2 × CH$_2$Ph), 71.5 (CH$_2$Ph), 71.1 (H-3´), 70.9 (C-2), 70.2 (C-5‴´), 70.1 (C-2‴´), 68.7 (C-2´´), 68.2 (C-5´´), 68.1 (C-4‴´), 61.9 (C-6‴´), 52.0 (OCH_3), 21.1 (CH_3CO), 18.0 (C-6, C-6´´).

NMR at -40 ^{o}C

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.05 (m, 2H), 8.00 (m, 2H), 7.73 (m, 2H,), 7.65 (m, 2H, *o*-Bz), 7.53–7.01 (m, 41H, *m*-Bz, *p*-Bz, Bn), 6.81 (m, 2H, *m*-Bz), 6.02 (d, 1H, $^3J_{3‴,4‴}$ 3.2 Hz, H-4‴´), 5.88 (bs, 1H, H-1), 5.77 (dd, 1H, $^3J_{2‴,3‴}$ 10.4 Hz, $^3J_{1‴,2‴}$ 7.9 Hz, H-2‴´), 5.61 (d, 1H, $^3J_{1´,2´}$ 3.2 Hz, H-1´), 5.55 (dd, 1H, $^3J_{2‴,3‴}$ 10.4 Hz, $^3J_{3‴,4‴}$ 3.2 Hz, H-3‴´), 5.42 (m, 2H, $^3J_{1´´,2´´}$ 1,9 Hz, $^3J_{1‴,2‴}$ 7.9 Hz, H-2´´, H-1‴´), 5.06 (bs, 1H, $^3J_{1´´,2´´}$ 1.9 Hz, H-1´´), 4.97 (d, 1H, ^2J 12.0 Hz, CH_2Ph), 4.83 (d, 2H, ^2J 11.0 Hz, CH_2Ph), 4.74 (d, 1H, ^2J 11.7 Hz, CH_2Ph), 4.70–4.64 (m, 4H, ^2J 11.3 Hz, CH_2Ph, H-6‴´), 4.50 (m, 5H, ^2J 11.4 Hz, CH_2Ph, H-2, H-4´, H-5‴´),

4.43 (m, 1H, ^{2}J 10.7 Hz, H-6´´´), 4.22 (d, 1H, ^{2}J 10.4 Hz, CH_2Ph), 4.13 (d, 1H, ^{2}J 12.6 Hz, CH_2Ph), 4.05 (dd, 1H, $^{3}J_{2´,3´}$ 10.3 Hz, H-3´), 4.00 (dd, 1H, $^{3}J_{1´,2´}$ 3.2 Hz, $^{3}J_{2´,3´}$ 10.3 Hz, H-2´), 3.90 (m, 1H, $^{3}J_{3,4}$ 9.5 Hz, H-4), 3.73 (dd, 1H, $^{3}J_{2´´,3´´}$ 3.0 Hz, $^{3}J_{3´´,4´´}$ 9.5 Hz, H-3´´), 3.65 (m, 1H, H-5), 3.53 (dd, 1H, $^{3}J_{3,4}$ 9.5 Hz, H-3), 3.47 (m, 1H, $^{3}J_{4´´,5´´}$ 9.5 Hz, H-5´´), 3.25 (t, 1H, $^{3}J_{4´´,5´´}$ 9.5 Hz, H-4´´), 3.12 (s, 3H, OCH_3), 2.03 (s, 3H, CH_3CO), 1.58 (d, 3H, $^{3}J_{5,6}$ 6.0 Hz, H-6), 1.20 (d, 3H, H-6´´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.9 (CH_3CO), 168.6 (COO), 165.8, 165.5, 165.5, 165.4 (C=O), 138.5, 138.0, 137.8, 137.4, 137.0 (*i*-Ph), 133.7, 133.5, 133.4, 133.1, (*p*-Bz), 129.8, 129.7, 129.4, 129.3 (*o*-Bz), 129.3, 129.2, 129.0, 128.7 (*i*-Bz), 128.7, 128.6, 128.4, 128.3,128.3, 128.2, 128.2, 127.9, 127.9, 127.7, 127.6, 127.6, 127.2, (*m*-Bz, *o*-Ph, *m*-Ph), 128.3. 127.6, 127.5, 127.4,127.3 (*p*-Ph), 100.9 (C-1´´´), 98.9 (C-1´´), 97.3 (C-1´), 94.6 (C-1), 81.5 (C-4´´), 77.6 (C-3´´),77.5 (C-4´), 76.7 (C-4), 76,3 (C-3´),74.6 (*C*H_2Ph), 73.3 (C-2´), 72.3 (C-5, *C*H_2Ph), 71.5 (*C*H_2Ph), 71.3 (C-3´´´), 71.0 (*C*H_2Ph), 70.8 (*C*H_2Ph), 70.2 (C-5´´´), 69.7 (C-2), 69.2 (C-2´´´), 68.0 (C-2´´), 67.8 (C-5´´), 67.4 (C-4´´´), 61.6 (C-6´´´), 52.3 (OCH_3), 21.3 (CH_3CO), 17.9 (C-6, C-6´´).

2-(4-Nitrophenoxy)ethyl (2-*O*-acetyl-3,4-di-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-[2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl]-(1→4)-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-3,4-di-*O*-benzyl-α-L-rhamnopyranoside (69)



Via **68** and **32.** Compound **68** (120 mg, 0.07 mmol), compound **32** (80 mg, 0.09 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (5 mL). After 20 min the mixture was cooled to –25 ^oC and $CF_3SO_3SiMe_3$ (20 μL, 0.11 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature, and stirring was continued for additional 2 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.15 mL, 1.1 mmol), molecular sieves were filtered off and washed with chloroform (3 × 2 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 toluene - EtOAc) gave compound **69** as colourless foam.

Yield: 87 mg (51%)

R_f: 0.18 (2 : 1 PE - EtOA)

Via **65** and **40.** Compound **65** (122 mg, 0.07 mmol), compound **40** (84 mg, 0.09 mmol) and molecular sieves (4Å, 2 g) were dried for 2 h under high vacuum. The mixture was suspended in dry CH_2Cl_2 (5 mL). After 20 min the mixture was cooled to –25 ^oC and $CF_3SO_3SiMe_3$ (20 μL, 0.11 mmol) was added dropwise. After stirring for 1 h the mixture was slowly warmed up to room temperature, and stirring was continued for additional 2 h at ambient temperature (monitored by TLC). The solution was neutralized by Et_3N (0.15 mL, 1.1 mmol), molecular sieves were filtered off and washed with chloroform (3 × 2 mL). The combined organic solutions were concentrated. Purification by column chromatography (6 : 1 Toluene - EtOAc) gave compound **69** as colourless foam.

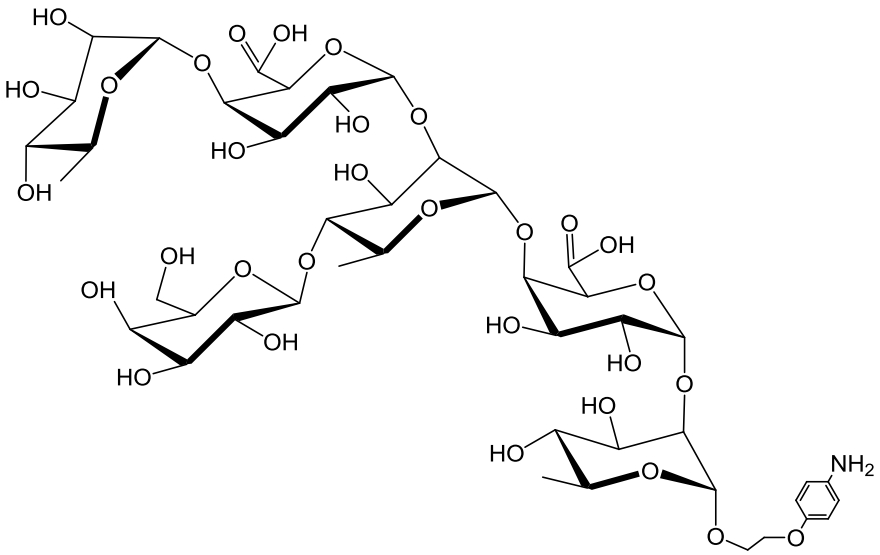
Yield: 51 mg (30%)

^{1}H NMR (500.13 MHz, $CDCl_3$): δ 8.19 (m, 2H, *m*-$OPhNO_2$), 8.05 (m, 2H), 7.89 (m, 2H), 7.71 (m, 2H), (*o*-Bz), 7.63–7.02 (m, 59H, *o*-Bz, *m*-Bz, *p*-Bz, Bn), 6.91 (m, 2H, *o*-$OPhNO_2$), 6.00 (d, 1H, $^3J_{3''''',4''''}$ 3.5 Hz, H-4´´´´´), 5.75 (dd, 1H, $^3J_{2''''',3''''}$ 10.5 Hz, $^3J_{1''''',2''''}$ 8.0 Hz, H-2´´´´´), 5.60 (d, 1H, $^3J_{1'',2''}$ 1.3 Hz, H-1´´), 5.53 (dd, 1H, $^3J_{2''''',3''''}$ 10.5 Hz, $^3J_{3''''',4''''}$ 3.5 Hz, H-3´´´´´), 5.45 (dd, 1H, $^3J_{1''''',2''''}$ 1,8 Hz, $^3J_{2''''',3''''}$ 3.2 Hz, H-2´´´´), 5.41 (d, 1H, $^3J_{1''''',2''''}$ 8.0 Hz, H-1´´´´´), 5.09(d, 1H, $^3J_{1''''',2''''}$ 1.8 Hz, H-1´´´´), 5.04 (d, 1H, $^3J_{1',2'}$ 3.5 Hz, H-1´), 4.97 (d, 1H, $^3J_{1''',2'''}$ 3.7 Hz, H-1´´´), 4.84 (d, 1H, CH_2Ph), 4.82 (m, 2H, ^2J 11.0 Hz, CH_2Ph, H-5´), 4.76 (d, 1H, $^3J_{1,2}$ 1.7 Hz, H-1), 4.69 (m, 2H, CH_2Ph, H-5´´´), 4.63 (m, 3H, CH_2Ph), 4.60 (m, 3H, H-6´´´´´, CH_2Ph), 4.58 (m, 3H, ^2J 11.0 Hz, CH_2Ph), 4.54 (m, 4H, ^2J 11.0 Hz, CH_2Ph, H-6´´´´´, H-4´´´), 4.50 (d, 1H, ^2J 11.7 Hz, CH_2Ph), 4.45 (m, 2H, ^2J 11.7 Hz, CH_2Ph), 4.42 (m, 3H, ^2J 11.7 Hz, CH_2Ph, H-5´´´´´, H-5´´´), 4.32 (d, 1H, ^2J 11.0 Hz, CH_2Ph), 4.21 (d, 1H, ^2J

12.3 Hz, CH_2Ph), 4.16 (m, 1H, $^3J_{1'',2''}$ 1.3 Hz, H-2´´), 4.13 (m, 2H, CH_2CH_2O, H-4´), 4.00 (m, 2H, H-2, CH_2CH_2O), 3.94 (m, 3H, ^2J 12.9 Hz, $^3J_{1',2'}$ 3.5 Hz, $^3J_{2''',3'''}$ 3.2 Hz, CH_2CH_2O, H-2´, H-3´´´), 3.85 (t, 1H, $^3J_{3'',4''}$ 9.5 Hz, H-4´´), 3.79 (m, 2H, $^3J_{2''',3'''}$ 3.2 Hz, H-2´´´, H-3), 3.75 (m, 2H, $^3J_{2'''',3''''}$ 3.2 Hz, $^3J_{3'''',4''''}$ 9.5 Hz, H-3´´´´, H-3´), 3.69 (m, 2H, $^3J_{4,5}$ 9.5 Hz, $^3J_{5,6}$ 6.3 Hz, H-5), 3.60 (dd, 1H, $^3J_{2'',3''}$ 3.2 Hz, H-3´´), 3.53(m, 2H, H-5´´, H-5´´´´), 3.51 (s, 3H, OCH_3), 3.38 (t, 1H, $^3J_{4,5}$ 9.5 Hz, H-4), 3.28 (t, 1H, $^3J_{3'''',4''''}$ 9.5 Hz, H-4´´´´), 3.21 (s, 3H, OCH_3), 2.02 (s, 3H, CH_3CO), 1.45 (d, 3H, $^3J_{5'',6''}$ 6.0 Hz, H-6´´), 1.32 (d, 3H, $^3J_{5,6}$ 6.3 Hz, H-6), 1.20 (d, 3H, $^3J_{5'''',6''''}$ 6.3 Hz, H-6´´´´); **^{13}C NMR (125.8 MHz, $CDCl_3$):** δ 169.8 (CH_3*C*O), 169.0, 168.0 (COO), 166.1, 165.5, 165.5, 165.2 (C=O), 163.7 (*p*-OPhNO_2), 141.7 (*i*-OPhNO_2), 138.9, 138.6, 138.4, 138.3, 138.2, 138,2, 138.2, 138.1, 137.7 (*i*-Ph), 133.5, 133.3, 133.2, 132.9 (*p*-Bz), 129.9, 129.7, 129.6, 129.5 (*o*-Bz), 129.3, 129.2, 128.8, 128.8 (*i*-Bz), 128.7, 128.6, 128.4, 128.3, 128.3, 128.2, 128.2, 128.1, 128.1, 128.0, 127.8, 127.7, 127.7, 127.5, 127.4, 127.4, 127,3, 126.9, 125.5 (*m*-Bz, *o*-Ph, *m*-Ph, *p*-Ph), 125.9 (*m*-OPhNO_2), 114.5 (*o*-OPhNO_2), 101.1 (C-1´´´´´), 98.9 (C-1´´´´), 97.5 (C-1), 97.3 (C-1´´´), 97.1 (C-1´, C-1´´), 80.2 (C-4), 79.6 (C-4´´´´), 79.0 (C-3´´), 78.7 (C-3), 78.0 (C-3´, C-3´´´´), 77.4 (C-3´´´), 77.2 (C-4´´), 75.5 (C-2´), 75.3 (*C*H_2Ph), 74.8 (*C*H_2Ph), 74.6 (C-5´´´), 74.3 (C-2), 73.9 (C-2´´´), 73.5 (C-2´´), 72.7 (2 × *C*H_2Ph), 72.4 (*C*H_2Ph), 72.1 (*C*H_2Ph), 72.0 (C-3´´´´´, C-4´´´), 71.8 (*C*H_2Ph), 71.7 (*C*H_2Ph), 70.9 (C-5´), 70.8 (C-5´´´´´), 70.4 (C-5´´´), 69.9 (C-2´´´´´), 68.7 (C-2´´´´), 68.4 (C-5), 68.1 (C-4´´´´´, C-5´´´´), 67.7 (CH_2*C*H_2O), 67.6 (C-5´´), 65.4 (*C*H_2CH_2O), 61.8 (C-6´´´´´), 52.7 (OCH_3), 52.0 (OCH_3), 21.1 (CH_3CO), 18.1 (C-6´´), 18.0 (C-6, C-6´´´´).

HRMS, ESI-TOF/MS positive (m/z): calcd for $C_{139}H_{141}NO_{38}$ $[M+Na]^+$: 2454.9024, found: 2454.9028.

2-(4-aminoperoxy)ethyl (α-L-rhamnopyranosyl-(1→4)-(α-D-galactopyranosyluronate)-(1→2)-[β-D-galactopyranosyl]-(1→4)-α-L-rhamnopyranosyl-(1→4)-(α-D-galactopyranosyluronate)-(1→2)-α-L-rhamnopyranoside (71)



10% Palladium on charcoal (20 mg) was added to a solution of compound **69** (95 mg, 0.04 mmol) inmixture of methanol and ethylacetat (1 : 1, v/v, 10 mL), and the reaction mixture was stirred at ambient temperature under an atmosphere of hydrogen. After 48 h (monitored by TLC) the reaction mixture was filtered over celite by elution with methanol, and combined organic solutions were concentrated to obtain compound **70**. Lithiumhydroxid (4 mg, 0.17 mmol) was added to a suspension of compound **70** in a mixture of methanol and water (2 : 1, v/v, 5 ml). After stirring for 15 min at ambient temperature (monitored by TLC) the solution was passed through a column of Dowex-50 (H^+). Methanol was removed from the solution by evaporation under reduced pressure and the residue was repeatedly dissolved in water and lyophilized to obtain tetrasaccharid **71** as a colourless foam.

Yield: 37 mg (85%)

R_f: 0.15 (1 : 1 $CHCl_3$ - MeOH)

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6. ABBREVIATIONTS

abs.	absolute
Ac	acetyl
All	allyl
aq	aqueous
Bz	benzoyl
Bn	benzyl
br.	broud
calcd	calculated
CI	chemical ionization
COSY	correlated spectroscopy
dd	doublet of doublets
ddd	doublet of doublets doublet of doublets
dddd	doublet of doublets doublet of doublets doublet of doublets
dec.	decomposition
DBU	1,8-Diaazabicyclo[5.4.0]undec-7-en
DEPT	distortionless enhancement by polarization transfer
DMF	N,N-dimethylformamide
DMSO	dimethylsulfoxide
DNA	deoxyribonucleic acid
dq	doublet of quartets
dt	doublet of triplets
dRG	dimmer of rhamnogalacturonan
EI	electron impact
ESI	electrospray
Et	ethyl
FAB	fast atom bombardment
Fig.	Figure
GalA	galacturonic acid
Gal*p*A	galactopyranuronic acid
HG	homogalacturonan

HMBC	heteronuclear multiple bond correlation
HPLC	high performance liquid chromatography
HRMS	high resolution mass spectroscopy
HSQC	heteronuclear single quantum coherence
Hz	hertz
lit.	literature
m	multiplet
Me	methyl
MHz	megahertz
M.p.	melting point
MPLC	medium pressure liquid chromatography
MS	Mass spectroscopy
MS 4Å	molecular sieves 4 angstrem
m/z	mass to charge ratio
NMR	Nuclear magnetic resonance
NOESY	nuclear Overhauser effect spectroscopy
pH	pondus hydrogenii
Ph	phenyl
q	quartet
ref.	Referenced
R_f	retention factor
RG	rhamnogalacturonan
RT	room temperature
s	singlet
t	triplet
TfOH	trifluromethan sulfonic acid
TMSOTf	trimethylsilyl trifluromethane sulfonate
TLC	thin layer chromatography
[α]	optical rotation
δ	chemical shift

ERKLÄRUNG

Ich versichere hiermit an Eides statt, dass ich die vorliegende Arbeit selbstständig angefertigt und ohne fremde Hilfe verfasst habe, keine außer den von mir angegebenen Hilfsmitteln und Quellen dazu verwendet habe und die den benutzten Werken inhaltlich und wörtlich entnommenen Stellen als solche kenntlich gemacht habe

Rostock, 25.09.2013