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Synthesis of rhamnogalacturonan I fragments by a modular design principle☆

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Abstract—The improved syntheses of methyl 2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranoside (**12**) and 1,2-di-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranose (**15**), which were used as glycosyl acceptor and donor, respectively, are described. Glycosylation of the O-4 position of both rhamnose derivatives with 2,3,4,6-tetra-*O*-benzoyl-α-D-galactopyranosyl bromide (**26**) provided disaccharides **27** and **29**. After partial deprotection of **27** and coupling of the resulting **28** with disaccharide **19**, tetrasaccharide **31** was obtained. Furthermore, transforming of **29** into the corresponding bromide **30** and coupling with galacturonates **16** and **32** provided trisaccharides **33** and **34**, respectively, which could be regarded as building blocks of ramified rhamnogalacturonan fragments. The preparation of tetra- (**21**) and hexasaccharide (**25**) of rhamnogalacturonan I is reported to demonstrate the feasibility of the synthesis of larger pectin fragments using the modular design principle with this type of building blocks.

Keywords: D-Galacturonic acid; L-Rhamnose; D-Galactose; Oligosaccharides; Pectin fragments; Glycosylation; Building blocks

1. Introduction

Recent studies have shown that many plants used in traditional medicine to treat various types of diseases contain polysaccharides exhibiting biological activity of different kinds. Pectins are an example for complex polysaccharides possessing such an activity.[1,2] Pectin structures consist of a homogalacturonan backbone interrupted by ramified rhamnogalacturonan regions.[3,4] The latter, the so-called hairy region, contains α-(1→2)-linked L-rhamnose units carrying neutral carbohydrate side chains, typically composed of D-galactose and D-arabinose.[5] The enzymes responsible for the glycosylation of rhamnose residues with the first galactose or arabinose molecule have not been identified at this point.[§,6,7] Therefore, classical synthetic carbohydrate chemistry must be used to obtain these structures.[8] Pursuing our programme directed towards the chemical synthesis of well-defined pectin fragments for structure–activity relationship investigations,[9,10] we report herein the preparation of a rhamnogalacturonan I (RG-I) tetra- and hexasaccharide by means of a modular design principle. Furthermore, the synthesis of building blocks for D-galactose-ramified RG-I fragments is described.

2. Results and discussion

The backbone of the RG-I polymer is composed of repeating units of the disaccharide →2)-α-L-Rha*p*-(1→4)-α-D-Gal*p*A-(1→. In these oligomers, the first

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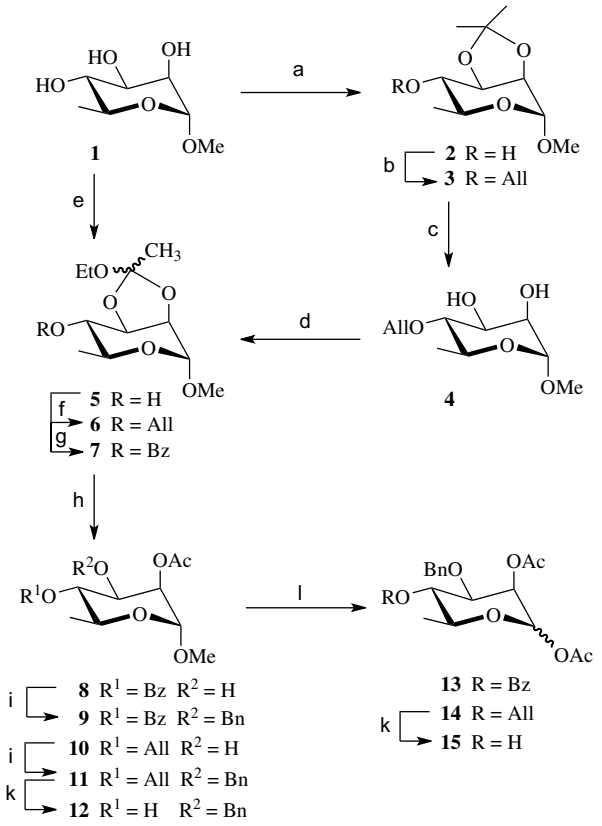
D-galactopyranose residue is β-glycosidically linked to the O-4 position of a rhamnose moiety. Our strategy adopted for the synthesis of larger RG-I oligomers, as well as building blocks for D-galactose-ramified RG-I fragments, involved in the preparation of L-rhamnose intermediates that allowed stereoselective formation of the required α-glycosidic bond to D-galacturonates, the regioselective deblocking of a protected O-4 position, the preparation of RG-I-modules and finally the coupling of these modules by a modular design principle.

For the synthesis of suitable L-rhamnose derivatives, we evaluated two routes as shown in Scheme 1. Methyl α-L-rhamnopyranoside (**1**)[11] was isopropylidenated (**2**),[12] allylated (**3**),[13] and then hydrolyzed[13] to give intermediate **4**. For the allylation reaction, *N*,*N*-dimethylformamide (DMF) was replaced by dry tetrahydrofuran as the solvent to avoid the need for the tedious removal of residual traces of the former solvent.



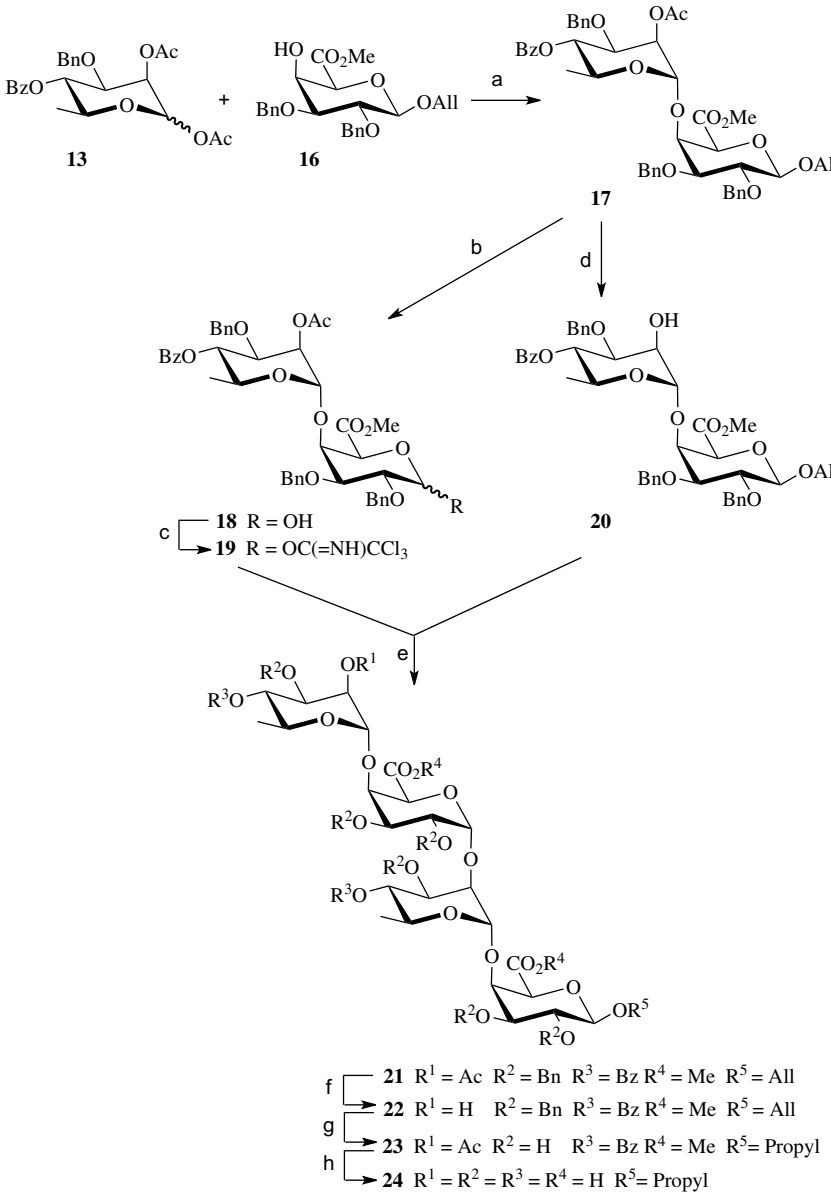
Scheme 1. Alternative pathways for the preparation of L-rhamnose derivatives **12** and **15** used as glycosyl acceptors for the introduction of a D-galactose residue at their O-4 positions. Reagents and conditions: (a) anhyd $CuSO_4$, dry acetone, 10 h, 20 °C (**2** 98%); (b) allyl bromide, NaH, dry THF, 20 h, 20 °C, Ar atmosphere (**3** 75%); (c) H_2SO_4 (cat.), EtOH–toluene (1:1), 2 h, reflux (**4** 86%); (d) $CH(OEt)_3$, camphorsulfonic acid, dry CH_2Cl_2, 35 min, 20 °C, Ar atmosphere (**6** 98%); (e) $CH(OEt)_3$, camphorsulfonic acid, dry DMF, 40 min, 20 °C, Ar atmosphere, (**5** 65%); (f) allyl bromide, NaH, dry DMF, 3 h, 0 °C→20 °C, Ar atmosphere (**6** 98%); (g) benzoyl chloride, dry pyridine, 9 h, −20 °C→20 °C, Ar atmosphere (**7** 98%); (h) 60% aq acetic acid, 30 min, 20 °C (**8** 90%, **10** 91%); (i) benzyl 2,2,2-trichloroacetamide, CF_3SO_3H (cat.), dry CH_2Cl_2–heptane, 22 h, −10 °C→20 °C, Ar atmosphere (**9** 64%, **11** 78%); (k) $PdCl_2$, AcOH, NaOAc, H_2O, 4–6 h, 40 °C (**12** 63%, **15** 67%); (l) Ac_2O, AcOH, H_2SO_4 (cat.), 3 h, −30 °C→0 °C (**13** 91%, **14** 77%).

Treatment of **4** with triethylorthoacetate in CH_2Cl_2 followed by regioselective opening of the orthoester structure in **6**[14] led to the formation of an acetyl protecting group at the O-2 position (**10**). This acetyl group was involved in neighbouring participation in a later glycosylation reaction and served as a temporary protecting group during the block wise synthesis of higher pectin fragments. The regioselective ring opening of orthoester **6** was proven by ^{1}H NMR spectroscopy. As expected, the acetyl substituent at O-2 position caused a considerable downfield shift of the H-2 signal from δ 3.90 ppm in the ^{1}H NMR spectrum of compound **4** to δ 5.01 ppm in the spectrum of **10**.

In a previous paper, we described an alternative route targeting the preparation of the 4-*O*-benzoyl derivative **8**.[15] Here, the formation of the orthoester structure in **5** could only be achieved in a solvent mixture of DMF and toluene. In multi-gram scale experiments, the use of DMF as a solvent crucially prolonged work-up times resulting in the migration of the acetyl groups in **8** as well as in **10**. Therefore, for scale-up, the pathway via the isopropylidene derivative **2** was more convenient because this route avoided DMF in every reaction step.

Benzylation of **8** and **10** using benzyl trichloroacetimidate and a catalytic amount of trifluoromethanesulfonic acid[16] provided **9**[15] and **11** in 64% and 78% yield, respectively. Acetolysis[17] of **9** and **11** gave predominantly the α-acetate **13α**[15] and compound **14** in 84% and 71%, respectively. Small amounts of the β-acetate (**14β**) could be isolated by flash chromatography. The stereochemistry at the anomeric centre was evident only from the geminal ^{13}C–^{1}H coupling constants $J_{C\text{-}1,H\text{-}1}$. The observed values of 173.5 Hz and 161.5 Hz for **14α** and **14β**, respectively, verified the proposed structures.[18] Deallylation of compounds **11** and **14** with the aid of palladium(II)chloride[19] provided intermediates **12** and **15** in 63% and 67% yield, respectively, which served as glycosyl acceptors for the introduction of a galactose residue into the O-4 position.

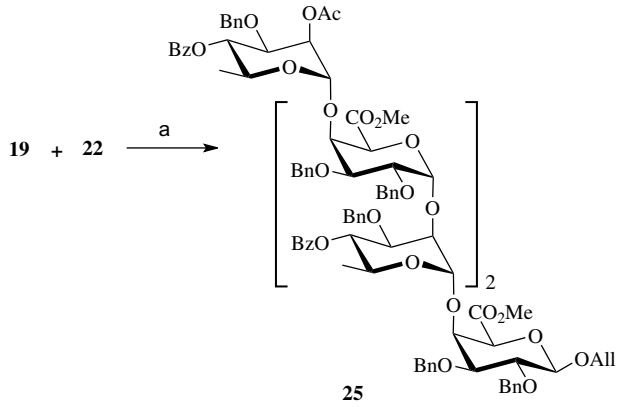
The 4-*O*-benzoyl derivate **13** was employed as glycosyl donor for the preparation of disaccharide module **17** by coupling with the galacturonate acceptor **16** in the presence of trimethylsilyl trifluoromethanesulfonate (Scheme 2). The disaccharide synthesis as well as the transformation of module **17** into either glycosyl acceptor **20** by selective deacetylation of the O-2′ position with 0.28 M methanolic hydrochloric acid[20] or into glycosyl donor **19** by deallylation and the introduction of the trichloroacetimidate function have been described previously.[15] Contrary to the results observed by Reiffarth and Reimer[21] who employed a similar block synthetic approach,[22] trimethylsilyl trifluoromethane-



Scheme 2. Synthesis of rhamnogalacturonan tetrasaccharide **21** by a modular design principle and its partial deprotection. Reagents and conditions: (a) **13**:**16** molar ratio 1.3:1, $CF_3SO_3SiMe_3$, mol. sieves, dry CH_2Cl_2, 18 h, 20 °C, Ar atmosphere, darkness (**17**, 88%); (b) $PdCl_2$, AcOH, NaOAc, H_2O, 4–6 h, 40 °C (**18** 75%); (c) trichloroacetonitrile, DBU (cat.), dry CH_2Cl_2, 2 h, −20 °C→20 °C, Ar atmosphere (**19** 69%); (d) 0.28 M methanolic HCl, 36 h, 20 °C, Ar atmosphere (**20** 98%); (e) $CF_3SO_3SiMe_3$, mol. sieves, dry CH_2Cl_2, 21 h, −70 °C→20 °C, Ar atmosphere, darkness (**21** 60%); (f) 0.28 M methanolic HCl, 48–72 h, 20 °C, Ar atmosphere (**22** 97%); (g) Pd/C, H_2, EtOH, 18 h, 20 °C (**23** 97%); (h) LiOH, MeOH, H_2O, 15 min, 20 °C (**24** 86%).

sulfonate-promoted glycosylation of acceptor **20** with donor **19** in a molar ratio of 1:1, provided tetrasaccharide **21** in 60% isolated yield after chromatographic purification (Scheme 2). In a model reaction, the benzyl protecting groups of **21** were removed by hydrogenolysis over Pd–C resulting in the propyl glycoside **23**. The anomeric centre was not deprotected in these experiments to maintain the configuration and obtain well-resolved NMR spectra. Next, the cleavage of the ester linkages was achieved in methanol and water in the presence of lithium hydroxide at room temperature to provide the nearly completely deprotected tetrasaccharide **24** in excellent yield.

Selective deacetylation of tetrasaccharide **21** using again 0.28 M methanolic hydrochloric acid yielded the glycosyl acceptor **22**, which was glycosylated (Scheme 3) with donor **19** to give hexasaccharide **25** in 59% yield after HPLC purification. The α-configuration at the newly generated stereogenic centre in the tetrasaccharide as well as in the hexasaccharide was verified by ^{13}C NMR spectroscopy. For the completely protected rhamnogalacturonate oligomers the α-linked anomeric

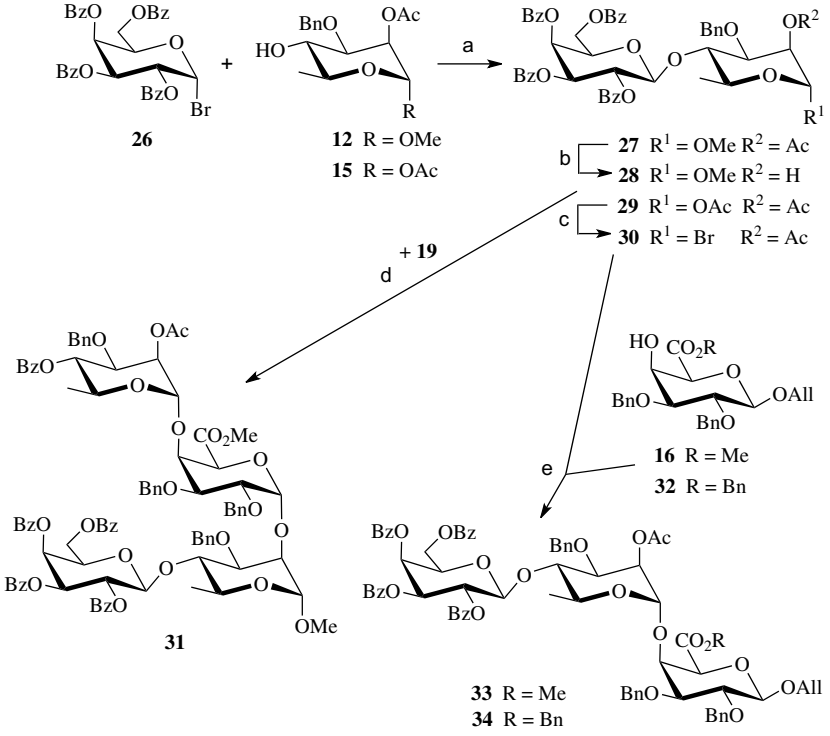


Scheme 3. The extension of the synthesis of rhamnogalacturonan I fragments by a modular design principle to furnish hexasaccharide **25**. Reagents and conditions: (a) $CF_3SO_3SiMe_3$, mol. sieves, dry CH_2Cl_2, 21 h, −70 °C→20 °C, Ar atmosphere, darkness (**25** 59%).

carbons resonated between δ_C 97.60 and 99.77, while the signals for the β-linked anomeric carbon (C-1) appeared in the range of 102.72–102.84. All NMR data were in accordance with the proposed structures. It should be noted that in the crude glycosylation reaction mixtures, traces (<5%) of β-linked oligosaccharides were observed by NMR investigations. However, the total isolated amounts of these isomers were too small for full characterization.

Furthermore, the coupling of the benzoylated galactosyl bromide **26**[23,24] prepared using the procedure by Kochetkov and co-workers[25] with either methyl rhamnoside **12** or diacetate **15** as glycosyl acceptors was performed in the presence of silver trifluoromethanesulfonate (Scheme 4). After standard work-up and purification by HPLC, disaccharides **27** and **29** were obtained in 66% and 68% yields, respectively. The protected disaccharide **27** was subjected to selective deacetylation to give 58% of the glycosyl acceptor **28**. Alternatively, diacetate **29** was transformed in 90% yield into the corresponding bromide **30** using the procedure by Gillard and Israel.[26] In an effort to evaluate the capability of the prepared galactosyl-rhamnosides to serve as structural elements for the synthesis of ramified RG-1 fragments, acceptor **28** was glycosylated with rhamnogalacturonate **19** to provide tetrasaccharide **31** in 62% isolated yield. Again, traces (less than 5%) of a β-linked isomer were observed in the ^{13}C NMR spectra of the crude reaction mixture.

Finally, the glycosylation of galacturonates **16** and **32**[27] with bromide **30** as donor gave trisaccharides **33** (68%) and **34** (74%), respectively (Scheme 4). Analytical and spectral data of **33** and **34** confirmed their structures. To establish the 1,2-*trans*-glycosidic linkage between L-rhamnose and D-galacturonate moieties, the geminal ^{13}C–^{1}H coupling constants were again



Scheme 4. Synthesis of D-galactose-ramified rhamnogalacturonan fragments **31**, **33** and **34** of which trisaccharides **33** and **34** represent potential modules for larger oligomers. Reagents and conditions: (a) CF_3SO_3Ag, 2,6-*tert*-butyl-4-methyl-pyridine, mol. sieves, dry CH_2Cl_2, 20 h, −65 °C→20 °C, Ar atmosphere, darkness (**27** 66%, **29** 68%); (b) 0.28 M methanolic HCl, 12 h, 20 °C, Ar atmosphere (**28** 58%); (c) Me_3SiBr, dry CH_2Cl_2, 19 h, −10 °C→20 °C, Ar atmosphere (**30** 90%); (d) $CF_3SO_3SiMe_3$, mol. sieves, dry CH_2Cl_2, 21 h, −70 °C→20 °C, Ar atmosphere, darkness (**31** 62%); (e) CF_3SO_3Ag, 2,6-*tert*-butyl-4-methyl-pyridine, mol. sieves, dry CH_2Cl_2, 20 h, −65 °C→20 °C, Ar atmosphere, darkness (**33** 68%, **34** 74%).

determined. Because the observed values of **33** and **34** are $J_{C\text{-}1',H\text{-}1'} = 170 \pm 0.5$ Hz, a comparison with the data reported for other α-L-rhamnose examples verified the proposed structure.[18] Based on these results, compounds **33** and **34** are considered to represent trisaccharide modules that can be transformed into glycosyl donor as well as glycosyl acceptors comparable to the disaccharide module **17**, procedure shown in Scheme 2.

In conclusion, simple conversion of disaccharide **17** into both glycosyl donor **19** and glycosyl acceptor **20**, and their successful coupling to tetrasaccharide **21** verified our hypothesis that rhamnogalacturonates protected permanently by benzyl groups and temporarily by acetyl and allyl groups are suitable as modules for the synthesis of larger RG-1 fragments by a modular design principle. This concept was extended to the preparation of hexasaccharide **25**. Furthermore, complete deprotection with exception of the reducing end of tetrasaccharide **21** was easily achieved in two steps. For the synthesis of β-galactosyl ramified RG-1 fragments, modules **33** and **34** were prepared and will be used in future experiments.

3. Experimental

3.1. General methods

Melting points were determined with a Boetius microheating plate BHMK 05 (Rapido, Dresden) and were not corrected. Optical rotations were 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 (125.76 MHz, 75.47 MHz and 62.89 MHz) were recorded using Bruker instruments AVANCE 500, ARX 300 and AC 250, with $CDCl_3$, CD_3OD or Me_2SO-d_6 as solvents. NMR spectra were calibrated using solvent signals ($CDCl_3$: δ ^{1}H 7.25, δ ^{13}C 77.0; CD_3OD: δ ^{1}H 4.78, δ ^{13}C 49.0; Me_2SO-d_6: δ ^{1}H 2.50, δ ^{13}C 39.7). The ^{1}H and ^{13}C NMR signals were assigned by DEPT and two-dimensional ^{1}H,^{1}H COSY, 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 following solvent systems (v/v) were used: (A) 1:1, (B) 2:1, (C) 3:1 and (D) 1:2 heptane–ethyl acetate, (E) 10:1, (F) 1.5:1 and (G) 1:2 chloroform–MeOH. The spots were made visible by spraying with ethanolic 10% H_2SO_4 solution and charring them for 3–5 min with a heat gun. Detection of benzyl derivatives was effected by UV fluorescence. Preparative flash chromatography, MPLC and HPLC were performed by elution from columns of slurry-packed Silica Gel 60 (Merck, 40–63 μm) and Nucleosil 100-7 (KNAUER, 7.0 μm), respectively. All solvents and reagents were purified and dried according to the standard procedures.[28] After classical work-up of the reaction mixtures, organic layers were dried over $MgSO_4$ and then concentrated under reduced pressure (rotary evaporator).

3.2. Methyl 4-*O*-allyl-α-L-rhamnopyranoside (4)[13]

Colourless syrup; $[\alpha]_D^{24}$ −86.1 (*c* 1.0, $CHCl_3$), lit.[13] $[\alpha]_D$ −85.3 (*c* 0.57, $CHCl_3$); ^{1}H NMR (250.13 MHz, $CDCl_3$): δ 1.29 (d, 3H, $^3J_{5,6} = 6.4$ Hz, H-6), 2.69 (br d, 2H, 2 × OH), 3.20 (t, 1H, H-4), 3.32 (s, 3 H, OCH_3), 3.62 (m, 1H, H-5), 3.81 (dd, 1H, $^3J_{3,4} = 9.5$ Hz, H-3), 3.90 (dd, 1H, $^3J_{2,3} = 3.4$ Hz, H-2), 4.19 (m, 2H, $CH_2CH{=}CH_2$), 4.62 (d, 1H, $^3J_{1,2} = 1.5$ Hz, H-1), 5.12, 5.27 (2m, 2H, $CH_2CH{=}CH_2$), 5.91 (m, 1H, $CH_2CH{=}CH_2$); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ 17.88 (C-6), 54.78 (OCH_3), 67.03 (C-5), 71.01 (C-2), 71.34 (C-3), 73.84 ($CH_2CH{=}CH_2$), 81.35 (C-4), 100.38 (C-1), 117.28 ($CH_2CH{=}CH_2$), 134.77 ($CH_2CH{=}CH_2$).

3.3. Methyl 2-*O*-acetyl-4-*O*-allyl-α-L-rhamnopyranoside (10)

Via **5**: Sodium hydride (288 mg, 7.2 mmol, 60% dispersion in oil) was successively added to a stirred solution of methyl 2,3-*O*-methylorthoacetyl α-L-rhamnopyranoside (**5**)[15] (523 mg, 2.0 mmol) in dry *N*,*N*-dimethylformamide (8 mL) and dry toluene (8 mL) at 0 °C under an argon atmosphere. The solution was kept 30 min at that temperature, then allyl bromide (1 mL, 12.0 mmol) was added. The mixture was allowed to attain room temperature and stirring was continued for another 2 h. After complete reaction (**6**, TLC: $R_f = 0.53$, solvent A), MeOH (1 mL) was added at 0 °C, and after stirring for additional 20 min, the reaction mixture was concentrated. After dissolving the residue in 60% aq acetic acid (25 mL), the resulting solution was stirred 30 min at ambient temperature (monitored by TLC). The reaction mixture was then concentrated and repeatedly co-concentrated with toluene. The crude product was purified by flash chromatography (eluent gradient EtOAc 0%→30% in heptane) to give **10** (453 mg, 87%) as a colourless syrup.

Via **4**: Camphorsulfonic acid (21 mg, 0.09 mmol) and triethylorthoacetate (0.41 mL, 2.2 mmol) were successively added to a solution of methyl 4-*O*-allyl-α-L-rhamnopyranoside[13] (**4**, 218 mg, 1.0 mmol) in dry CH_2Cl_2 (8 mL). After stirring for 35 min at ambient temperature under an argon atmosphere (**6**, TLC: $R_f = 0.53$, solvent A), triethylamine (1 mL) was added, and the mixture was concentrated. The residue was dissolved in chloroform (50 mL), and the organic solution

was washed with ice water (2 × 20 mL), dried and concentrated. Exactly the same procedure as above was used for the orthoester ring opening to yield **10** (237 mg, 91%) as a colourless syrup: $[\alpha]_D^{22}$ −21.7 (*c* 1.0, $CHCl_3$); $R_f = 0.34$ (solvent A); ^{1}H NMR (250.13 MHz, $CDCl_3$): δ 1.31 (d, 3H, H-6), 2.12 (s, 3 H, $OCOCH_3$), 2.35 (br d, 1H, OH), 3.19 (t, 1H, H-4), 3.31 (s, 3H, OCH_3), 3.64 (m, 1H, $^3J_{5,6} = 6.4$ Hz, H-5), 3.99 (dd, 1H, $^3J_{3,4} = 9.5$ Hz, H-3), 4.12, 4.21 (2m, 2H, $CH_2CH{=}CH_2$), 4.59 (d, 1H, $^3J_{1,2} = 1.5$ Hz, H-1), 5.01 (dd, 1H, $^3J_{2,3} = 3.7$ Hz, H-2), 5.11, 5.21 (2m, 2H, $CH_2CH{=}CH_2$), 5.91 (m, 1H, $CH_2CH{=}CH_2$); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ 17.91 (C-6), 21.04 ($OCOCH_3$), 54.89 (OCH_3), 67.22 (C-5), 69.96 (C-3), 72.60 (C-2), 73.99 ($CH_2CH{=}CH_2$), 81.50 (C-4), 98.34 (C-1), 117.12 ($CH_2CH{=}CH_2$), 134.78 ($CH_2CH{=}CH_2$), 170.78 ($OCOCH_3$). Anal. Calcd for $C_{12}H_{20}O_6$ (260.28): C, 55.37; H, 7.74. Found: C, 55.45; H, 7.69.

3.4. Methyl 2-*O*-acetyl-4-*O*-allyl-3-*O*-benzyl-α-L-rhamnopyranoside (11)

A catalytic amount of trifluoromethanesulfonic acid (14 μL, 0.15 mmol) dissolved in dry CH_2Cl_2 (1 mL) was added to a solution of compound **10** (350 mg, 1.3 mmol) and benzyl 2,2,2 trichloroacetimidate (0.5 mL, 2.7 mmol) in a mixture of dry CH_2Cl_2 (4 mL) and dry heptane (7 mL) at −10 °C under an argon atmosphere. After stirring for 3.5 h at that temperature, the mixture was allowed to attain room temperature and stirring was continued for another 18 h (monitored by TLC). Then, the mixture was passed through a layer of alkaline alumina by elution with CH_2Cl_2–heptane (2:3, v/v) and concentrated. After suspending the residue in heptane–diethyl ether (6:1, v/v, 10 mL) the formed carbohydrate-free crystals were filtered off, washed with heptane–diethyl ether (6:1, v/v, 20 mL) and the combined filtrate and washings were concentrated. The crude product was purified by flash chromatography (eluent solvent C) to give compound **11** (367 mg, 78%) as a colourless foam: $[\alpha]_D^{22}$ −33.1 (*c* 1.0, $CHCl_3$); $R_f = 0.65$ (solvent A); ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 1.26 (d, 3H, H-6), 2.06 (s, 3H, $OCOCH_3$), 3.21 (t, 1H, H-4), 3.25 (s, 3H, OCH_3), 3.60 (m, 1H, $^3J_{5,6} = 6.1$ Hz, H-5), 3.75 (dd, 1H, $^3J_{3,4} = 9.5$ Hz, H-3), 4.02, 4.29 (2m, 2H, $CH_2CH{=}CH_2$), 4.52 (d, 1H, $^3J_{1,2} = 1.5$ Hz, H-1), 4.43, 4.58 (2d, 2H, $^2J = 11.3$ Hz, $CH_2C_6H_5$), 5.07, 5.17 (2m, 2H, $CH_2CH{=}CH_2$), 5.24 (dd, 1H, $^3J_{2,3} = 3.4$ Hz, H-2), 5.84 (m, 1H, $CH_2CH{=}CH_2$), 7.19–7.30 (m, 5H, $CH_2C_6H_5$); ^{13}C NMR (75.47 MHz, $CDCl_3$): δ 17.91 (C-6), 21.07 ($OCOCH_3$), 54.80 (OCH_3), 67.49 (C-5), 68.93 (C-2), 71.69 ($CH_2C_6H_5$), 74.19 ($CH_2CH{=}CH_2$), 77.75 (C-3), 79.82 (C-4), 98.65 (C-1), 116.68 ($CH_2CH{=}CH_2$), 127.62, 127.78, 127.90, 128.32, 128.88, 138.09 ($CH_2C_6H_5$), 135.01 ($CH_2CH{=}CH_2$), 170.40 ($OCOCH_3$). Anal. Calcd for $C_{19}H_{26}O_6$ (350.41): C, 65.13; H, 7.48. Found: C, 65.17; H, 7.37.

3.5. Acetolysis of methyl 2-*O*-acetyl-4-*O*-allyl-3-*O*-benzyl-α-L-rhamnopyranoside (11)

Concd sulfuric acid (0.16 mL) dissolved in acetic anhydride (3 mL) was added to a solution of compound **11** (1.84 g, 5.25 mmol) in acetic anhydride–acetic acid (2.5:1, v/v, 20 mL) in three portions at −30 °C over a period of 1 h. After stirring for 1.5 h at 0 °C (monitored by TLC), cold aq 10% K_2SO_4 (200 mL) was slowly added and the stirring was continued for 30 min at 0 °C. The reaction mixture was extracted with chloroform (3 × 50 mL), and the combined organic phases were washed successively with cold aq $NaHCO_3$ (3 × 50 mL), water (2 × 50 mL) dried and concentrated. The residue was co-concentrated with toluene (3 times) to remove the remaining traces of acetic acid. The residue was then purified by flash chromatography (eluent gradient ethyl acetate 0%→50% in heptane) to provide **14α** (1.41 g, 71%) and **14β** (119 mg, 6%) in a ratio of 12:1, respectively.

3.6. 1,2-Di-*O*-acetyl-4-*O*-allyl-3-*O*-benzyl-α-L-rhamnopyranose (14α)

Colourless foam; $[\alpha]_D^{21}$ −28.2 (*c* 1.0, chloroform); $R_f = 0.68$ (solvent A); ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 1.24 (d, 3H, H-6), 2.00, 2.08 (2s, 6H, 2 × $OCOCH_3$), 3.25 (t, 1H, H-4), 3.66 (m, 1H, $^3J_{5,6} = 6.3$ Hz, H-5), 3.75 (dd, 1H, $^3J_{3,4} = 9.5$ Hz, H-3), 4.03, 4.29 (2m, 2H, $CH_2CH{=}CH_2$), 4.44, 4.61 (2d, 2H, $^2J = 11.3$ Hz, $CH_2C_6H_5$), 5.08, 5.12 (2m, 2H, $CH_2CH{=}CH_2$), 5.24 (dd, 1H, $^3J_{2,3} = 2.2$ Hz, H-2), 5.84 (m, 1H, $CH_2CH{=}CH_2$), 5.89 (d, 1H, $^3J_{1,2} = 1.9$ Hz, H-1), 7.20–7.31 (m, 5H, $CH_2C_6H_5$); ^{13}C NMR (75.47 MHz, $CDCl_3$): δ 17.95 (C-6), 20.89, 20.93 (2 × $OCOCH_3$), 67.87 (C-2), 70.02 (C-5), 71.92 ($CH_2C_6H_5$), 74.21 ($CH_2CH{=}CH_2$), 76.54 (C-3), 79.85 (C-4), 91.13 (C-1), 117.03 ($CH_2CH{=}CH_2$), 127.80, 127.98, 128.40, 129.01, 137.81 ($CH_2C_6H_5$, one signal is isochronic), 134.79 ($CH_2CH{=}CH_2$), 168.55, 170.03 (2 × $OCOCH_3$). Anal. Calcd for $C_{20}H_{26}O_7$ (378.42): C, 63.48; H, 6.93. Found: C, 63.54; H 6.84.

3.7. 1,2-Di-*O*-acetyl-4-*O*-allyl-3-*O*-benzyl-β-L-rhamnopyranose (14β)

Colourless foam; $[\alpha]_D^{21}$ −7.1 (*c* 0.1, $CHCl_3$); $R_f = 0.65$ (solvent A); ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 1.36 (d, 3H, H-6), 2.07, 2.12 (2s, 6H, 2 × $OCOCH_3$), 3.28 (t, 1H, H-4), 3.49 (m, 1H, $^3J_{5,6} = 6.1$ Hz, H-5), 3.60 (dd, 1H, $^3J_{3,4} = 9.5$ Hz, H-3), 4.09, 4.36 (2m, 2H, $CH_2CH{=}CH_2$), 4.47, 4.67 (2d, 2H, $^2J = 11.3$ Hz, $CH_2C_6H_5$), 5.15, 5.23 (2m, 2H, $CH_2CH{=}CH_2$), 5.55

(dd, 1H, $^3J_{2,3} = 3.4$ Hz, H-2), 5.69 (d, 1H, $^3J_{1,2} = 1.2$ Hz, H-1), 5.88 (m, 1H, $CH_2CH{=}CH_2$), 7.25–7.37 (m, 5H, $CH_2C_6H_5$); ^{13}C NMR (75.47 MHz, $CDCl_3$): δ 17.83 (C-6), 20.82, 20.89 ($2 \times OCOCH_3$), 67.58 (C-2), 71.55 ($CH_2C_6H_5$), 72.70 (C-5), 74.31 ($CH_2CH{=}CH_2$), 79.06 (C-4), 79.42 (C-3), 91.05 (C-1), 117.05 ($CH_2CH{=}CH_2$), 127.82, 127.99, 128.37, 128.44, 137.42 ($CH_2C_6H_5$, one signal is isochronic), 134.72 ($CH_2CH{=}CH_2$), 168.80, 170.55 ($2 \times OCOCH_3$). Anal. Calcd for $C_{20}H_{26}O_7$ (378.42): C, 63.48; H 6.93. Found: C, 63.51; H, 6.81.

3.8. Deallylation of compounds 11 and 14α

To a solution of compound **11** or **14α** (0.8 mmol) in a mixture of acetic acid and water (20:1, v/v, 25 mL) sodium acetate (656 mg, 8.0 mmol) and palladium(II)chloride (563 g, 3.2 mmol) were added. After stirring for 4–6 h at 40 °C (monitored by TLC), the reaction mixture was filtered and the filtrate was concentrated. The residue was dissolved in heptane–chloroform (2:1 v/v, 100 mL), the organic layer was washed with water (3×50 mL), dried and concentrated. The crude products were purified by column chromatography (eluent solvent C) to provide **12** (248 mg, 63%) as colourless foam and **15** (181 mg, 67%) as colourless crystals, respectively.

3.9. Methyl 2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranoside (12)

$[\alpha]_D^{21}$ +11.1 (*c* 0.9, $CHCl_3$); $R_f = 0.46$ (solvent A); ^{1}H NMR (250.13 MHz, $CDCl_3$): δ 1.25 (d, 3H, $^3J_{5,6} = 6.1$ Hz, H-6), 2.05 (s, 3H, $OCOCH_3$), 2.20 (br d, 1H, OH), 3.27 (s, 3H, OCH_3), 3.41–3.66 (m, 3H, H-3, H-4, H-5), 4.56 (d, 1H, $^3J_{1,2} = 1.5$ Hz, H-1), 4.32, 4.63 (2d, 2H, $^2J = 11.3$ Hz, $CH_2C_6H_5$), 5.27 (dd, 1H, $^3J_{2,3} = 3.4$ Hz, H-2), 7.15–7.32 (m, 5H, $CH_2C_6H_5$); ^{13}C NMR (62.89 MHz, $CDCl_3$): δ 17.68 (C-6), 20.94 ($OCOCH_3$), 54.89 (OCH_3), 67.88 (C-2), 67.94 (C-5), 71.38 ($CH_2C_6H_5$), 71.55 (C-4), 77.62 (C-3), 98.92 (C-1), 128.00, 128.11, 128.35, 128.43, 128.53, 137.57, ($CH_2C_6H_5$), 170.29 ($OCOCH_3$). Anal. Calcd for $C_{16}H_{22}O_6$ (310.34): C, 61.92; H, 7.15. Found: C, 61.83; H, 7.07.

3.10. 1,2-Di-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranose (15)

Mp 76 °C (from ethyl acetate–heptane); $[\alpha]_D^{25}$ +2.9 (*c* 1.1, $CHCl_3$); $R_f = 0.52$ (solvent A); ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 1.24 (d, 3H, $^3J_{5,6} = 6.1$ Hz, H-6), 2.00, 2.08 (2s, 6H, $OCOCH_3$), 2.37 (br d, 1H, OH), 3.52 (t, 1H, H-4), 3.64 (dd, 1H, $^3J_{3,4} = 9.5$ Hz, H-3), 3.68 (m, 1H, H-5), 4.36, 4.66 (2d, 2H, $^2J = 11.0$ Hz, $CH_2C_6H_5$), 5.26 (dd, 1H, $^3J_{2,3} = 3.5$ Hz, H-2), 5.94 (d, 1H, $^3J_{1,2} = 1.9$ Hz, H-1), 7.20–7.29 (m, 5H, $CH_2C_6H_5$); ^{13}C NMR (75.47 MHz, $CDCl_3$): δ 17.75 (C-6), 20.85, 20.92 ($2 \times OCOCH_3$), 66.91 (C-2), 70.44 (C-5), 71.16 (C-4), 71.64 ($CH_2C_6H_5$), 77.25 (C-3), 91.40 (C-1), 128.18, 128.21, 128.64, 137.28 ($CH_2C_6H_5$, two signals are isochronic), 170.04 ($OCOCH_3$). Anal. Calcd for $C_{17}H_{22}O_7$ (338.35): C, 60.35; H, 6.55. Found: C, 60.43; H 6.61.

3.11. Methyl 2-*O*-acetyl-4-*O*-benzoyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-4-*O*-benzoyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (21)

Glycosyl acceptor **20**[20] (384 mg, 0.5 mmol), donor **19**[15] (458 mg, 0.5 mmol) and molecular sieves (4 Å, ca. 7.0 g) were dried under high vacuum for 1 h at ambient temperature. Then, the solids were suspended in dry CH_2Cl_2 (15 mL), and the reaction mixture was stirred for 2 h at room temperature under an inert atmosphere in the dark. After cooling to −70 °C, trimethylsilyl trifluoromethanesulfonate (100 μL, 0.6 mmol) was added, and the suspension was stirred 3 h at that temperature. The reaction mixture was allowed to warm-up to room temperature and stirring was continued for an additional 18 h. After complete reaction (monitored by TLC), the mixture was passed through a layer of alkaline alumina by elution with chloroform. Filtrate and eluent (ca. 50 mL) were combined, dried and concentrated. Purification by HPLC (eluent gradient ethyl acetate 0%→50% in heptane) provided tetrasaccharide **21** (447 mg, 60%) as a colourless foam: $[\alpha]_D^{22}$ +65.9 (*c* 1.0, $CHCl_3$); $R_f = 0.39$ (solvent A); ^{1}H NMR (500.13 MHz, $CDCl_3$): δ 1.15 (d, 3H, $^3J_{5''',6'''} = 6.2$ Hz, H-6‴), 1.27 (d, 3H, $^3J_{5',6'} = 6.5$ Hz, H-6′), 2.07 (s, 3H, $OCOCH_3$), 3.35 (s, 3H, $OCH_{3''}$), 3.52 (dd, 1H, $^3J_{3,4} = 3.3$ Hz, H-3). 3.76 (dd, 1H, $^3J_{2,3} = 9.7$ Hz, H-2), 3.76 (m, 1H, H-5‴), 3.80 (m, 1H, H-5′), 3.80 (dd, 1H, $^3J_{2'',3''} = 9.8$ Hz, H-2″), 3.80 (s, 3H, OCH_3), 3.83 (dd, 1H, $^3J_{3''',4'''} = 9.9$ Hz, H-3‴), 3.99 (dd, 1H, $^3J_{3',4'} = 9.9$ Hz, H-3′), 4.03 (d, 1H, H-5), 4.13 (dd, 1H, $^3J_{3'',4''} = 3.5$ Hz, H-3″), 4.16 (m, 1H, $CH_2CH{=}CH_2$), 4.21–4.98 (s and d, 12H, $6 \times CH_2C_6H_5$), 4.30 (dd, 1H, $^3J_{2',3'} = 3.1$ Hz, H-2′), 4.38 (d, 1H, $^3J_{1,2} = 7.6$ Hz, H-1), 4.40 (dd, 1H, $^3J_{4,5} = 0.9$ Hz, H-4), 4.42 (dd, 1H, $^3J_{4'',5''} = 1.6$ Hz, H-4″), 4.55 (m, 1H, $CH_2CH{=}CH_2$), 4.92 (d, 1H, H-5″), 5.00 (d, 1H, $^3J_{1'',2''} = 3.5$ Hz, H-1″), 5.07 (dd, 1H, $^3J_{1''',2'''} = 1.4$ Hz, H-1‴), 5.18 (t, 1H, $^3J_{4''',5'''} = 9.9$ Hz, H-4‴), 5.22, 5.34 (2m, 2H, $CH_2CH{=}CH_2$), 5.40 (d, 1H, $^3J_{1',2'} = 1.4$ Hz, H-1′), 5.40 (t, 1H, $^3J_{4',5'} = 9.9$ Hz, H-4′), 5.54 (dd, 1H, $^3J_{2''',3'''} = 3.3$ Hz, H-2‴), 5.96 (m, 1H, $CH_2CH{=}CH_2$), 7.00–7.37 (m, 30H, $6 \times CH_2C_6H_5$), 7.42, 7.56, 7.97 (3m, 10H, $2 \times OCOC_6H_5$); ^{13}C NMR (125.76 MHz, $CDCl_3$): δ 17.59 (C-6‴), 17.64 (C-6′), 21.08 ($OCOCH_3$), 51.91 ($OCH_{3''}$), 52.43 (OCH_3), 67.12 (C-5‴), 67.45 (C-5′),

68.16 (C-2‴), 70.42 (C-5″), 70.78 ($CH_2CH{=}CH_2$), 70.92, 71.65, 71.85, 72.88, 72.96, 73.10, ($6 \times CH_2C_6H_5$), 72.70 (C-4‴), 73.17 (C-4′), 73.59 (C-5), 74.05 (C-4″), 74.22 (C-2″), 74.10 (C-3‴), 74.61 (C-2′), 76.02 (C-3′), 76.72 (C-4), 77.20 (C-3″), 78.76 (C-2), 79.95 (C-3), 97.60 (C-1″), 99.10 (C-1‴), 99.70 (C-1′), 102.73 (C-1), 117.74 ($CH_2CH{=}CH_2$), 126.83, 127.14, 127.35, 127.38, 127.58, 127.75, 127.87, 127.89, 128.08, 128.11, 128.18, 128.22, 128.29, 128.32, 128.36, 128.40, 128.43, 128.51, 128.53, 128.92, 129.68, 129.75, 129.80, 129.83, 129.97, 133.10, 133.03, 137.50, 137.72, 137.83, 137.91, 138.33, 138.67 ($6 \times CH_2C_6H_5$, $2 \times COC_6H_5$, 15 signals are isochronic), 133.74 ($CH_2CH{=}CH_2$), 165.69, 165.83 ($2 \times OCOC_6H_5$), 168.16, 168.86, (C-6, C-6″), 169.88 ($OCOCH_3$). Anal. Calcd for $C_{87}H_{92}O_{22}$ (1489.67): C, 70.15; H 6.23. Found: C, 70.18; H, 6.22.

3.12. Methyl 4-*O*-benzoyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-4-*O*-benzoyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (22)

Compound **21** (149 mg, 0.1 mmol) was added under stirring to a methanolic HCl solution [0.28 M, 10 mL, prepared by adding of 0.2 mL acetyl chloride to 10 mL ice-cold dry MeOH], and the mixture was kept under an argon atmosphere for 48–72 h at room temperature (monitored by TLC). The reaction solution was then filtered through a layer of alkaline alumina by elution with chloroform. The filtrate and eluent (ca. 40 mL) were combined, dried and concentrated. The crude product was purified by MPLC (eluent solvent B) to give **22** (140 mg, 97%) as a colourless foam: $[\alpha]_D^{20}$ +70.0 (*c* 1.0, $CHCl_3$); $R_f = 0.33$ (solvent A); ^{1}H NMR (500.13 MHz, $CDCl_3$): δ 1.15 (d, 3H, $^3J_{5‴,6‴} = 6.1$ Hz, H-6‴), 1.28 (d, 3H, H-6′), 3.38 (s, 3H, $OCH_{3″}$), 3.51 (dd, 1H, $^3J_{3,4} = 3.1$ Hz, H-3). 3.72 (dd, 1H, $^3J_{2,3} = 9.5$ Hz, H-2), 3.77 (dd, 1H, $^3J_{2″,3″} = 10.1$ Hz, H-2″), 3.79 (m, 1H, H-5‴), 3.80 (m, 1H, $^3J_{5′,6′} = 6.4$ Hz, H-5′), 3.80 (s, 3H, OCH_3), 3.81 (dd, 1H, $^3J_{3‴,4‴} = 9.8$ Hz, H-3‴), 4.00 (dd, 1H, $^3J_{3′,4′} = 10.1$ Hz, H-3′), 4.02 (d, 1H, H-5), 4.12 (dd, 1H, $^3J_{3″,4″} = 3.4$ Hz, H-3″), 4.15 (dd, 1H, $^3J_{2‴,3‴} = 3.4$ Hz, H-2‴), 4.17 (m, 1H, $CH_2CH{=}CH_2$), 4.32–5.00 (s and d, 12H, $6 \times CH_2C_6H_5$), 4.32 (dd, 1H, $^3J_{2′,3′} = 3.1$ Hz, H-2′), 4.38 (d, 1H, $^3J_{1,2} = 7.6$ Hz, H-1), 4.40 (dd, 1H, $^3J_{4,5} = 0.9$ Hz, H-4), 4.43 (dd, 1H, $^3J_{4″,5″} = 1.6$ Hz, H-4″), 4.53 (m, 1H, $CH_2CH{=}CH_2$), 4.91 (d, 1H, H-5″), 5.03 (d, 1H, $^3J_{1″,2″} = 3.1$ Hz, H-1″), 5.14 (dd, 1H, $^3J_{1‴,2‴} = 1.5$ Hz, H-1‴), 5.24 (t, 1H, $^3J_{3‴,4‴} = 10.1$ Hz, H-4‴), 5.22, 5.34 (2m, 2H, $CH_2CH{=}CH_2$), 5.39 (d, 1H, $^3J_{1′,2′} = 1.8$ Hz, H-1′), 5.40 (t, 1H, $^3J_{3′,4′} = {}^3J_{4′,5′} = 10.1$ Hz, H-4′), 5.97 (m, 1H, $CH_2CH{=}CH_2$), 7.00–7.36 (m, 30H, $6 \times CH_2C_6H_5$), 7.46, 7.56, 7.97 (3m, 10H, $2 \times OCOC_6H_5$); ^{13}C NMR (125.76 MHz, $CDCl_3$): δ 17.49 (C-6‴), 17.64 (C-6′), 51.92 (OCH_3''), 52.44 (OCH_3), 66.83 (C-5′), 67.43 (C-5‴), 68.11 (C-2‴), 70.51 (C-5″), 70.76 ($CH_2CH{=}CH_2$), 71.31, 71.65, 71.69, 72.86, 73.09, 73.15 ($6 \times CH_2C_6H_5$), 72.86 (C-4‴), 73.15 (C-4′), 73.57 (C-5), 73.94 (C-4″), 74.26 (C-2″), 76.17 (C-3‴), 74.45 (C-2′), 76.00 (C-3′), 77.20 (C-4), 77.26 (C-3″), 78.73 (C-2), 80.02 (C-3), 97.41 (C-1″), 99.00 (C-1‴), 101.29 (C-1′), 102.72 (C-1), 117.74 ($CH_2CH{=}CH_2$), 126.86, 127.13, 127.26, 127.67, 127.70, 127.78, 128.01, 128.10, 128.13, 128.17, 128.25, 128.33, 128.39, 128.42, 128.50, 129.66, 129.75, 129.86, 129.95, 133.03, 133.12, 133.03, 133.09, 137.50, 137.72, 137.83, 137.91, 138.33, 138.67 ($6 \times CH_2C_6H_5$, $2 \times OCOC_6H_5$ 19 signals are isochronic), 133.74 ($CH_2CH{=}CH_2$), 165.73, 165.81 ($2 \times OCOC_6H_5$), 168.16, 168.86, (C-6, C-6″). Anal. Calcd for $C_{85}H_{90}O_{21}$ (1447.63): C, 70.52; H, 6.27. Found: C, 70.54; H 6.23.

3.13. Methyl 2-*O*-acetyl-4-*O*-benzoyl-α-L-rhamnopyranosyl-(1→4)-(methyl α-D-galactopyranosyluronate)-(1→2)-4-*O*-benzoyl-α-L-rhamnopyranosyl-(1→4)-(propyl β-D-galactopyranosid)uronate (23)

To a solution of compound **21** (149 mg, 0.1 mmol) in ethanol (8 mL) 10% palladium-on-charcoal (ca. 20 mg) was added. The suspension was stirred for 18 h at room temperature under an atmosphere of hydrogen (monitored by TLC). Then, the mixture was filtered over Celite, eluted with ethanol and the combined filtrates were concentrated. The residue was dissolved in water and lyophilized to yield compound **23** (95 mg, 97%) as a colourless powder. For NMR investigations the product was evaporated several times together with CD_3OD: $[\alpha]_D^{25}$ +1.2 (*c* 1.0, $CHCl_3$); $R_f = 0.34$ (solvent E); ^{1}H NMR (500.13 MHz, $CDCl_3$): δ 0.89 (t, 3H, $CH_2CH_2CH_3$), 1.17 (d, 3H, $^3J_{5‴,6‴} = 6.2$ Hz, H-6‴), 1.22 (d, 3H, $^3J_{5′,6′} = 6.4$ Hz, H-6′), 1.65 (dt, 2H, $CH_2CH_2CH_3$), 2.11 (s, 3H, $OCOCH_3$), 3.44 (m, 2H, $CH_2CH_2CH_3$), 3.72 (s, 3H, $OCH_{3″}$), 3.77 (dd, 1H, $^3J_{2,3} = 9.7$ Hz, H-2), 3.78 (s, 3H, OCH_3), 3.86 (dd, 1H, $^3J_{3,4} = 3.7$ Hz, H-3), 3.88 (2m, 2H, H-5′, H-5‴), 3.94 (dd, 1H, $^3J_{3′,4′} = 10.1$ Hz, H-3′), 4.09 (dd, 1H, $^3J_{2′,3′} = 3.1$ Hz, H-2′), 4.12 (dd, 1H, $^3J_{3″,4″} = 3.6$ Hz, H-3″), 4.17 (dd, 1H, $^3J_{2″,3″} = 9.8$ Hz, H-2″), 4.25 (d, 1H, $^3J_{1,2} = 7.3$ Hz, H-1), 4.26 (dd, 1H, $^3J_{3‴,4‴} = 9.8$ Hz, H-3‴), 4.22 (d, 1H, H-5), 4.43 (dd, 1H, $^3J_{4,5} = 0.9$ Hz, H-4), 4.50 (dd, 1H, $^3J_{4″,5″} = 0.9$ Hz, H-4″), 4.93 (d, 1H, H-5″), 5.17 (d, 1H, $^3J_{1″,2″} = 3.1$ Hz, H-1″), 5.43 (dd, 1H, $^3J_{1‴,2‴} = 1.4$ Hz, H-1‴), 5.12 (t, 1H, $^3J_{4‴,5‴} = 9.8$ Hz, H-4‴), 5.26 (d, 1H, $^3J_{1′,2′} = 1.4$ Hz, H-1′), 4.92 (t, 1H, $^3J_{4′,5′} = 10.1$ Hz, H-4′), 5.37 (dd, 1H, $^3J_{2‴,3‴} = 3.6$ Hz, H-2‴), 7.39, 7.51, 7.96 (3m, 10H, $2 \times OCOC_6H_5$); ^{13}C NMR (125.76 MHz, $CDCl_3$): δ 10.80 ($CH_2CH_2CH_3$), 18.02 (C-6″), 18.07 (C-6′), 20.94 ($OCOCH_3$), 23.91 ($CH_2CH_2CH_3$), 52.75 ($OCH_{3″}$), 52.89 (OCH_3), 68.20 (C-5‴), 68.31 (C-5′), 68.43 (C-3‴), 69.86 (C-2″), 68.94 (C-2′),

71.13 (C-3″), 71.75 (C-2), 71.76 (C-5″), 72.21 (C-3′), 72.24 ($CH_2CH_2CH_3$), 72.95 (C-2‴), 73.86 (C-5, C-3, one signal is isochronic), 74.50 (C-4‴), 74.95 (C-4′), 78.51 (C-4), 79.26 (C-4″), 99.73 (C-1″), 100.65 (C-1‴), 101.03 (C-1′), 104.70 (C-1′), 129.60, 129.72, 130.66, 130.69, 131.27, 131.33, 134.40, 134.42 ($2 \times OCOC_6H_5$, four signals are isochronic), 167.50, 167.72 ($2 \times COC_6H_5$), 170.51, 171.37, (C-6, C-6″), 171.97 ($OCOCH_3$). Anal. Calcd for $C_{45}H_{58}O_{24}$ (982.94): C, 54.99; H 5.95. Found: C, 54.89; H 5.98.

3.14. Propyl α-L-rhamnopyranosyl-(1→4)-α-D-galactopyranosyluronic acid-(1→2)-α-L-rhamnopyranosyl-(1→4)-β-D-galactopyranosiduronic acid (24)

To a suspension of compound **23** (49 mg, 0.05 mmol) in MeOH and water (2:1, v/v, 10 mL) lithium hydroxide (24 mg, 0.1 mmol) was added. After stirring for 15 min at room temperature (monitored by TLC), the solution was passed through a column of Dowex-50 (H^+) resin. In the following, MeOH was removed from the filtrate by evaporation in vacuo, and the residue was repeatedly dissolved in water and lyophilized to give compound **24** (30 mg, 86%) as a colourless powder. For NMR investigations the product was evaporated several times together with CH_3OD: $[\alpha]_D^{25}$ +2.3 (*c* 0.5, Me_2SO); $R_f = 0.21$ (solvent G); ^1H NMR (500.13 MHz, Me_2SO-d_6): δ 0.83 (t, 3H, $CH_2CH_2CH_3$), 1.14, 1.16 (2d, 6H, H-6′, H-6‴), 1.53 (dt, 2H, $CH_2CH_2CH_3$), 3.24 (m, 2H, $CH_2CH_2CH_3$), 3.32 (dd, 1H, $^3J_{2,3} = 9.7$ Hz, H-2), 3.40–4.02 (4m, 11H, H-3, H-2′, H-3′, H-4′, H-5′, H-2″, H-3″, H-2‴, H-3‴, H-4‴, H-5‴), 4.26 (d, 1H, $^3J_{1,2} = 7.3$ Hz, H-1), 3.92 (d, 1H, H-5), 4.22 (dd, 1H, $^3J_{4,5} = 0.9$ Hz, H-4), 4.32 (dd, 1H, $^3J_{4'',5''} = 0.9$ Hz, H-4″), 4.33 (d, 1H, H-5″), 4.94 (d, 1H, $^3J_{1'',2''} = 3.1$ Hz, H-1″), 5.13 (dd, 1H, $^3J_{1''',2'''} = 1.4$ Hz, H-1‴), 5.15 (d, 1H, $^3J_{1',2'} = 1.4$ Hz, H-1′); ^{13}C NMR (125.76, Me_2SO-d_6): δ 10.83 ($CH_2CH_2CH_3$), 18.10, 18.17 (C-6′, C-6‴), 23.89 ($CH_2CH_2CH_3$), 70.30, 70.95, 71.49, 71.82, 72.01, 72.14, 73.03, 73.80, 74.52, 75.04, 78.11, 78.74, 79.18 (C-2, C-3, C-4, C-5, C-2′, C-3′, C-4′, C-5′, C-2″, C-3″, C-4″, C-5″, $CH_2CH_2CH_3$), 99.49 (C-1″), 99.65 (C-1‴), 100.10 (C-1′), 103.41 (C-1), 170.38, 171.32 (C-6, C-6″). Anal. Calcd for $C_{27}H_{44}O_{21}$ (704.63): C, 46.02; H, 6.29. Found: C: 45.99; H, 6.35.

3.15. Methyl 2-*O*-acetyl-4-*O*-benzoyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-4-*O*-benzoyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(methyl 2,3-di-*O*-benzyl-α-D-galactopyranosyluronate)-(1→2)-4-*O*-benzoyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (25)

Glycosyl acceptor **22** (145 mg, 0.1 mmol), donor **19**[15] (92 mg, 0.1 mmol) and molecular sieves (4 Å, 800 mg) were dried 1 h at ambient temperature under high vacuum. Then, the solids were suspended in dry CH_2Cl_2 (8 mL), and the reaction mixture was stirred for 2 h at room temperature under an inert atmosphere in the dark. After cooling to −70 °C, trimethylsilyl trifluoromethanesulfonate (83 μL, 0.5 mmol) was added, and stirring was continued for 3 h at that temperature. Subsequently, the reaction mixture was allowed to warm-up to room temperature and stirring was continued for an additional 18 h. After complete reaction (monitored by TLC), the mixture was passed through a layer of alkaline alumina by elution with chloroform. Filtrate and eluent (ca. 30 mL) were combined, dried and concentrated. The crude product was purified by HPLC (eluent gradient ethyl acetate 0%→50% in heptane) to afford hexasaccharide **25** (133 mg, 59%) as a colourless foam: $[\alpha]_D^{20}$ +77.7 (*c* 1.0, $CHCl_3$); $R_f = 0.32$ (solvent A); ^1H NMR (500.13 MHz, $CDCl_3$): δ 1.17, 1.20, 1.21 (3d, 9H, H-6′, H-6″, H-6‴″), 2.09 (s, 3H, $OCOCH_3$), 3.37, 3.39 (2s, 6H, $OCH_{3''}$, $OCH_{3'''}$), 3.79 (s, 3H, OCH_3), 3.53 (dd, 1H, $^3J_{2,3} = 10.1$ Hz, H-2), 3.72 (dd, 1H, $^3J_{3,4} = 3.6$ Hz, H-3), 3.76 (m, 1H, H-5‴″), 3.87 (dd, 1H, $^3J_{3''',4'''} = 9.8$ Hz, H-3‴), 3.70–5.40 (m, H-2′, H-3′, H-4′, H-5′, H-2″, H-3″, H-4″, H-5″, H-2‴, H-3‴, H-4‴, H-5‴, H-2‴″, H-3‴″, H-4‴″, H-5‴″, $CH_2CH{=}CH_2$, $CH_2CH{=}CH_2$, $9 \times CH_2C_6H_5$), 4.04 (d, 1H, H-5), 4.27 (dd, 1H, $^3J_{4,5} = 0.9$ Hz, H-4), 4.36 (d, 1H, $^3J_{1,2} = 7.5$ Hz, 1-H), 4.91, 5.02, 5.05, 5.29 (4d, 4H, H-1′, H-1″, H-1‴, H-1‴″), 5.21 (t, 1H, $^3J_{3''''',4''''} = 10.1$ Hz, H-4‴″), 5.40 (d, 1H, $^3J_{1''''',2''''} = 1.9$ Hz, H-1‴″), 5.56 (dd, 1H, $^3J_{2''''',3''''} = 3.1$, H-2‴″), 5.96 (m, 1H, $CH_2CH{=}CH_2$), 7.05–7.17 (m, 15H, $3 \times CH_2C_6H_{5Rha}$), 7.18–7.39 (m, 30H, $6 \times CH_2C_6H_{5GalA}$), 7.42, 7.56, 8.00 (3m, 15H, $3 \times OCOC_6H_5$); ^{13}C NMR (125.76 MHz, $CDCl_3$): δ 17.59, 17.67, 17.69 (C-6′, C-6‴, C-6‴″), 22.63 (OCH_3), 51.74, 51.76 (OCH_3'', OCH_3''''), 52.28 (OCH_3), 67.18, 67.41, 67.52 (C-5′, C-5‴, C-5‴″), 68.34 (C-2‴″), 70.41, 70.57, 70.73, 70.99, 71.43, 71.75, 71.77, 71.91, 72.45, 72.51, 72.88, 73.04, 73.27, 73.31, 73.43, 73.64, 73.83, 74.33, 74.38, 74.47, 74.57, 75.08, 75.22, 75.50, 75.99, 76.19, 76.79, 77.20 (C-4, C-5, C-2′, C-3′, C-4′, C-2″, C-3″, C-4″, C-5″, C-2‴, C-3‴, C-4‴, C-2‴″, C-3‴″, C-4‴″, C-5‴″, C-3‴‴, C-4‴‴, $9 \times CH_2C_6H_5$, $CH_2CH{=}CH_2$), 78.79 (C-2), 80.44 (C-3), 97.05, 97.42 (C-1″, C-1‴″), 98.81, 99.77 (C-1′, C-1‴), 98.93 (C-1‴″), 102.84 (C-1), 117.60 ($CH_2CH{=}CH_2$), 126.83, 126.95, 127.08, 127.13, 127.27, 127.35, 127.42, 127.53, 127.68, 127.73, 127.82, 127.96, 128.08, 128.19, 128.28, 128.34, 128.50, 128.61, 128.86, 129.67, 129.78, 130.00, 130.14, 132.94, 132.98, 137.56, 137.66, 137.77, 137.83, 137.89, 137.97, 138.05, 138.42, 138.70, 138.75, 138.89 ($9 \times CH_2C_6H_5$, $3 \times OCOC_6H_5$),133.84 ($CH_2CH{=}CH_2$), 165.68, 165.70, 165.72 ($3 \times OCOC_6H_5$), 168.09 (C-6), 168.81, 168.89 (C-6″, C-6‴″), 169.79 ($COCH_3$). Anal. Calcd for $C_{129}H_{134}O_{35}$ (2244.46): C, 69.03; H, 6.02. Found: C, 69.10; H, 6.00.

3.16. Glycosylation of the rhamnose derivatives 12 and 15 with 2,3,4,6-tetra-*O*-benzoyl-α-D-galactopyranosyl bromide (26)

Rhamnose acceptor **12** or **15** (0.5 mmol), bromide **26**[23–25] (330 mg, 0.5 mmol) and molecular sieves (4 Å, 4.0 g) were dried for 1 h at ambient temperature under high vacuum in the dark. Then, the solids were suspended in dry CH_2Cl_2 (10 mL), 2,6-di-*tert*-butyl-4-methyl-pyridine (123 mg, 0.6 mmol) was added and the suspension was stirred 30 min at room temperature under an argon atmosphere in the dark. After chilling to −65 °C, silver trifluoromethansulfonate (141 mg, 0.55 mmol) was added, and the reaction mixture was stirred for 2 h at that temperature. Subsequently, the mixture was allowed to attain room temperature and stirring was continued for further 18 h. At completion (monitored by TLC), the reaction mixture was passed through a layer of alkaline alumina by elution with chloroform. The combined filtrate and eluent (ca. 50 mL) were extracted with cold aq 3% hydrochloric acid (2 × 20 mL), ice water (20 mL), cold aq $NaHCO_3$ (2 × 20 mL), ice water (2 × 20 mL), dried and concentrated. Finally, the residue was purified by HPLC (eluent solvent B) to give the desired disaccharides **27** (293 mg, 66%) and **29** (312 mg, 68%), respectively, both as colourless foam.

3.17. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranoside (27)

$[\alpha]_D^{23}$ +12.5 (*c* 1.0, $CHCl_3$); $R_f = 0.42$ (solvent A); ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 1.46 (d, 3H, $^3J_{5,6} = 5.7$ Hz, H-6), 2.05 (s, 3H, $OCOCH_3$), 3.34 (s, 3H, OCH_3), 3.77 (m, 3H, H-3, H-4, H-5), 4.21, 4.41 (2d, 2H, $^2J = 11.4$ Hz, $CH_2C_6H_5$), 4.34 (t, 1H, $^3J_{5',6'a} = {}^3J_{5',6'b} = 6.6$ Hz, H-5′), 4.44, 4.71 (2dd, 2H, $^2J_{6'a,6'b} = 11.2$ Hz, H-6′), 4.60 (d, 1H, $^3J_{1,2} = 1.6$ Hz, H-1), 5.20 (dd, 1H, $^3J_{2,3} = 3.3$ Hz, H-2), 5.35 (d, 1H, $^3J_{1',2'} = 8.2$ Hz, H-1′), 5.63 (dd, 1H, $^3J_{3',4'} = 3.6$ Hz, H-3′), 5.82 (dd, 1H, $^3J_{2',3'} = 10.4$ Hz, H-2′), 6.05 (d, 1H, H-4′), 7.21–8.12 (m, 25H, 4 × $OCOC_6H_5$, $CH_2C_6H_5$); ^{13}C NMR (75.47 MHz, $CDCl_3$): δ 17.98 (C-6), 20.92 ($OCOCH_3$), 54.84 (OCH_3), 61.79 (C-6′), 66.68 (C-5), 68.25 (C-4′), 68.32 (C-2), 70.23 (C-2′), 70.76 (C-5′), 71.51 ($CH_2C_6H_5$), 71.67 (C-3′), 76.92 (C-4), 77.77 (C-3), 98.40 (C-1), 101.00 (C-1′), 127.32, 127.70, 128.23, 128.29, 128.32, 128.40, 128.61, 129.12, 129.62, 129.67, 129.70, 129.88, 133.17, 133.22, 133.22, 133.52 (4 × $OCOC_6H_5$, $CH_2C_6H_5$, 14 signals are isochronic) 165.39, 165.47, 165.53 (4 × $OCOC_6H_5$), 170,23 ($OCOCH_3$). Anal. Calcd for $C_{50}H_{48}O_{15}$ (888.91): C, 67.56; H 5.44. Found: C, 67.52; H 5.37.

3.18. 2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-1,2-di-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranose (29)

$[\alpha]_D^{21}$ +45.2 (*c* 1.0, $CHCl_3$); $R_f = 0.44$ (solvent A); ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 1.41 (d, 3H, $^3J_{5,6} = 5.8$ Hz, H-6), 1.96, 2.05 (2s, 6H, 2 × $OCOCH_3$), 3.65 (dd, 1H, $^3J_{3,4} = 9.5$ Hz, H-3), 3.76 (m, 2H, H-4, H-5), 4.16, 4.36 (2d, 2H, $^2J = 11$ Hz, $CH_2C_6H_5$), 4.25 (t, 1H, $^3J_{5',6'a} = 6.7$ Hz, $J_{5',6'b}$ 6.6 Hz, H-5′), 4.35 (d, 1H, $^2J_{6'a,6'b} = 11$ Hz, H-6′a), 4.60 (dd, 1H, H-6′b), 5.09 (dd, 1H, $^3J_{2,3} = 3.6$ Hz, H-2), 5.24 (d, 1H, $^3J_{1',2'} = 7.9$ Hz, H-1′), 5.53 (dd, 1H, $^3J_{3',4'} = 3.4$ Hz, H-3′), 5.73 (dd, 1H, $^3J_{2',3'} = 10.4$ Hz, H-2′), 5.88 (d, 1H, $^3J_{1,2} = 1.8$ Hz, H-1), 5.91 (d, 1H, H-4′), 7.09–8.04 (m, 25H, 4 × $OCOC_6H_5$, $CH_2C_6H_5$); ^{13}C NMR (75.47 MHz, $CDCl_3$): δ 18.25 (C-6), 21.03, 21.16 (2 × $OCOCH_3$), 62.04 (C-6′), 67.62 (C-2), 68.46 (C-4′), 69.50 (C-5), 70.55 (C-2′), 71.12 (C-5′), 71.97 (C-3′), 71.97 ($CH_2C_6H_5$), 76.72 (C-4), 77.72 (C-3), 91.09 (C-1), 101.27 (C-1′), 127.62, 128.11, 128.50, 128.64, 128.70, 128.89, 129.33, 129.58, 129.90, 129.93, 129.96, 130.14, 133.53, 133.82 (4 × $OCOC_6H_5$, $CH_2C_6H_5$, 16 signals are isochronic), 168.76, 170.14 (2 × $OCOCH_3$). Anal. Calcd for $C_{51}H_{48}O_{16}$ (916.92): C, 66.80; H 5.28. Found: C, 66.73; H 5.20.

3.19. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-3-*O*-benzyl-α-L-rhamnopyranoside (28)

Compound **27** (149 mg, 0.1 mmol) was dissolved in methanolic HCl (0.28 M, 10 mL, prepared by adding 0.2 mL acetyl chloride to 10 mL ice-cold dry MeOH), and the solution was stirred for 12 h at room temperature under an argon atmosphere (monitored by TLC). The solution was neutralized by filtration through a layer of alkaline alumina using chloroform as an eluent. Filtrate and eluent (ca. 40 mL) were combined, concentrated and the crude product was purified by HPLC (eluent solvent C) to yield **28** (98 mg, 58%) as a colourless foam: $[\alpha]_D^{24}$ +29.1 (*c* 1.0, $CHCl_3$); $R_f = 0.42$ (solvent A); ^{1}H NMR (300.13 MHz, $CDCl_3$): δ 1.40 (s, 3H, $^3J_{5,6} = 6.0$ Hz, H-6), 1.85 (br d, 1H, OH), 3.30 (s, 3H, OCH_3), 3.61 (dd, 1H, $^3J_{3,4} = 9.1$ Hz, H-3), 3.72 (m, 1H, H-5), 3.76–3.82 (m, 2H, H-2, H-4), 4.27 (m, 1H, $^3J_{5',6'} = 6.6$ Hz, H-5′), 4.29, 4.34 (2d, 2H, $^2J = 11.7$ Hz, $CH_2C_6H_5$), 4.39, 4.60 (2m, 2H, $^3J_{6'a,6'b} = 11.0$ Hz, H-6′a, H-6′b), 4.63 (d, 1H, $^3J_{1,2} = 1.9$ Hz, H-1), 5.27 (d, 1H, $^3J_{1',2'} = 8.2$ Hz, H-1′), 5.61 (dd, 1H, $^3J_{3',4'} = 3.5$ Hz, H-3′), 5.77 (dd, 1H, $^3J_{2',3'} = 10.4$ Hz, H-2′), 5.96 (dd, 1H, H-4′), 7.11–8.09 (m, 25H, 4 × $OCOC_6H_5$, $CH_2C_6H_5$); ^{13}C NMR (75.47 MHz, $CDCl_3$): δ 17.94 (C-6), 54.81 (OCH_3), 61.88 (C-6′), 66.40 (C-5), 67.90 (C-4), 68.25 (C-4′), 70.28 (C-2′), 70.99 (C-5′), 71.72 (C-3′), 71.84 ($CH_2C_6H_5$), 77.15 (C-2), 80.13 (C-3), 99.89 (C-1), 101.29 (C-1′), 127.18, 127.96, 128.00,

128.26, 128.34, 128.40, 128.47, 128.64, 129.14, 129.22, 129.35, 129.66, 129.72, 129.75, 129.93, 129.96, 133.20, 133.26, 133.54, 133.77 ($CH_2C_6H_5$, 4 × $OCOC_6H_5$, 10 signals are isochronic), 165.32, 165.50, 165.58, 166.03 (4 × $OCOC_6H_5$). Anal. Calcd for $C_{48}H_{46}O_{14}$ (846.87): C, 68.08.; H 5.47. Found: C, 68.14; H 5.52.

3.20. 2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranosyl bromide (30)

Trimethylsilyl bromide (31 μL, 0.24 mmol) was added to a stirred solution of **29** (147 mg, 0.16 mmol) in dry CH_2Cl_2 (3 mL) at −10 °C under an argon atmosphere. After stirring for 1 h at that temperature, the mixture was allowed to attain room temperature and stirring was continued for further 24 h (TLC solvent A). Then, the reaction mixture was concentrated and dried to yield **30** (135 mg, 90%) as a colourless foam: $R_f = 0.48$ (solvent A); ^{1}H NMR (250.13 MHz, $CDCl_3$): δ 1.45 (d, 3H, $^3J_{5,6} = 6.1$ Hz, H-6), 2.03 (s, 3H, $OCOCH_3$), 3.77–4.06 (m, 2H, H-4, H-5), 4.11 (dd, 1H, $^3J_{3,4} = 3.4$ Hz, H-3), 4.18–4.45 (m, 5H, H-5′, H-6′a, H-6′b, $CH_2C_6H_5$), 5.28 (dd, 1H, $^3J_{2,3} = 9.5$ Hz, H-2), 5.32 (d, 1H, $^3J_{1',2'} = 7.6$ Hz, H-1′), 5.59 (dd, 1H, $^3J_{3',4'} = 3.4$ Hz, H-3′), 5.81 (dd, 1H, $^3J_{2',3'} = 10.7$ Hz, H-2′), 5.97 (d, 1H, H-4′), 6.03 (d, 1H, $^3J_{1,2} = 1.2$ Hz, H-1), 7.14–8.12 (m, 25H, 4 × $OCOC_6H_5$, $CH_2C_6H_5$).

3.21. Methyl 2-*O*-acetyl-4-*O*-benzoyl-3-*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 (31)

Glycosyl acceptor **28** (95 mg, 0.11 mmol), donor **19**[15] (103 mg, 0.11 mmol) and molecular sieves (4 Å, 900 mg) were dried 1 h at ambient temperature under high vacuum. Then, the solids were suspended in dry CH_2Cl_2 (8 mL), and the reaction mixture was stirred for 2 h at room temperature under an inert atmosphere in the dark. After cooling to −70 °C, trimethylsilyl trifluoromethanesulfonate (36 μL, 0.2 mmol) was added and stirring was continued for 3 h at that temperature. At that point, the reaction mixture was allowed to warm-up to room temperature and stirring was continued for an additional 18 h. At completion (monitored by TLC), the reaction mixture was passed through a layer of alkaline alumina by elution with chloroform. Filtrate and eluent (ca. 30 mL) were combined, dried and concentrated. The crude product was purified by HPLC (eluent gradient EtOAc 0%→50% in heptane) to give tetrasaccharide **31** (109 mg, 62%) as a colourless foam: $[\alpha]_D^{22}$ +61.9 (*c* 0.53, $CHCl_3$); $R_f = 0.45$ (solvent A); ^{1}H NMR (500.13 MHz, $CDCl_3$): δ 1.35 (d, 3H, $^3J_{5,6} = 6.0$ Hz, H-6), 1.45 (d, 3H, $^3J_{5'',6''} = 6.0$ Hz, H-6″), 2.05 (s, 3H, $OCOCH_3$), 3.22 (s, 3H, OCH_3), 3.30 (s, 3H, OCH_3'), 3.35–3.90 (m, 7H, H-2′, H-3′, H-3, H-4, H-5, H-3″, H-5″), 3.91–5.00 (m, 13H, 4 × $CH_2C_6H_5$, H-4′, H-5′, H-5‴, H-6‴a, H-6‴b), 4.65 (d, 1H, $^3J_{1,2} = 2.5$ Hz, H-1), 4.93 (d, 1H, $^3J_{1',2'} = 3.5$ Hz, H-1′), 5.00–5.80 (m, 3H, H-2, H-2″, H-4″), 5.07 (d, 1H, $^3J_{1'',2''} = 1.8$ Hz, H-1″), 5.38 (d, 1H, $^3J_{1''',2'''} = 7.9$ Hz, H-1‴), 5.55 (dd, 1H, $^3J_{3''',4'''} = 2.8$ Hz, H-3‴), 5.77 (dd, 1H, $^3J_{2''',3'''} = 10.4$ Hz, H-2‴), 5.99 (dd, 1H, H-4‴), 7.00–8.10 (m, 45H, 4 × $CH_2C_6H_5$, 5 × $OCOC_6H_5$); ^{13}C NMR (125.76 MHz, $CDCl_3$): δ 17.40 (C-6), 17.58 (C-6″), 21.03 ($OCOCH_3$), 51.99 (OCH_3), 54.79 (OCH_3'), 61.70 (C-6‴), 72.89, 73.02, 73.10, 73.56 (4 × $CH_2C_6H_5$), 67.10, 67.36, 68.39, 68.81, 70.24, 71.43, 71.99, 74.37, 74.47, 74.65, 75.54, 76.39, 78.06, 78.15, 79.24, 79.35 (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″), 98.09 (C-1), 98.36 (C-1′), 99.72 (C-1″), 101.22 (C-1‴), 125.56, 126.38, 127.04, 127.17, 127.37, 127.47, 127.63, 127.83, 127.93, 128.09, 128.13, 128.31, 128.44, 128.63, 128.69, 128.82, 128.88, 129.00, 129.15, 129.21, 129.27, 129.37, 129.47, 129.70, 129.80, 132.89, 133.03, 133.19, 133.41, 133.51, 137.71, 137.92, 138.01, 138.32 (4 × $CH_2C_6H_5$, 5 × $OCOC_6H_5$, 20 signals are isochronic), 165.34, 165.48, 165.51, 165.64, 166.14 (5 × $OCOC_6H_5$), 168.45 (C-6′), 170.14 ($OCOCH_3$). Anal. Calcd for $C_{91}H_{90}O_{26}$ (1599.67): C, 68.32; H 5.67. Found: C, 68.14; H 5.53.

3.22. Glycosylation of acceptors 16 and 32 with donor 30

Acceptor **16** or **32** (0.3 mmol), bromide **30** (281 mg, 0.3 mmol) and molecular sieves (4 Å, 2.4 g) were dried for 1 h at ambient temperature under high vacuum in the dark. The solids were suspended in dry CH_2Cl_2 (8 mL), 2,6-di-*tert*-butyl-4-methyl-pyridine (74 mg, 0.36 mmol) was added, and the suspension was stirred for 30 min at room temperature under an argon atmosphere in the dark. After chilling to −65 °C, silver trifluoromethansulfonate (85 mg, 0.33 mmol) was added, and the reaction mixture was stirred 2 h at that temperature. At this point, the mixture was allowed to attain room temperature and stirring was continued for further 18 h. At completion (monitored by TLC), the reaction mixture was passed through a layer of alkaline alumina by elution with chloroform. The filtrate and eluent (ca. 50 mL) were extracted with cold aq 3% hydrochloric acid (2 × 20 mL), ice water (20 mL), cold aq $NaHCO_3$ (2 × 20 mL), ice water (2 × 20 mL), dried and concentrated. Finally, the residue was purified by HPLC (eluent solvent B) to give the desired trisaccharides **33** (262 mg, 68%) and **34** (302 mg, 74%), respectively, both as colourless foam.

3.23. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (33)

$[\alpha]_D^{24}$ +43.6 (*c* 1.0, $CHCl_3$); $R_f = 0.46$ (solvent A); ^1H NMR (500.13 MHz; $CDCl_3$): δ 1.40 (d, 3H, $^3J_{5',6'} = 6.3$ Hz, H-6′), 1.92 (s, 3H, $OCOCH_3$), 3.52 (dd, 1H, $^3J_{3',4'} = 9.8$ Hz, H-3′), 3.55 (m, 1H, H-5′), 3.68–3.74 (m, 3H, H-4′, H-2, H-3), 3.76 (s, 3H, OCH_3), 4.03 (s, 1H, H-5), 4.08–4.49 (m, 7H, $2 \times CH_2C_6H_5$, $CH_2CH{=}CH_2$, H-4), 4.34 (d, 1H, $^3J_{1,2} = 7.6$ Hz, H-1), 4.41 (dd, 1H, $^3J_{5'',6''} = 6.3$ Hz, H-6″a), 4.44 (s, 1H, H-5″), 4.63 (dd, 1H, $^2J_{6''a,6''b} = 11.0$ Hz, H-6″b), 4.70 (s, 2H, $CH_2C_6H_5$), 4.71, 4.86 (2d, 2H, $^2J = 10.7$ Hz, $CH_2C_6H_5$), 5.18, 5.30 (2m, 2H, $CH_2CH{=}CH_2$), 5.28 (d, 1H, $^3J_{1'',2''} = 7.9$ Hz, H-1″), 5.32 (d, 1H, $^3J_{1',2'} = 1.9$ Hz, H-1′), 5.39 (dd, 1H, $^3J_{2',3'} = 2.8$ Hz, H-2′), 5.52 (dd, 1H, $^3J_{3'',4''} = 3.5$ Hz, H-3″), 5.79 (dd, 1H, $^3J_{2'',3''} = 10.4$ Hz, H-2″), 5.94 (dd, 1H, H-4″), 5.91 (m, 1H, $CH_2CH{=}CH_2$), 7.15–8.10 (m, 35H, $3 \times CH_2C_6H_5$, $4 \times OCOC_6H_5$); ^{13}C NMR (125.76 MHz, $CDCl_3$): δ 17.89 (C-6′), 20.90 ($OCOCH_3$), 52.78 (OCH_3), 61.90 (C-6″), 67.36 (C-5′), 68.13 (C-2′), 68.34 (C-4), 70.20 (C-2″), 70.76, 73.06, 75.22 ($3 \times CH_2C_6H_5$), 70.87 (C-4″), 71.56 ($CH_2CH{=}CH_2$), 71.85 (C-5″), 71.90 (C-3″), 73.87 (C-5), 76.33 (C-4′), 77.50 (C-3), 78.15 (C-2), 81.11 (C-3′), 98.21 (C-1′), 100.89 (C-1″), 102.71 (C-1), 117.62 ($CH_2CH{=}CH_2$), 132.50 ($CH_2CH{=}CH_2$), 127.37, 127.42, 127.48, 127.61, 127.64, 128.21, 128.23, 128.26, 128.33, 128.39, 128.41, 128.44, 128.50, 128.65, 128.80, 128.84, 129.26, 129.30, 129.49, 129.67, 129.71, 129.76, 129.92, 130.83, 133.17, 133.20, 133.48, 133.79, 137.80, 138.07, 138.35 ($3 \times CH_2C_6H_5$, $4 \times OCOC_6H_5$, 11 signals are isochronic), 165.35, 165.53, 166.02, 167.71, ($4 \times OCOC_6H_5$), 168.28 (C-6), 169.64 ($OCOCH_3$). Anal. Calcd for $C_{73}H_{72}O_{21}$ (1285.34): C, 68.21; H 5.65. Found: C, 68.30; H 5.72.

3.24. Benzyl 2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl-(1→4)-2-*O*-acetyl-3-*O*-benzyl-α-L-rhamnopyranosyl-(1→4)-(allyl 2,3-di-*O*-benzyl-β-D-galactopyranosid)uronate (34)

$[\alpha]_D^{21}$ +54.3 (*c* 1.0, $CHCl_3$); $R_f =$ 0.48 (solvent A); ^1H NMR (500.13 MHz, $CDCl_3$): δ 1.37 (d, 3H, $^3J_{5',6'} = 5.8$ Hz, H-6′), 1.95 (s, 3H, $OCOCH_3$), 3.51 (dd, 1H, $^3J_{3,4} = 2.7$ Hz, H-3), 3.72 (d, 1H, $^3J_{2,3} = 9.8$ Hz, H-2), 3.65–3.78 (m, 3H, H-3′, H-4′, H-5′), 4.03 (d, 1H, $^3J_{4,5} = 1.2$ Hz, H-5), 4.06–4.16 (m, 2H, $CH_2C_6H_5$, $CH_2CH{=}CH_2$), 4.29 (t, 1H, $^3J_{5'',6''a} = 6.6$ Hz, $^3J_{5'',6''b} = 6.7$ Hz, H-5″), 4.35 (d, 1H, $^3J_{1,2} = 7.6$ Hz, H-1), 4.38–4.51 (m, 4H, H-6″a, H-4, $CH_2C_6H_5$, $CH_2CH{=}CH_2$), 4.61–4.87 (m, 5H, H-6″b, $2 \times CH_2C_6H_5$), 5.14–5.36 (m, 2H, $CH_2CH{=}CH_2$), 5.24 (s, 2H, $CH_2C_6H_5$), 5.30 (d, 1H, $^3J_{1'',2''} = 7.9$ Hz, H-1″), 5.34 (d, 1H, $^3J_{1',2'} = 0.9$ Hz, H-1′), 5.56 (dd, 1H, $^3J_{3'',4''} = 3.4$ Hz, H-3″), 5.80 (dd, 1H, $^3J_{2'',3''} = 10.4$ Hz, H-2″), 5.85–6.00 (m, 1H, $CH_2CH{=}CH_2$), 5.96 (d, 1H, H-4″), 7.15–8.08 (m, 40 H, $4 \times CH_2C_6H_5$, $4 \times OCOC_6H_5$); ^{13}C NMR (125.76 MHz, $CDCl_3$): δ 18.08 (C-6′), 20.91 ($OCOCH_3$), 61.94 (C-6″), 67.35, 70.69, 71.52, 73.09 ($4 \times CH_2C_6H_5$), 67.48 (C-5′), 68.20 (C-2′), 68.45 (C-4″), 70.11 (C-2″), 70.92 (C-5″), 71.83 (C-3″), 72.00 (C-4), 73.61 (C-5), 75.24 ($CH_2CH{=}CH_2$), 76.74 (C-4′), 77.43 (C-3′), 78.15 (C-2), 81.27 (C-3), 98.19 (C-1′), 101.13 (C-1″), 102.73 (C-1), 117.53 ($CH_2CH{=}CH_2$), 127.51, 127.57, 127.61, 127.64, 127.73, 128.23, 128.25, 128.31, 128.33, 128.36, 128.43, 128.58, 128.63, 128.84, 129.27, 129.36, 129.52, 129.69, 129.71, 129.76, 129.92, 133.03, 133.19, 133.25, 133.46, 135.36, 137.84, 138.08, 138.35 ($4 \times CH_2C_6H_5$, $4 \times OCOC_6H_5$, 19 signals are isochronic), 133.87 ($CH_2CH{=}CH_2$), 165.41, 165.56, 166.03 ($4 \times OCOC_6H_5$), 167.02 (C-6), 169.65 ($OCOCH_3$). Anal. Calcd for $C_{79}H_{76}O_{21}$ (1361.44): C, 69.69; H 5.63. Found: C, 69.63; H 5.69.

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