

An Expeditious Route to the Synthesis of Kelampayosides A and B

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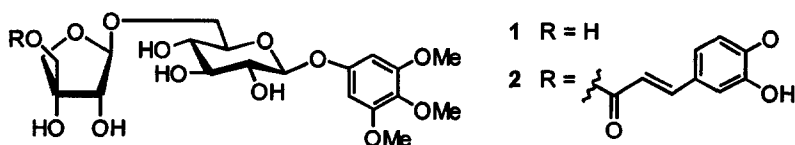
Abstract: Chemoselective NIS/ cat. TfOH-mediated glycosylation of ethyl 2,3,4-tri-*O*-benzoyl-1-thio- β -D-glucopyranoside (13) with ethyl 2,3-di-*O*-acetyl-5-*O*-benzyl-1-thio- α/β -D-*erythro*-apiofuranoside (4a) gave dimer 14 in an excellent yield. $\text{BF}_3 \cdot \text{Et}_2\text{O}$ -catalysed condensation of the α -trichloroacetimidate 31, accessible in two steps from 14, with 3,4,5-trimethoxyphenol gave β -linked derivative 32 followed by deprotection gave Kelampayoside A. Protecting group manipulations of 32 and subsequent caffeoylation of resulting 36 followed by deprotection gave Kelampayoside B. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Carbohydrates, Chemoselective Glycosidation, Apiose, Fries-rearrangement.

Introduction

More than ten years ago, Shiraga *et al.*¹ showed that 3,4,5-trimethoxyphenyl β -D-*erythro*-apiofuranosyl-(1 \rightarrow 6)- β -D-glucopyranoside (1, see Figure 1), isolated earlier² from the dried stem bark of *Cinnamomum cassia* Blume, exhibits antiulcerogenic activity in rats. Recently, Kitagawa *et al.*³ isolated the same active compound 1 as well as its 5"-*O*-caffeoyl derivative 2 (so-called kelampayoside A and B, respectively) from the bark of *Anthocephalus chinensis*. Both 1 and 2 are characterized by the presence of the rare apiofuranose sugar, the occurrence of which is restricted⁴ to the plant kingdom, and the rather electron-rich 3,4,5-trimethoxyphenyl moiety. Thus far only scarce information⁵ on the glycosylating properties of apiofuranosyl donors is available. Moreover, it was anticipated that a Lewis acid catalyzed introduction of the requisite β -linked 3,4,5-trimethoxyphenyl portion could be accompanied by Fries-type rearrangement⁶ resulting in the formation of the unwanted *C*-aryl derivative. The aforementioned chemical and, to a lesser extent, pharmacological aspects seemed to us a justifiable objective in preparing⁷ kelampayosides A (1) and B (2).

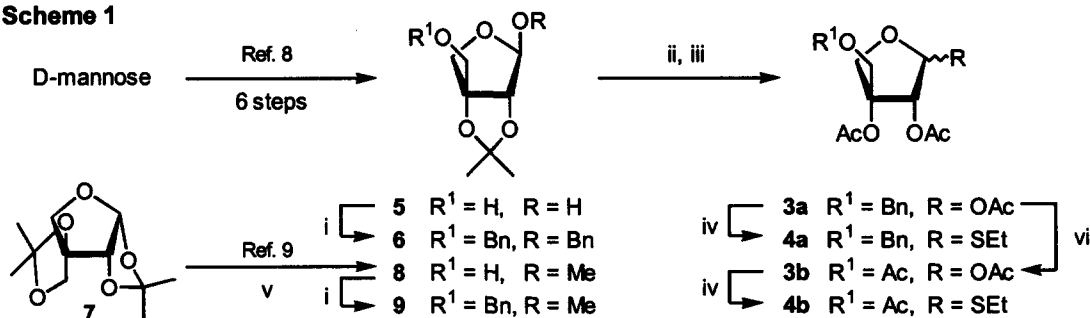
Figure 1



Results and discussion

Prior to the assembly of the target molecules **1** and **2**, attention was focused on the glycosylating properties of apiofuranosyl donors **3a** and **4a-b**. The 1,2,3-tri-*O*-acetyl-5-*O*-benzyl- α/β -D-apiofuranose (**3a**, see Scheme 1) was prepared from 2,3-*O*-isopropylidene- β -D-*erythro*-apiofuranose⁸ (**5**) by sequential benzylation (\rightarrow **6**), acidolysis and acetylation according to the procedure of Tapiéro^{5a}. An alternative route to **3a** entails treatment⁹ of commercially available, although expensive, 1,2:3,5-di-*O*-isopropylidene- α -D-*threo*-apiofuranose (**7**) with hydrogen chloride in dry methanol to give methyl 2,3-*O*-isopropylidene- β -D-*erythro*-apiofuranoside⁹ (**8**), which was converted into **3a** by the same three-step procedure used before for the conversion of **5** into **3a**. Reaction of **3a** with ethanethiol in the presence of a catalytic amount of SnCl₄ gave ethyl 2,3-di-*O*-acetyl-5-*O*-benzyl-1-thio- α/β -D-*erythro*-apiofuranoside (**4a**) in 83% yield. In the same way, the fully acetylated ethyl 1-thio- α/β -D-apiofuranoside **4b** was prepared from **3b**^{5a}, which in turn was readily accessible by hydrogenolysis and acetylation of **3a**.

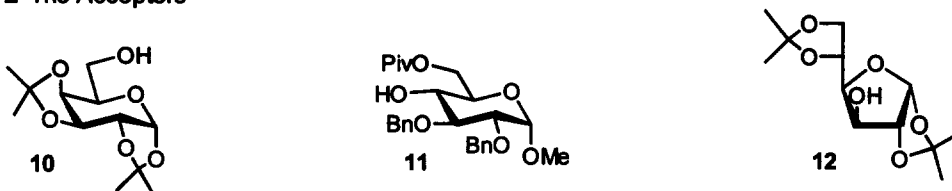
Scheme 1



Reagents and Conditions: (i) BnBr, NaH, DMF, **6**: 85%, **9**: 82%; (ii) 80% formic acid, 60°C; (iii) Ac₂O, DMAP, pyridine (79% based on 2 steps); (iv) EtSH, cat. SnCl₄, CH₂Cl₂, **4a**: 83%, **4b**: 86%; (v) dry HCl in MeOH, 81%; (vi) a) H₂, 10% Pd/C; b) Ac₂O, pyridine, (92%, 2 steps).

The results of the glycosylations of the primary and secondary acceptors **10**¹⁰, **11**¹¹ and **12** with apiofuranosyl donors **3a** and **4a-b** are recorded in Table 1. It can be seen that trimethylsilyl triflate (TMSOTf) assisted glycosylation of acceptors **10** and **11** with 1-*O*-acetyl- α/β -D-*erythro*-apiofuranose **3a** proceeded in a moderate yield (entry 1 and 2). Conversely, the condensation of ethyl 1-thio- α/β -D-*erythro*-apiofuranoside **4a** with the individual acceptors **10-12** in the presence of *N*-iodosuccinimide and catalytic triflic acid¹² (NIS / cat. TfOH) proceeded in a highly stereoselective fashion and excellent yield (entry 3, 4 and 5). A similar result was obtained (entry 6) using the fully acetylated ethyl 1-thio-apiosyl donor **4b**.

The latter auspicious results were an incentive to explore (see Scheme 2) the feasibility whether the functionalized dimer **14**, a key intermediate en route to kelampayoside A and B, could be prepared via a chemoselective glycosylation of the partially benzoylated ("disarmed")¹³ ethyl 1-thio-glucosyl acceptor **13**¹⁴

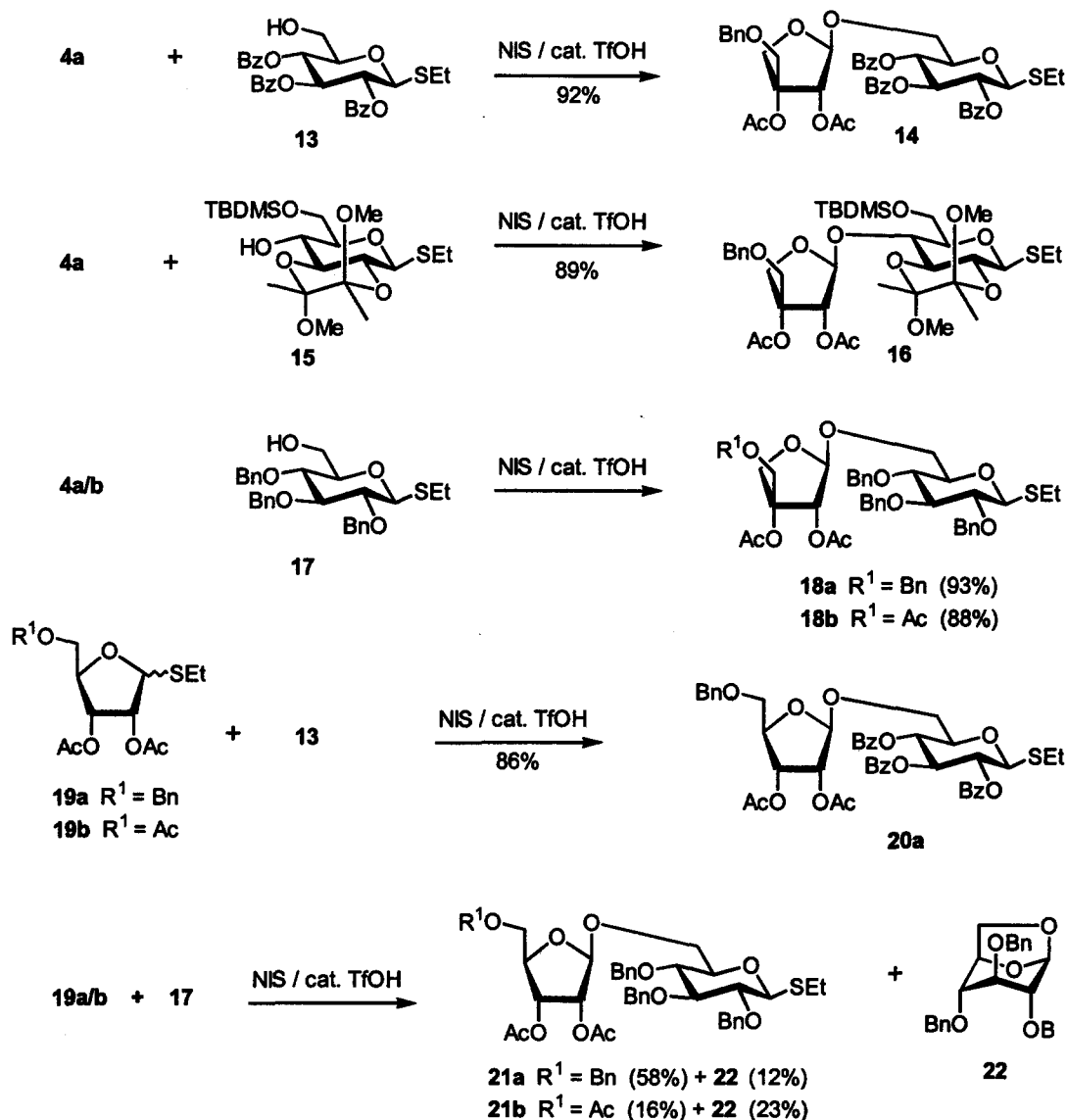
Figure 2 The Acceptors**Table 1.** Results of glycosylations of acceptors (10–12) with apiosyl donors (3a and 4a–b).

Entry	Donor	Acceptor	Promoter	Temperature	Time	Yield ^a
1	3a	10	cat. TMSOTf	23°C	15 min	73%
2	3a	11	cat. TMSOTf	23°C	15 min	52%
3	4a	10	NIS / cat. TfOH	0°C	1 min	98%
4	4a	11	NIS / cat. TfOH	0°C	1 min	93%
5	4a	12	NIS / cat. TfOH	0°C	1 min	95%
6	4b	11	NIS / cat. TfOH	0°C	1 min	91%

^a In all cases, only the β -isomer was detected by ¹H NMR spectroscopy.

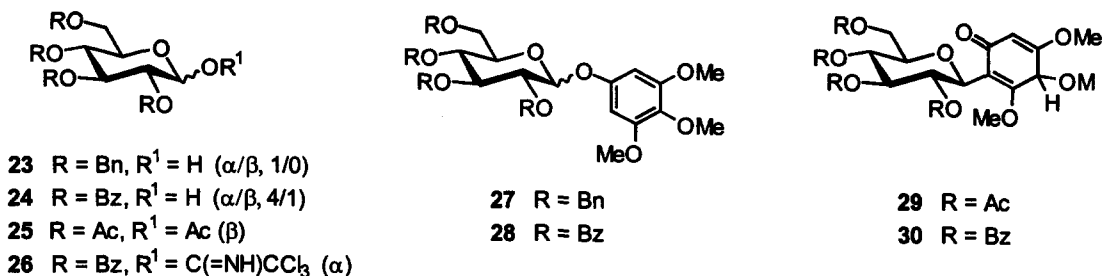
with the also in principle "disarmed" ethyl 1-thio-apiosyl donor 4a. It was established that NIS / cat. TfOH mediated glycosylation of the glycosyl acceptor 13 with donor 4a proceeded with a high degree of chemoselectivity to give the β -linked dimer 14 in 92% yield (see Scheme 2). The outcome of this experiment indicates that the deactivating effect of the 2-*O*-acetyl group in donor 4a is more than fully compensated by the intrinsically higher reactivity of a glycosylating species derived from a furanosyl than a pyranosyl donor. The latter effect may also explain the unexpected high chemoselectivity in the NIS / cat. TfOH-assisted glycosylation of both more hindered "semi disarmed"¹⁵ pyranosyl acceptor 15 (\rightarrow 16) and the partially benzylated ("armed")¹³ acceptor 17¹⁶ (\rightarrow 18a) with apiosyl donor 4a. The general nature of the furanosyl effect was also demonstrated (see Scheme 2) in the highly chemoselective glycosylation of "disarmed" acceptor 13 (\rightarrow 20a) with "disarmed" ethyl 2,3-di-*O*-acetyl-5-*O*-benzyl-1-thio- α/β -D-ribofuranoside¹⁷ (19a). In contrast to the high-yielding condensation of 17 with apiofuranosyl donor 4a, the glycosylation of 17 with ribofuranosyl donor 19a proceeds moderately as evidenced by the relatively low yield of 21a as well as the formation of the 1,6-anhydro derivative 22. The latter results showed that the apiofuranosyl donor (4a) is more reactive than the corresponding ribofuranosyl donor (19a). This observation was confirmed by the outcome of the glycosylation of 17 with fully acetylated ethyl 1-thio-apiofuranosyl and ethyl 1-thio-ribofuranosyl donors 4b and 19b, respectively. Thus, condensation of 17 with apiosyl donor 4b resulted in the formation of 18b in 88% yield, whereas glycosylation of 17 with ribofuranosyl donor 19b led mainly to the 1,6-anhydro product 22.

Scheme 2



At this stage, attention was focused on the introduction of the requisite β -linked 3,4,5-trimethoxyphenyl moiety in the target compounds 1 and 2. Initially, the glucopyranose derivatives 23 and 24 (Figure 3) were condensed with commercially available 3,4,5-trimethoxyphenol under Mitsunobu¹⁸ conditions. The results of this study are summarized in Table 2. It can be seen (entry 1) that Mitsunobu glycosylation of 3,4,5-trimethoxyphenol with anomerically pure 23 (α) proceeds as expected¹⁸ with inversion of configuration to give the O - β -glycoside 27. It is also evident (entry 2) that the β -directing effect of the 2- O -benzoyl group in the anomerically impure donor 24 is reflected in the predominant formation of the O - β -glycoside 28.

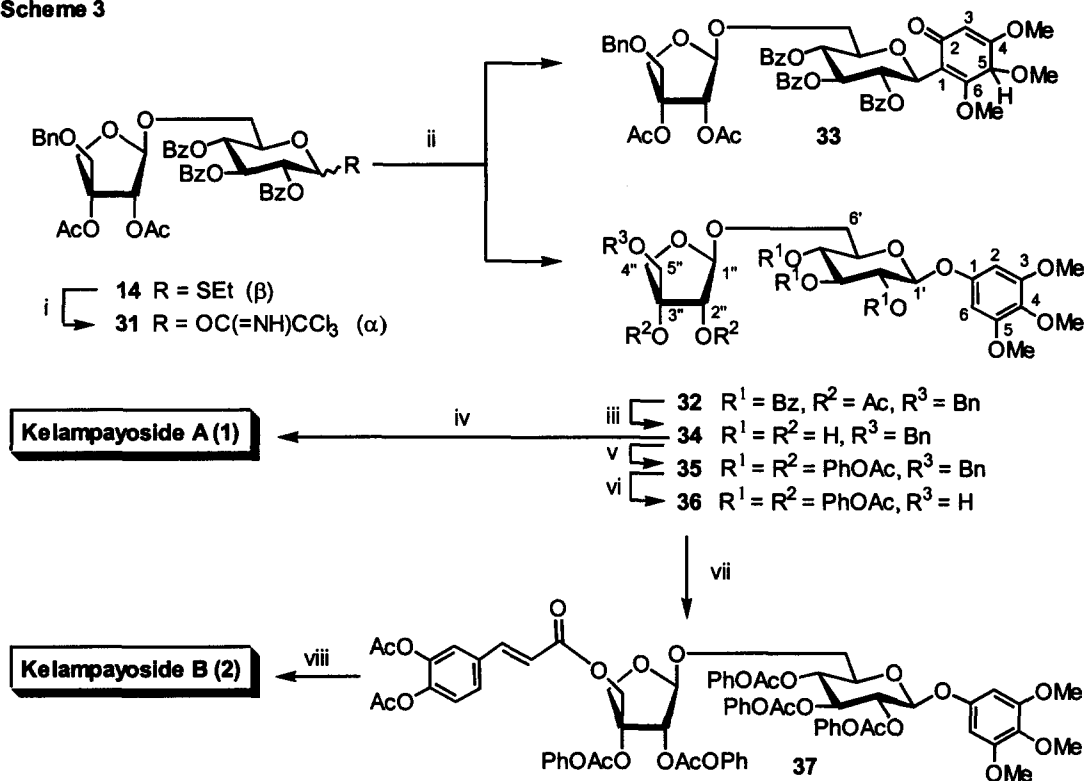
Figure 3

**Table 2.** Relevant data on the glycosylation of trimethoxyphenol with the glucopyranosyl donors 23–26.

Entry	Donor	Activator	Solvent	O-aryl	C-aryl
1	23	DEAD, Ph ₃ P	THF	62% (27: α/β , 0/1)	-
2	24	DEAD, Ph ₃ P	THF	55% (28: α/β , 1/7)	-
3	25	BF ₃ •Et ₂ O (1.0 equiv.)	CH ₂ Cl ₂	-	88% (29)
4	26	BF ₃ •Et ₂ O (0.25 equiv.)	CH ₂ Cl ₂	41% (28: α/β , 0/1)	18% (30)
5	26	BF ₃ •Et ₂ O (0.25 equiv.)	CH ₂ Cl ₂ /THF, (10/1, v/v)	64% (28: α/β , 0/1)	5% (30)

Another route to *O*-aryl glycosides comprises Lewis acid mediated glycosylation of free phenolic hydroxyl functions. On the other hand, it is well documented⁶ that the initially formed *O*-aryl glycoside may participate in an *O*→*C*-glycoside rearrangement to give a *C*-aryl glycoside (Fries-type rearrangement). Several studies towards the synthesis of *C*-aryl glycosides have shown that reactive glycosyl donors (fully *O*-alkylated or 2-deoxypyranosides) undergo more facile *O*→*C*-migration. In addition, it became clear that the construction of *O*-aryl glycosides can be executed successfully using boron trifluoride diethyl etherate (BF₃•Et₂O) as the promoter. For example, the synthesis of several¹⁹ *O*-aryl β -D-glucopyranosides from penta-*O*-acetyl- β -D-glucopyranose (25) and the corresponding aryl acceptors could be accomplished using an equimolar amount of BF₃•Et₂O in CH₂Cl₂. However, condensation of 25 with 3,4,5-trimethoxyphenol under these conditions led to the exclusive formation of *C*-aryl derivative 29 (Table 2, entry 3), indicating that the 3,4,5-trimethoxyphenyl glycoside is more prone to Fries-type rearrangement, due to the electron-donating methoxy substituents in the phenyl moiety. It occurred to us, that the application²⁰ of the α -trichloroacetimidate donor 26, which can be activated by a catalytic amount of BF₃•Et₂O, would have a beneficial effect on the outcome of the glycosylation reaction. Nevertheless, condensation of 26 with 3,4,5-trimethoxyphenol under the influence of a small amount of BF₃•Et₂O gave apart from the β -*O*-glucoside 28 an unacceptable quantity of the β -*C*-glucoside 30 (entry 4). It was therefore gratifying to find that 28 was the main product (entry 5) by executing the same glycosidation in CH₂Cl₂ containing a small amount of THF. Moreover, β -*O*-glucoside 28 could be readily separated by silica gel chromatography from the undesired β -*C*-glucoside 30. In an attempt to completely

Scheme 3



Reagents and conditions: (i) a) NIS / cat. TfOH, $\text{CH}_2\text{Cl}_2/\text{H}_2\text{O}$, (100/1, v/v); b) Cs_2CO_3 , CCl_3CN , CH_2Cl_2 (86%, 2 steps); (ii) 3,4,5-trimethoxyphenol, 0.25 equiv. $\text{BF}_3 \cdot \text{Et}_2\text{O}$, $\text{CH}_2\text{Cl}_2/\text{THF}$ (10/1, v/v), (32: 63%, 33: 4%); (iii) NaOMe, $\text{MeOH}/\text{CH}_2\text{Cl}_2$, (5/1, v/v), 88%; (iv) H_2 , 10% Pd/C, $i\text{-PrOH}/\text{H}_2\text{O}$ (10/1, v/v), 91%; (v) PhOAcCl, CH_2Cl_2 , pyridine, 88%; (vi) H_2 , 10% Pd/C, $i\text{-PrOH}/\text{EtOAc}/\text{H}_2\text{O}$ (12/8/1, v/v/v), 86%; (vii) 3,4-di-O-acetylcaffeoyl chloride, CH_2Cl_2 , pyridine, 77%; (viii) 0.005 M K_2CO_3 , $\text{MeOH}/\text{CH}_2\text{Cl}_2$ (1/2, v/v), 49%.

suppress $O \rightarrow C$ migration, the glycosidation was also carried out at lower temperature (-20°C) and in neat THF. However, under these conditions no condensation of trichloroacetimidate donor 26 with 3,4,5-trimethoxyphenol was observed.

On the basis of the latter results, it became apparent that the trichloroacetimidate derivative 31, which can be readily prepared (see Scheme 3) in two steps from the corresponding ethyl 1-thio-disaccharide 14, would be an ideal starting compound for the synthesis of kelampayoside A (1) and B (2). Indeed, condensation (see Scheme 3) of the α -trichloroacetimidate 31 with 3,4,5-trimethoxyphenol in the presence of a catalytic amount of $\text{BF}_3 \cdot \text{Et}_2\text{O}$ in $\text{CH}_2\text{Cl}_2/\text{THF}$ gave, after purification by silica gel chromatography, the 3,4,5-trimethoxyphenyl β -O-glycoside 32 and the corresponding β -C-aryl derivative 33 in a yield of 63% and 4%, respectively. Zemplén deacylation of 32 and subsequent hydrogenolysis of 34 gave homogeneous kelampayoside A (1), the

physical data of which were in full accord with those reported³ by Kitagawa *et al.* It was expected that kelampayoside B (2) could be prepared by regioselective acylation of kelampayoside A (1) with 3,4-di-*O*-acetylcaffeoyl chloride.²¹ However, the latter possibility was thwarted by the poor solubility of 1 and impelled us to adopt the following four-step approach. Acylation of 34 with phenoxyacetyl chloride followed by debenzoylation of 35 gave 36. Treatment of the latter compound with excess 3,4-di-*O*-acetylcaffeoyl chloride, and then mild deesterification of the phenoxyacetyl and acetyl groups of 37, gave kelampayoside B (2) in a yield of 29% over four steps. The ¹H and ¹³C NMR data of the target compound 2 were in excellent agreement with those reported³ for kelampayoside B (2).

Conclusion

The expeditious route of synthesis for kelampayosides described in this paper, clearly shows that apiofuranosyl donor 4 is an effective and highly potent glycosylating agent. In addition, BF₃•Et₂O catalyzed Fries-type rearrangement (*O*→*C*-aryl migration) of an electron-rich aryl group at the anomeric center of sugars can be attenuated by the addition of THF to the reaction mixture. These findings can be implemented in the design and synthesis of other biologically interesting oligosaccharides.

Experimental

General Methods and Materials

¹H NMR and ¹³C NMR spectra were recorded with a Bruker WM-200 (200/50.1 MHz), a Bruker WM-300 (300/75.1 MHz) or a Bruker MDX-600 spectrometer (600/150 MHz). Electrospray mass-spectra were recorded using Perkin-Elmer SCIEX API 165 Single Quadrupole LC/MS instrument. Dichloromethane was dried by refluxing over CaH₂ (5 g/L) for 5 h, then distilled and stored over molecular sieves (4Å). Pyridine was dried by refluxing over P₂O₅ (5 g/L) for 5 h, then distilled and stored over molecular sieves (4Å). Diethyl ether was freshly distilled from LiAlH₄ and dried over 4Å molecular sieves for 1 hour. Methanol (Rathburn, HPLC-grade) was stored over 3Å molecular sieves. The following chemicals were obtained from Acros Organics Co. and were used as received: triethylamine, trimethylsilyl trifluoromethanesulfonate (TMSOTf), trifluoromethanesulfonic acid (TfOH), *N*-iodosuccinimide (NIS), trichloroacetonitrile, phenoxyacetyl chloride, ethanethiol, stannic chloride, palladium on carbon (10%) and 3,4,5-trimethoxyphenol. Boron trifluoride diethyl etherate, diethyl azodicarboxylate and triphenyl phosphine were purchased from Aldrich. 1,2,3,5-Tetra-*O*-acetyl-β-D-ribofuranose and Dowex 50W X4 were purchased from Fluka. Reactions were followed by TLC-analysis conducted on Schleicher and Schüll DC Fertigfolien (F 1500 LS 254). Compounds were visualized by UV light and by spraying with 20% sulfuric acid in methanol followed by charring at 140 °C. Unsaturated compounds were visualized by spraying with a solution of KMnO₄ (2%) and K₂CO₃ (1%) in water. Eluents for column chromatography were of technical grade and distilled before use. All reactions were performed under anhydrous conditions at room temperature unless stated otherwise. Gel-filtration was performed on Sephadex LH-20 (Pharmacia). Column chromatography was performed on silica gel 60 0.063–0.200 mm (Baker).

Ethyl 2,3-di-*O*-acetyl-5-*O*-benzyl-1-thio-α/β-D-erythro-apiofuranoside (4a)

To a cooled mixture (0 °C) of compound 3a^{5a} (2.33g, 6.37 mmol) and ethanethiol (7.0 mmol, 517 μL) in CH₂Cl₂ (40 mL) was added a small amount of SnCl₄ (0.63 mmol, 73 μL). After stirring for 30 min, the reaction mixture was

diluted with CH_2Cl_2 , washed successively with 1 M KF, 1 M NaHCO_3 and with water. The organic layer was dried (MgSO_4), filtered and concentrated *in vacuo*. The crude product was purified by column chromatography (20 → 40% Et_2O /light petroleum) to furnish the *title compound 4a* (1.94 g, 83%) as a colourless syrup; [Found: C, 58.8; H, 6.5. $\text{C}_{18}\text{H}_{24}\text{O}_6\text{S}$ requires C, 58.68; H, 6.57%]; R_f (50% Et_2O /light petroleum) 0.5; δ_{H} (200 MHz, CDCl_3) 1.26 (m, 3H, CH_3 , SEt), 2.06, 2.07, 2.08, 2.11 (4 × s, 6H, CH_3 , Ac), 2.64 (m, 2H, CH_2 , SEt), 3.83, 4.18 (2 × m, 4H, H-4a, H-4b, H-5a, H-5b), 4.54, 4.56 (2 × s, CH_2 , Bn), 5.13 (d, 0.65H, H-2 β), 5.31 (d, 0.65H, H-1 β , $J_{1,2}$ 4.4 Hz), 5.45 (d, 0.35H, H-2 α), 5.53 (d, 0.35H, H-1 α , $J_{1,2}$ 5.7 Hz), 7.26–7.34 (m, 5H, Bn); δ_{C} (200 MHz, CDCl_3); 14.4, 14.5 (CH_3 , SEt), 19.8, 19.9, 20.6, 20.7 (CH_3 , Ac), 24.4, 24.6 (CH_2 , SEt), 68.2, 69.9 (C-4 α , C-5 α), 68.6, 72.3 (C-4 β , C-5 β), 72.5 (C-2 α), 72.8 (CH_2 , Bn), 76.0 (C-2 β), 82.8 (C-3 α), 84.5 (C-3 β), 86.4 (C-1 β), 86.8 (C-1 α), 126.9–127.7 (CH, Bn), 137.0, 137.2 (Cq, Bn), 168.6, 169.0 (C=O, Ac).

Ethyl 2,3,5-tri-*O*-acetyl-1-thio- α/β -D-erythro-apiofuranoside (4b)

To a cooled mixture (0 °C) of compound **3b**^{5a} (1.86g, 5.87 mmol) and ethanethiol (6.45 mmol, 477 μL) in CH_2Cl_2 (30 mL) was added a small amount of SnCl_4 (0.6 mmol, 70 μL). After stirring for 45 min the reaction mixture was diluted with CH_2Cl_2 , washed successively with 1 M KF, 1 M NaHCO_3 and with water. The organic layer was dried (MgSO_4), filtered and concentrated *in vacuo*. The crude product was purified by flash column chromatography (40% Et_2O /light petroleum) to furnish the *title compound 4b* (1.61 g, 86%) as a light yellow syrup; [Found: C, 48.9; H, 6.3. $\text{C}_{13}\text{H}_{20}\text{O}_7\text{S}$ requires C, 48.74; H, 6.29%]; R_f (50% Et_2O /light petroleum) 0.3; δ_{H} (300 MHz, CDCl_3) 1.28 (m, 3H, CH_3 , SEt), 2.06, 2.10, 2.12 (6 × s, 9H, CH_3 , Ac), 2.67 (m, 2H, CH_2 , SEt), 4.13, 4.30, 4.65 (3 × m, 4H, H-4a, H-4b, H-5a, H-5b), 5.14 (d, 0.65H, H-2 β), 5.28 (d, 0.65H, H-1 β , $J_{1,2}$ 3.9 Hz), 5.51 (d, 0.35H, H-2 α), 5.56 (d, 0.35H, H-1 α , $J_{1,2}$ 5.8 Hz); δ_{C} (200 MHz, CDCl_3) 14.6, 14.7 (CH_3 , SEt), 20.2, 20.4, 21.0 (3 × CH_3 , Ac), 25.0 (CH_2 , SEt), 62.3, 69.5 (C-4 α , C-5 α), 62.6, 69.5 (C-4 β , C-5 β), 72.4 (C-2 α), 76.4 (C-2 β), 82.4 (C-3 α), 83.4 (C-3 β), 86.5 (C-1 α), 86.7 (C-1 β), 168.4, 169.9 (C=O, Ac).

6-*O*-(2,3-Di-*O*-acetyl-5-*O*-benzyl- β -D-erythro-apiofuranosyl)-1,2:3,4-di-*O*-isopropylidene- α -D-galactopyranose (Table 1, entry 3)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a mixture of donor **4a** (0.60 mmol, 185 mg) acceptor **10** (0.50 mmol, 131 mg) and powdered molecular sieves in 1,2-dichloroethane/ Et_2O (12 mL, 1/1, v/v) at 0 °C under an atmosphere of N_2 . After 2 min, the reaction was filtered, diluted with CH_2Cl_2 , washed successively with 1 M $\text{Na}_2\text{S}_2\text{O}_3$, 1 M NaHCO_3 and H_2O , dried (MgSO_4), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (35% Et_2O /light petroleum) gave the *title compound* (276 mg, 98%) as a colourless syrup; [Found: C, 59.6; H, 6.7. $\text{C}_{28}\text{H}_{38}\text{O}_{12}$ requires C, 59.36; H, 6.76%]; R_f (50% Et_2O /light petroleum) 0.25; $[\alpha]_{\text{D}}^{20}$ -7.2° (c 1.0, CHCl_3); m/z 567.4 (M+H)⁺, 589.3 (M+Na)⁺; δ_{H} (300 MHz, CDCl_3) 1.28, 1.32, 1.42, 1.52 (4 × s, 12H, CH_3 , isopr.), 2.06, 2.08 (2 × s, 6H, CH_3 , Ac), 3.60 (dd, 1H, H-6a, $J_{5,6a}$ 7.2 Hz, $J_{6a,6b}$ 9.7 Hz), 3.75 (dd, 1H, H-6b, $J_{5,6b}$ 5.8 Hz), 3.93 (m, 1H, H-5), 4.00 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.02 (dd, 1H, H-4, $J_{3,4}$ 7.9 Hz, $J_{4,5}$ 1.9 Hz), 4.21 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.29 (dd, 1H, H-2, $J_{2,3}$ 2.4 Hz), 4.53 (m, 3H, H-3, CH_2 , Bn), 5.03 (s, 1H, H-2'), 5.36 (s, 1H, H-1'), 5.51 (d, 1H, H-1, $J_{1,2}$ 5.0 Hz), 7.27–7.37 (m, 5H, Bn); δ_{C} (200 MHz, CDCl_3) 20.5, 21.2 (2 × CH_3 , Ac), 24.3, 24.8, 25.7, 25.8 (4 × CH_3 , isopr.), 66.1 (C-6), 66.5, 70.2, 70.5, 70.8, 76.5 (C-2, C-3, C-4, C-5, C-2'), 69.6, 69.7, 73.2 (CH_2 , Bn, C-4', C-5'), 85.4 (C-3'), 96.1 (C-1), 105.8 (C-1'), 108.4, 109.0 (Cq, isopr.), 127.4–128.2 (CH, Bn), 137.8 (Cq, Bn), 169.1, 169.8 (C=O, Ac).

Methyl 4-*O*-(2,3-di-*O*-acetyl-5-*O*-benzyl- β -D-erythro-apiofuranosyl)-2,3-di-*O*-benzyl-6-*O*-pivaloyl- α -D-glucopyranoside (Table 1, entry 4)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a

mixture of donor **4a** (0.60 mmol, 221 mg) acceptor **11** (0.50 mmol, 221 mg) and powdered molecular sieves in 1,2-dichloroethane/Et₂O (12 mL, 1/1, v/v) at 0°C under an atmosphere of N₂. After 2 min, the reaction was filtered, diluted with CH₂Cl₂, washed successively with 1 M Na₂S₂O₃, 1 M NaHCO₃ and H₂O, dried (MgSO₄), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (35% Et₂O/light petroleum) followed further purification on a sephadex LH20 column (50% CH₂Cl₂/MeOH) to afford the *title compound* (333 mg, 93%) as a colourless syrup; [Found: C, 66.0; H, 6.8. C₄₂H₅₂O₁₃ requires C, 65.95; H, 6.85%]; R_f (33% Et₂O/light petroleum) 0.2; [α]_D²⁰ -6.1° (c 2, CHCl₃); *m/z* 765.5 (M+H)⁺, 787.4 (M+Na)⁺; δ_H (300 MHz, CDCl₃) 1.18 (s, 9H, Piv), 2.02, 2.04 (2 × s, 6H, Ac), 3.38 (s, 3H, OMe), 3.45 (dd, 1H, H-2, J_{2,3} 9.5 Hz), 3.60 (t, 1H, H-4, J_{4,5} 9.8 Hz), 3.79 (m, 2H, H-3, H-5), 4.00 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.11 (m, 1H, H-6a), 4.17 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.42 (m, 1H, H-6b), 4.54 (d, 1H, J_{1,2} 3.7 Hz), 4.61 (AB, CH₂, Bn), 4.70 (AB, CH₂, Bn), 4.75 (AB, CH₂, Bn), 5.10 (d, 1H, H-2'), 5.25 (d, 1H, H-1', J_{1,2'} 1.5 Hz), 7.26–7.38 (m, 20H, Bn); δ_C (200 MHz, CDCl₃) 20.4, 21.1 (2 × CH₃, Ac), 27.0 ((CH₃)₃, Piv), 38.6 (Cq, Piv), 55.0 (OMe), 62.3, 68.7, 72.6, 73.2, 75.5 (3 × CH₂, Bn, C-4', C-5', C-6), 68.4, 76.8, 77.3, 79.7 (C-2, C-3, C-4, C-5, C-2'), 84.4 (C-3'), 97.7 (C-1), 107.1 (C-1'), 127.5–128.2 (CH, arom.), 137.4, 137.8, 138.4 (Cq, Bn), 169.3, 169.6 (C=O, Ac), 177.6 (C=O, Piv).

3-O-(2,3-Di-O-acetyl-5-O-benzyl-β-D-erythro-apiofuranosyl)-1,2:5,6-di-O-isopropylidene-α-D-glucofuranose (Table 1, entry 5)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a mixture of donor **4a** (0.60 mmol, 221 mg) acceptor **12** (0.50 mmol, 130 mg) and powdered molecular sieves in 1,2-dichloroethane/Et₂O (12 mL, 1/1, v/v) at 0°C under an atmosphere of N₂. After 2 min, the reaction was filtered, diluted with CH₂Cl₂, washed successively with 1 M Na₂S₂O₃, 1 M NaHCO₃ and H₂O, dried (MgSO₄), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (35% Et₂O/light petroleum) gave the *title compound* (268 mg, 95%) as a colourless syrup; [Found: C, 59.6; H, 6.8. C₂₈H₃₈O₁₂ requires C, 59.36; H, 6.76%]; R_f (50% Et₂O/light petroleum) 0.3; [α]_D²⁰ -14.8° (c 1.1, CHCl₃); *m/z* 567.2 (M+H)⁺, 589.2 (M+Na)⁺; δ_H (300 MHz, CDCl₃) 1.26, 1.29, 1.38, 1.47 (4 × s, 12H, CH₃, isopr.), 2.06, 2.11 (2 × s, 6H, CH₃, Ac), 4.00 (m, 4H, H-4, H-5, H-6a, H-6b), 4.03 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.25 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.28 (d, 1H, H-3, J_{3,4} 3.1 Hz), 4.50 (d, 1H, H-2), 4.51 (AB, 2H, CH₂, Bn), 5.10 (s, 1H, H-2'), 5.26 (s, 1H, H-1'), 5.85 (d, 1H, H-1, J_{1,2} 3.7 Hz), 7.27–7.37 (m, 5H, Bn); δ_C (200 MHz, CDCl₃) 20.5, 21.1 (2 × CH₃, Ac), 25.1, 26.0, 26.6 (4 × CH₃, isopr.), 67.5, 69.3, 73.2, 73.6 (C-6, CH₂, Bn, C-4', C-5'), 72.0, 76.8, 77.4, 80.7, 81.7 (C-2, C-3, C-4, C-5, C-2'), 103.6 (C-1), 105.0 (C-1'), 108.9, 111.7 (Cq, isopr.), 127.4–128.2 (CH, Bn), 137.5 (Cq, Bn), 169.3, 169.8 (C=O, Ac).

Methyl 4-O-(2,3,5-tri-O-acetyl-β-D-erythro-apiofuranosyl)-2,3-di-O-benzyl-6-O-pivaloyl-α-D-glucopyranoside (Table 1, entry 6)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a mixture of donor **4b** (0.60 mmol, 192 mg) acceptor **11** (0.50 mmol, 221 mg) and powdered molecular sieves in 1,2-dichloroethane/Et₂O (12 mL, 1/1, v/v) at 0°C under an atmosphere of N₂. After 2 min, the reaction was filtered, diluted with CH₂Cl₂, washed successively with 1 M Na₂S₂O₃, 1 M NaHCO₃ and H₂O, dried (MgSO₄), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (50% Et₂O/light petroleum) gave the *title compound* (236 mg, 91%) as a colourless syrup; [Found: C, 62.2; H, 6.8. C₃₇H₄₈O₁₄ requires C, 62.00; H, 6.75%]; R_f (50% Et₂O/light petroleum) 0.2; [α]_D²⁰ -8.3° (c 2, CHCl₃); *m/z* 739.5 (M+Na)⁺; δ_H (300 MHz, CDCl₃) 1.19 (s, 9H, Piv), 2.00, 2.03, 2.06 (3 × s, 9H, Ac), 3.37 (s, 3H, OMe), 3.48 (dd, 1H, H-2, J_{2,3} 9.6 Hz), 3.63 (t, 1H, H-4, J_{4,5} 9.8 Hz), 3.80 (m, 1H, H-5), 3.84 (t, 1H, H-3, J_{3,4} 9.7 Hz), 4.13 (AB, 2H, H-4a', H-4b'), 4.15 (dd, 1H, H-6a), 4.41 (dd, 1H, H-6b), 4.55 (d, 1H, H-1, J_{1,2} 3.6 Hz), 4.60 (AB, 2H, H-5a', H-5b'), 4.60 (AB, CH₂, Bn), 4.68 (AB, CH₂, Bn), 4.88 (AB, CH₂, Bn), 5.12 (s, 1H, H-2'), 5.23 (s, 1H, H-1'), 7.26–7.38 (m, 20H, Bn); δ_C (200 MHz, CDCl₃) 20.3, 20.4,

20.8 (3 × CH₃, Ac), 27.0 ((CH₃)₃, Piv), 38.6 (Cq, Piv), 55.0 (OMe), 62.2, 62.6, 72.0, 73.1, 75.3 (2 × CH₂, Bn, C-4', C-5', C-6), 68.2, 76.3, 76.8, 79.6 (C-2, C-3, C-4, C-5, C-2'), 82.3 (C-3'), 97.6 (C-1), 106.6 (C-1'), 127.5–128.2 (CH, Bn), 137.7, 138.4 (Cq, Bn), 169.0, 169.3 (C=O, Ac), 177.6 (C=O, Piv).

Ethyl 6-*O*-(2,3-di-*O*-acetyl-5-*O*-benzyl-β-*D*-erythro-apiofuranosyl)-2,3,4-tri-*O*-benzoyl-1-thio-β-*D*-glucopyranoside (14)

N-Iodosuccinimide (4.75 mmol, 1.08 g) and a catalytic amount of triflic acid (0.43 mmol, 37 μL) was added to a mixture of donor **4a** (4.3 mmol, 1.59 g) acceptor **13** (3.6 mmol, 1.93 g) and powdered molecular sieves in 1,2-dichloroethane/Et₂O (100 mL, 1/1, v/v) at 0°C under an atmosphere of N₂. After 2 min, the reaction was filtered, diluted with CH₂Cl₂, washed successively with 1 M Na₂S₂O₃, 1 M NaHCO₃ and H₂O, dried (MgSO₄), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (50 → 75% Et₂O/light petroleum) gave the *title compound* **14** (2.79 g, 92%) as a light yellow syrup; [Found: C, 64.2; H, 5.5. C₄₅H₄₆O₁₄S requires C, 64.12; H, 5.50%]; R_f (66% Et₂O/light petroleum) 0.2; [α]_D²⁰ -7.2° (c 0.5, CHCl₃); *m/z* 843.2 (M+H)⁺, 865.3 (M+Na)⁺; δ_H (300 MHz, CDCl₃) 1.26 (3H, t, CH₃, SEt), 2.04, 2.06 (2 × s, CH₃, Ac), 2.74 (m, 2H, CH₂, SEt), 3.75 (m, 3H, H-6a, H-6b, H-5), 3.95 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.14 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.54 (s, 2H, CH₂, Bn), 4.75 (d, 1H, H-1, J_{1,2} 10.0 Hz), 5.03 (d, 1H, H-2'), 5.30 (d, 1H, H-1', J_{1',2'} 0.7 Hz), 5.41 (t, 1H, H-4, J_{4,5} 9.7 Hz), 5.47 (t, 1H, H-2, J_{2,3} 9.5 Hz), 5.87 (t, 1H, H-3, J_{3,4} 9.6 Hz), 7.24–7.55 (m, 14H, Bz, Bn), 7.78–7.96 (m, 6H, Bz); δ_C (200 MHz, CDCl₃) 14.8 (CH₃, SEt), 20.4, 21.1 (2 × CH₃, Ac), 24.0 (CH₂, SEt), 66.2 (C-6), 69.3, 73.1, 73.2 (CH₂, Bn, C-4', C-5'), 69.6, 70.6, 74.1, 76.4, 77.6 (C-2, C-3, C-4, C-5, C-2'), 83.4 (C-1), 85.2 (C-3'), 106.4 (C-1'), 127.4–133.3 (CH, arom.), 128.6, 128.7, 129.0 (3 × Cq, Bz), 137.8 (Cq, Bn), 164.6, 165.6 (C=O, Bz), 169.1, 169.8 (C=O, Ac).

Ethyl 4-*O*-(2,3-di-*O*-acetyl-5-*O*-benzyl-β-*D*-erythro-apiofuranosyl)-2,3-*O*-(2,3-dimethoxybutane-2,3-diyl)-6-*O*-tert-butyltrimethylsilyl-1-thio-β-*D*-glucopyranoside (16)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a mixture of donor **4a** (0.60 mmol, 221 mg) acceptor **15** (0.50 mmol, 226 mg) and powdered molecular sieves in 1,2-dichloroethane/Et₂O (12 mL, 1/1, v/v) at 0°C under an atmosphere of N₂. After 2 min, the reaction was filtered, diluted with CH₂Cl₂, washed successively with 1 M Na₂S₂O₃, 1 M NaHCO₃ and H₂O, dried (MgSO₄), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (20% Et₂O/light petroleum) gave the *title compound* **16** (337 mg, 89%) as a light yellow syrup; [Found: C, 56.7; H, 7.6. C₃₆H₅₈O₁₃SSi requires C, 56.97; H, 7.70%]; R_f (33% Et₂O/light petroleum) 0.6; [α]_D²⁰ -17.4° (c 0.9, CHCl₃); *m/z* 758.8 (M+H)⁺; δ_H (300 MHz, CDCl₃) 0.05, 0.08 (2 × s, 6H, CH₃, TBDMS), 0.88 (s, 9H, (CH₃)₃, TBDMS), 1.22 (t, 3H, CH₃, SEt), 1.31 (s, 6H, CH₃, BDA), 2.06 (s, 6H, CH₃, Ac), 2.61 (m, 2H, CH₂, SEt), 3.18, 3.28 (2 × s, 6H, OMe, BDA), 3.21 (m, 1H, H-6a), 3.48 (d, 1H, H-1, J_{1,2} 7.8 Hz), 3.60 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 3.78 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 3.88 (m, 3H, H-5, CH₂, Bn), 4.23 (dd, 1H, H-4, J_{3,4} 9.7 Hz, J_{4,5} 9.1 Hz), 4.48 (m, 2H, H-2, H-3), 5.17 (s, 1H, H-2'), 5.24 (s, 1H, H-1'), 7.26–7.38 (m, 5H, Bn); δ_C (200 MHz, CDCl₃) -5.0, -6.0 (2 × CH₃, TBDMS), 15.1 (CH₃, SEt), 17.7 (CH₃, BDA), 20.5, 21.3 (2 × CH₃, Ac), 23.7 (CH₂, SEt), 25.7 ((CH₃)₃, TBDMS), 47.9, 47.7 (2 × OMe, BDA), 61.4 (C-6), 69.9, 73.3, 73.7 (CH₂, Bn, C-4', C-5'), 69.1, 71.4, 72.5, 76.8, 80.3 (C-2, C-3, C-4, C-5, C-2'), 81.0 (C-1), 85.8 (C-3'), 106.0 (C-1'), 127.4–128.4 (CH, Bn), 137.6 (Cq, Bn), 169.1, 170.1 (C=O, Ac).

Ethyl 6-*O*-(2,3-di-*O*-acetyl-5-*O*-benzyl-β-*D*-erythro-apiofuranosyl)-2,3,4-tri-*O*-benzyl-1-thio-β-*D*-glucopyranoside (18a)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a mixture of donor **4a** (0.60 mmol, 221 mg) acceptor **17** (0.50 mmol, 239 mg) and powdered molecular sieves in 1,2-

dichloroethane/Et₂O (12 mL, 1/1, v/v) at 0°C under an atmosphere of N₂. After 2 min, the reaction was filtered, diluted with CH₂Cl₂, washed successively with 1 M Na₂S₂O₃, 1 M NaHCO₃ and H₂O, dried (MgSO₄), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (20% Et₂O/light petroleum) gave the *title compound 18a* (372 mg, 93%) as a colorless syrup; [Found: C, 67.6; H, 6.6. C₄₅H₅₂O₁₁S requires C, 67.48; H, 6.54%]; R_f 0.3 (50% Et₂O/light petroleum) 0.3; [α]_D²⁰ –2.2° (c 1, CHCl₃); *m/z* 801.5 (M+H)⁺, 823.4 (M+Na)⁺; δ_H (300 MHz, CDCl₃) 1.26 (t, 3H, CH₃, SEt), 2.05, 2.06 (2 × s, CH₃, Ac), 2.74 (m, 2H, CH₂, SEt), 3.48 (m, 5H, H-2, H-3, H-6a, H-6b, H-5), 3.62 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.08 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 5.41 (t, 1H, H-4, J_{4,5} 9.7 Hz), 5.47 (t, 1H, H-2, J_{2,3} 9.5 Hz), 5.87 (t, 1H, H-3, J_{3,4} 9.6 Hz), 4.46 (d, 1H, H-1, J_{1,2} 10.2 Hz), 4.64 (AB, 2H, CH₂, Bn), 4.80 (AB, 2H, CH₂, Bn), 4.83 (AB, 2H, CH₂, Bn), 5.46 (d, 1H, H-2'), 5.33 (d, 1H, H-1', J_{1',2'} 0.6 Hz), 7.24–7.44 (m, 20H, Bz, Bn); δ_C (200 MHz, CDCl₃) 15.2 (CH₃, SEt), 20.6, 21.4 (2 × CH₃, Ac), 24.8 (CH₂, SEt), 66.2 (C-6), 69.8, 73.4, 75.0, 75.4, 75.7 (4 × CH₂, Bn, C-4', C-5'), 76.6, 77.7, 78.3, 81.8, 84.8 (C-2, C-3, C-4, C-5, C-2'), 85.5 (C-3'), 86.5 (C-1), 105.8 (C-1'), 127.5–128.4 (CH, arom.), 137.9, 138.4 (Cq, Bn), 169.1, 170.1 (C=O, Ac).

Ethyl 6-*O*-(2,3,5-tri-*O*-acetyl-β-*D*-erythro-apiofuranosyl)-2,3,4-tri-*O*-benzyl-1-thio-β-*D*-glucopyranoside (18b)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a mixture of donor **4b** (0.60 mmol, 192 mg) acceptor **17** (0.50 mmol, 240 mg) and powdered molecular sieves in 1,2-dichloroethane/Et₂O (12 mL, 1/1, v/v) at 0°C under an atmosphere of N₂. After 2 min, the reaction was filtered, diluted with CH₂Cl₂, washed successively with 1 M Na₂S₂O₃, 1 M NaHCO₃ and H₂O, dried (MgSO₄), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (50% Et₂O/light petroleum) gave the *title compound 18b* (331 mg, 88%) as a light yellow syrup; [Found: C, 63.6; H, 6.5. C₄₀H₄₈O₁₂S requires C, 63.81; H, 6.43%]; R_f (33% Et₂O/light petroleum) 0.4; [α]_D²⁰ +13.2° (c 1.3, CHCl₃); *m/z* 753.3 (M+H)⁺, 775.2 (M+Na)⁺; δ_H (200 MHz, CDCl₃) 4.51 (d, 1H, H-1, J_{1,2} 10.2 Hz), 5.25 (s, 1H, H-1'); δ_C (200 MHz, CDCl₃) 15.3 (CH₃, SEt), 20.3, 20.4, 20.8 (3 × CH₃, Ac), 24.7 (CH₂, SEt), 66.2 (C-6), 69.9, 75.4, 75.8, 75.9 (3 × CH₂, Bn, C-4', C-5'), 76.6, 77.7, 78.3, 81.8, 84.8 (C-2, C-3, C-4, C-5, C-2'), 85.8 (C-3'), 86.6 (C-1), 106.1 (C-1'), 127.5–128.4 (CH, arom.), 137.9, 138.4, 138.5 (Cq, Bn), 168.8, 169.1, 170.1 (C=O, Ac).

Ethyl 2,3-di-*O*-acetyl-5-*O*-benzyl-1-thio-α/β-*D*-ribofuranoside (19a)

To a cooled mixture (0 °C) of 1,2,3-tri-*O*-acetyl-5-*O*-benzyl-β-*D*-ribofuranose (1.83 g, 5.0 mmol) and ethanethiol (6 mmol, 0.44 mL) in CH₂Cl₂ (25 mL) was added a small amount of SnCl₄ (0.5 mmol, 58 μL). After stirring for 60 min the reaction mixture was diluted with CH₂Cl₂, washed successively with 1 M KF, 1 M NaHCO₃ and with water. The organic layer was dried (MgSO₄), filtered and concentrated *in vacuo*. The crude product was purified by flash column chromatography (35% Et₂O/light petroleum) to furnish the *title compound 19a* (1.60 g, 87%) as a light yellow syrup; [Found: C, 58.5; H, 6.5. C₁₈H₂₄O₆S requires C, 58.68; H, 6.57%]; R_f (50% Et₂O/light petroleum) 0.4; δ_H (300 MHz, CDCl₃) 1.24 (m, 3H, CH₃, SEt), 2.08, 2.10 (2 × s, 6H, CH₃, Ac), 2.68 (m, 2H, CH₂, SEt), 3.63, 3.65 (2 × s, 2H, H-5α, H-5β), 4.20 (dd, 1H, H-3α, J_{2,3} 6.1 Hz, J_{3,4} 3.3 Hz), 3.29 (dd, 1H, H-3β, J_{2,3} 5.1 Hz, J_{3,4} 4.8 Hz), 4.55 (dd, 2H, CH₂, Bn), 5.31 (d, 0.65H, H-1α, J_{1,2} 5.9 Hz), 5.28 (m, 1H, H-2α), 5.39 (m, 1H, H-2β), 3.83, 4.18 (2 × m, 4H, H-4α, H-4b, H-5α, H-5b), 5.13 (d, 0.65H, H-2β), 5.62 (d, 1H, H-1β, J_{1,2} 5.0 Hz), 7.26–7.34 (m, 5H, Bn); δ_C (200 MHz, CDCl₃) 14.7 (CH₃, SEt), 20.3 (CH₃, Ac), 25.1, 23.7 (CH₂, SEt), 68.6, 70.0 (C-5α, C-5β), 73.0 (CH₂, Bn), 70.6, 71.4, 72.1, 73.6, 79.0, 81.1 (C-2α, C-2β, C-3α, C-3β, C-4α, C-4β), 84.8, 86.6 (C-1α, C-1β), 127.2, 128.0 (CH, Bn), 137.5 (Cq, Bn), 169.1, 169.4 (C=O, Ac).

Ethyl 2,3,5-tri-*O*-acetyl-1-thio-α/β-*D*-ribofuranoside (19b)

To a cooled mixture (0 °C) of 1,2,3,5-tetra-*O*-acetyl-β-*D*-ribofuranose (7.95 g, 25.0 mmol) and ethanethiol (30

mmol, 2.22 mL) in CH_2Cl_2 (75 mL) was added a small amount of SnCl_4 (2.5 mmol, 288 μL). After stirring for 60 min the reaction mixture was diluted with CH_2Cl_2 , washed successively with 1 M KF, 1 M NaHCO_3 and with water. The organic layer was dried (MgSO_4), filtered and concentrated *in vacuo*. The crude product was purified by flash column chromatography (35% Et_2O /light petroleum) to furnish the *title compound 19b* (7.28 g, 91%) as a colourless syrup; [Found: C, 48.8; H, 6.3. $\text{C}_{13}\text{H}_{20}\text{O}_7\text{S}$ requires C, 48.74; H, 6.29%]; R_f (33% Et_2O /light petroleum) 0.4; δ_{H} (300 MHz, CDCl_3) 1.24 (t, 3H, CH_3 , SEt), 2.05–2.08 (6 \times s, 9H, CH_3 , Ac), 2.65 (m, 2H, CH_2 , SEt), 4.11 (dd, 0.7H, H-5'' β , $J_{5',5''}$ 11.9 Hz, $J_{5',4}$ 4.5 Hz), 4.16 (dd, 0.3H, H-5'' α , $J_{5',5''}$ 12.0 Hz, $J_{5',4}$ 4.0 Hz), 4.22 (m, 1H, H-4), 4.30 (dd, 0.3H, H-5' α , $J_{5',4}$ 3.8 Hz), 4.33 (dd, 0.7H, H-5' β , $J_{5',4}$ 3.4 Hz), 5.13 (t, 0.3H, H-3 α , $J_{3,4}$ 6.0 Hz), 5.15 (d, 0.7H, H-1 β , $J_{1,2}$ 4.4 Hz), 5.21 (t, 0.7H, H-3 β , $J_{3,4}$ 5.3 Hz), 5.31 (t, 0.7H, H-2 β , $J_{2,3}$ 4.8 Hz), 5.34 (t, 0.7H, H-2 α , $J_{2,3}$ 6.0 Hz), 5.59 (d, 0.3H, H-1 α , $J_{1,2}$ 5.6 Hz); δ_{C} (200 MHz, CDCl_3) 14.5 (CH_3 , SEt), 20.3, 20.4, 20.5 (3 \times CH_3 , Ac), 24.2, 24.9 (CH_2 , SEt), 62.5 (C-5 α), 63.2 (C-5 β), 70.1, 70.9 (C-3 α , C-4 α), 71.2, 74.0 (C-3 β , C-4 β), 76.3 (C-2 α), 79.2 (C-2 β), 85.1 (C-1 β), 86.4 (C-1 α), 169.0, 169.9 (C=O, Ac).

Ethyl 6-O-(2,3-di-O-acetyl-5-O-benzyl- β -D-ribofuranosyl)-2,3,4-tri-O-benzoyl-1-thio- β -D-glucopyranoside (20a)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a mixture of donor **19a** (0.60 mmol, 221 mg) acceptor **13** (0.50 mmol, 268 mg) and powdered molecular sieves in 1,2-dichloroethane/ Et_2O (12 mL, 1/1, v/v) at 0°C under an atmosphere of N_2 . After 2 min, the reaction was filtered, diluted with CH_2Cl_2 , washed successively with 1 M $\text{Na}_2\text{S}_2\text{O}_3$, 1 M NaHCO_3 and H_2O , dried (MgSO_4), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (12% EtOAc /toluene) followed by gel-filtration using an LH20 column (50% CH_2Cl_2 /MeOH) gave the *title compound 20a* (362 mg, 86%) as a colourless oil; [Found: C, 64.2; H, 5.6. $\text{C}_{45}\text{H}_{46}\text{O}_{14}\text{S}$ requires C, 64.12; H, 5.50%]; R_f (33% Et_2O /light petroleum, v/v) 0.2; $[\alpha]_{\text{D}}^{20}$ -7.1° (c 0.5, CHCl_3); m/z 865.4 ($\text{M}+\text{Na}^+$); δ_{H} (300 MHz, CDCl_3) 1.27 (t, 3H, CH_3 , SEt), 2.05, 2.07 (2 \times s, CH_3 , Ac), 2.71 (m, 2H, CH_2 , SEt), 3.75 (m, 3H, H-6a, H-6b, H-5), 4.39 (AB, 2H, CH_2 , Bn), 4.79 (d, 1H, H-1, $J_{1,2}$ 9.8 Hz), 4.99 (d, 1H, H-2'), 5.26 (d, 1H, H-1', $J_{1',2'}$ 0.7 Hz), 5.40 (t, 1H, H-4, $J_{4,5}$ 9.7 Hz), 5.45 (t, 1H, H-2, $J_{2,3}$ 9.5 Hz), 5.87 (t, 1H, H-3, $J_{3,4}$ 9.6 Hz), 7.23–7.53 (m, 14H, Bz, Bn), 7.78–7.96 (m, 6H, Bz); δ_{C} (200 MHz, CDCl_3) 14.9 (CH_3 , SEt), 20.3, 21.0 (2 \times CH_3 , Ac), 24.0 (CH_2 , SEt), 66.2 (C-6), 69.3, 73.1 (CH_2 , Bn, C-5'), 72.2, 74.3, 77.6, 78.2, 79.8, 81.6, 84.8 (C-2, C-3, C-4, C-5, C-2', C-3', C-4'), 86.5 (C-1), 105.3 (C-1'), 127.5–128.4 (CH, arom.), 137.9, 138.4 (Cq, Bn), 164.7, 165.2, 165.6 (C=O, Bz), 169.5, 169.7 (C=O, Ac).

Ethyl 6-O-(2,3-di-O-acetyl-5-O-benzyl- β -D-ribofuranosyl)-2,3,4-tri-O-benzyl-1-thio- β -D-glucopyranoside (21a)

N-Iodosuccinimide (0.63 mmol, 142 mg) and a catalytic amount of triflic acid (0.06 mmol, 5 μL) was added to a mixture of donor **19a** (0.60 mmol, 221 mg) acceptor **17** (0.50 mmol, 239 mg) and powdered molecular sieves in 1,2-dichloroethane/ Et_2O (12 mL, 1/1, v/v) at 0°C under an atmosphere of N_2 . After 2 min, the reaction was filtered, diluted with CH_2Cl_2 , washed successively with 1 M $\text{Na}_2\text{S}_2\text{O}_3$, 1 M NaHCO_3 and H_2O , dried (MgSO_4), and concentrated *in vacuo*. Purification of the crude product by flash chromatography (12% EtOAc /toluene) followed by gel-filtration using an LH20 column (50% CH_2Cl_2 /MeOH) gave the *title compound 21a* (232 mg, 58%) as an oil; [Found: C, 67.3; H, 6.6. $\text{C}_{45}\text{H}_{52}\text{O}_{11}\text{S}$ requires C, 67.48; H, 6.54%]; $[\alpha]_{\text{D}}^{20}$ $+3.4^\circ$ (c 1, CHCl_3); R_f (50% Et_2O /light petroleum) 0.4; m/z 801.5 ($\text{M}+\text{H}^+$); δ_{H} (300 MHz, CDCl_3) 1.25 (3H, t, CH_3 , SEt), 2.05, 2.07 (2 \times s, CH_3 , Ac), 2.70 (m, 2H, CH_2 , SEt), 4.46 (d, 1H, H-1, $J_{1,2}$ 10.2 Hz), 5.35 (d, 1H, H-1', $J_{1',2'}$ 0.3 Hz), 7.24–7.44 (m, 20H, Bn); δ_{C} (200 MHz, CDCl_3) 15.0 (CH_3 , SEt), 20.5 (CH_3 , Ac), 24.9 (CH_2 , SEt), 66.7 (C-6), 71.4 (C-5'), 73.2, 74.9, 75.4, 75.6 (4 \times CH_2 , Bn), 72.2, 74.3, 77.6, 78.2, 79.8, 81.6, 84.8 (C-2, C-3, C-4, C-5, C-2', C-3', C-4'), 86.5 (C-1), 105.3 (C-1'), 127.5–128.4 (CH, arom.), 137.9, 138.4 (Cq, Bn), 169.5, 169.7 (C=O, Ac).

3,4,5-Trimethoxyphenyl 2,3,4,6-tetra-*O*-benzyl- β -D-glucopyranoside (27)

To a stirred solution of 2,3,4,6-tetra-*O*-benzyl- β -D-glucopyranose (**23**, 540.7 mg, 1 mmol) and 3,4,5-trimethoxyphenol (267 mg, 1.5 mmol) in THF (3 mL) at 0 °C was added Ph_3P (262 mg, 1 mmol) and a solution of diethyl azodicarboxylate (164 μL , 1 mmol) in THF. The mixture was stirred overnight (15 h). The solution was concentrated under reduced pressure and the residue was dissolved in CH_2Cl_2 (25 mL) and washed with 10% aq. NaHCO_3 and water. The organic layer was dried over MgSO_4 , filtered and concentrated. The product was purified by silica gel column chromatography. Elution was effected with Et_2O /light petroleum, (1/2 \rightarrow 1/1, v/v) to afford the *title compound* **27** (437 mg, 62%) as a colourless oil; [Found: C, 72.8; H, 6.6. $\text{C}_{43}\text{H}_{46}\text{O}_9$ requires C, 73.07; H, 6.56%]; R_f (Et_2O /light petroleum, 1/1, v/v) 0.25; $[\alpha]_D^{20} +1.3^\circ$ (c 2, CHCl_3); m/z 706.4 ($\text{M}+\text{H}^+$); δ_{H} (600 MHz, CDCl_3) 3.7–3.9 (m, 6H, H-2', H-3', H-4', H-5', H-6a', H-6b') 3.74 (s, 6H, 3-OMe, 5-OMe), 3.84 (s, 3H, 4-OMe), 4.70 (AB, 2H, CH_2 , Bn), 4.84 (AB, 2H, CH_2 , Bn), 4.93 (AB, 2H, CH_2 , Bn), 4.97 (d, 1H, H-1', $J_{1,2}$ 7.4 Hz), 5.00 (AB, 2H, CH_2 , Bn), 6.40 (s, 1H, H-2, H-6), 7.20–7.36 (m, 20H, 4 \times Bn); δ_{C} (200 MHz, CDCl_3) 56.3 (3-OMe, 5-OMe), 61.3 (4-OMe), 69.5 (C-6'), 74.0, 75.4, 76.2 (CH_2 , Bn), 75.5, 78.3, 82.5, 85.1, 95.5 (C-2', C-3', C-4', C-5'), 95.5 (C-2, C-6), 103.0 (C-1'), 128.1–128.8 (CH, Bn), 138.3, 138.7, 138.8 (Cq, Bn), 133.8 (C-4), 153.9, 154.5 (C-1, C-3, C-5).

3,4,5-Trimethoxyphenyl 2,3,4,6-tetra-*O*-benzoyl- β -D-glucopyranoside (28) and**1-(2,3,4,6-tetra-*O*-benzoyl-1-deoxy- β -D-glucopyranosyl)-2-oxo-4,5,6-trimethoxy-1,4-cyclohexadiene (30)**

A mixture of trichloroacetimidate donor **26** (748 mg, 1.00 mmol) and 3,4,5-trimethoxyphenol (267 mg, 1.5 mmol) was dissolved in CH_2Cl_2 (12 mL) and pulverized molecular sieves (4 Å, 2 g) were added. The resulting mixture was stirred for 20 min under an atmosphere of argon and then 1 mL of a 0.25 M solution of $\text{BF}_3\cdot\text{OEt}_2$ in CH_2Cl_2 was slowly added over a period of 30 min. TLC analysis ($\text{CH}_2\text{Cl}_2/\text{MeOH}$, 50/1, v/v) showed the disappearance of the imidate **26** and the formation of two lower running products. The reaction mixture was neutralized with Et_3N , filtered and the filtrate was washed with 10% aq. NaHCO_3 and water. The organic phase was dried (MgSO_4), filtered and concentrated *in vacuo*. Purification of the crude syrup was accomplished using a silica gel column ($\text{CH}_2\text{Cl}_2/\text{MeOH}$ 0 \rightarrow 1%) to afford homogeneous **28** (312 mg, 41%) as a white amorphous solid; [Found: C, 67.5; H, 4.9. $\text{C}_{43}\text{H}_{38}\text{O}_{13}$ requires C, 67.71; H, 5.02%]; R_f ($\text{CH}_2\text{Cl}_2/\text{MeOH}$, 100/1, v/v) 0.65; $[\alpha]_D^{20} -12.6^\circ$ (c 0.5, CHCl_3); m/z 785.3 ($\text{M}+\text{Na}^+$); δ_{H} (300 MHz, CDCl_3) 3.60 (s, 6H, 3-OMe, 5-OMe), 3.74 (s, 3H, 4-OMe), 4.35 (m, 2H, H-5'), 4.54 (dd, 1H, H-6'a, $J_{5,6a}$ 6.0 Hz, $J_{6a,6b}$ 12.1 Hz), 4.70 (dd, 1H, H-6'b, $J_{5,6b}$ 3.0 Hz), 5.36 (d, 1H, H-1', $J_{1,2}$ 7.7 Hz), 5.75 (m, 1H, H-2', H-4'), 6.01 (t, 1H, H-3', $J_{3,4} \approx J_{2,3}$ 9.6 Hz), 6.23 (s, 1H, H-2, H-6), 7.27–7.42 (m, 12H, 4 \times Bz), 7.85–8.00 (m, 8H, 4 \times Bz); δ_{C} (200 MHz, CDCl_3) 55.9 (3-OMe, 5-OMe), 60.9 (4-OMe), 63.3 (C-6'), 69.5, 71.8, 72.7, 76.6 (C-2', C-3', C-4', C-5'), 95.6 (C-2, C-6), 100.6 (C-1'), 128.4–133.5 (CH, Bz), 128.9 129.0, 129.3 (Cq, Bz), 133.8 (C-4), 153.5, 153.4 (C-1, C-3, C-5), 165.0, 165.2, 165.7, 166.1 (C=O, Bz). Further elution with 5% methanol in CH_2Cl_2 gave *C*-aryl glycoside **30** (137 mg, 18%) as a syrup; [Found: C, 67.7; H, 5.1. $\text{C}_{43}\text{H}_{38}\text{O}_{13}$ requires C, 67.71; H, 5.02%]. R_f (5% $\text{MeOH}/\text{CH}_2\text{Cl}_2$) 0.35; $[\alpha]_D^{20} -83.9^\circ$ (c 1, CHCl_3); m/z 785.2 ($\text{M}+\text{Na}^+$); δ_{H} (300 MHz, CDCl_3) 2.89 (s, 3H, 5-OMe), 3.58, 3.70 (2 \times s, 2 \times 3H, 4-OMe, 6-OMe), 4.05 (m, 2H, H-5'), 4.31 (dd, 1H, H-6'a, $J_{5,6a}$ 6.0 Hz, $J_{6a,6b}$ 12.1 Hz), 4.42 (d, 1H, H-1', $J_{1,2}$ 9.7 Hz), 4.53 (dd, 1H, H-6'b, $J_{5,6b}$ 3.1 Hz), 5.48 (t, 1H, H-4', $J_{4,5}$ 9.6 Hz), 5.48 (d, 1H, H-3 or H-5, $J_{3,5}$ 1.4 Hz), 5.57 (d, 1H, H-3 or H-5), 5.78 (t, 1H, H-3', $J_{3,4}$ 9.6 Hz), 5.89 (t, 1H, H-2', $J_{2,3}$ 9.6 Hz), 7.26–7.42 (m, 12H, 4 \times Bz), 7.85–8.00 (m, 8H, 4 \times Bz); δ_{C} (200 MHz, CDCl_3) 52.1 (5-OMe), 55.9, 56.5 (4-OMe, 6-OMe), 66.6, 69.1 (C-6'), 73.0, 73.1, 75.1, 75.8, 78.3, 78.4 (C-1', C-2', C-3', C-4', C-5', C-2''), 79.9 (C-1), 104.7, 105.4 (C-3, C-5), 128.0–133.4 (CH, Bz), 128.7 129.0, 130.1 (Cq, Bz), 165.1, 165.3, 165.6, 165.8 (C=O, Bz), 166.7, 167.4 (C-4, C-5), 186.7 (C-2).

1-(2,3,4,6-Tetra-*O*-acetyl-1-deoxy- β -D-glucopyranosyl)-2-oxo-4,5,6-trimethoxy-1,4-cyclohexadiene (29)

1,2,3,4,6-penta-*O*-acetyl- β -D-glucopyranose (**25**, 390.4 mg, 1 mmol) and 3,4,5-trimethoxyphenol (267 mg, 1.5

mmol) were dissolved in CH_2Cl_2 (3 mL). $\text{BF}_3 \cdot \text{OEt}_2$ (126 μL , 1 mmol) was added and the reaction mixture was stirred for 15 h. The mixture was diluted with CH_2Cl_2 and washed with 10% aq. NaHCO_3 and water. The organic layer was dried over MgSO_4 , filtered and concentrated. The crude product was purified by silica gel column chromatography and elution was effected with methanol in dichloromethane (0→10%) to afford the *title compound* **29** (453 mg, 88%) as a white solid; [Found: C, 53.6; H, 5.8. $\text{C}_{23}\text{H}_{30}\text{O}_{13}$ requires C, 53.70; H, 5.88%]; R_f (10% $\text{MeOH}/\text{CH}_2\text{Cl}_2$) 0.35; $[\alpha]_D^{20} -96.3^\circ$ (c 0.5, CHCl_3); m/z 537.3 ($\text{M}+\text{Na}$) $^+$; δ_H (600 MHz, CDCl_3) 1.99 (s, 3H, CH_3 , Ac), 2.00 (s, 3H, CH_3 , Ac), 3.05 (s, 3H, 5-OMe), 3.57 (m, 2H, H-5'), 3.77, 3.79 (2 \times s, 2 \times 3H, 4-OMe, 6-OMe), 3.90 (dd, 1H, H-6'a, $J_{5,6a'}$ 3.3 Hz, $J_{6a',6b'}$ 12.1 Hz), 4.06 (m, 2H, H-6'b, H-1', $J_{1',2'}$ 9.7 Hz), 4.95 (t, 1H, H-4', $J_{4',5'}$ 9.6 Hz), 5.13 (t, 1H, H-3', $J_{3',4'}$ 9.6 Hz), 5.43 (t, 1H, H-2', $J_{2',3'}$ 9.6 Hz), 5.61 (s, 2H, H-3, H-5); δ_C (200 MHz, CDCl_3) 20.3, 20.5 (4 \times CH_3 , Ac), 52.1 (5-OMe), 55.8, 56.1 (4-OMe, 6-OMe), 61.8 (C-6'), 68.0, 69.0, 74.6, 75.6, 77.4 (C-1', C-2', C-3', C-4', C-5'), 79.5 (C-1), 104.3, 104.8 (C-3, C-5), 166.7, 167.3 (C-4, C-5), 168.9, 169.2, 169.9 (C=O, Ac), 186.6 (C-2).

6-O-(2,3-Di-O-acetyl-5-O-benzyl- β -D-erythro-apiofuranosyl)-2,3,4-tri-O-benzoyl- α -D-glucopyranosyl trichloroacetimidate (31)

To a stirred solution of compound **14** (1.66 g, 1.97 mmol) in dichloromethane/water (20.20 mL, 100/1, v/v) was added in approximately 45 min a 0.1 M stock-solution of NIS/cat. TfOH (25 \pm 3 mL) and the progress of the reaction was followed by TLC-analysis (5% $\text{MeOH}/\text{CH}_2\text{Cl}_2$). After complete disappearance of the starting material the reaction was stopped by adding a 10% aq. $\text{Na}_2\text{S}_2\text{O}_3$ solution. The organic layer was separated and washed with 10% aq. NaHCO_3 solution and water then dried (MgSO_4), filtered and concentrated. The crude product was purified by silica gel column chromatography ($\text{CH}_2\text{Cl}_2/\text{MeOH}$, 100/0 \rightarrow 95/5, v/v) and after concentration of the appropriate fractions the corresponding hemiacetal was obtained. R_f 0.3 (5% $\text{MeOH}/\text{CH}_2\text{Cl}_2$). The compound was dried by evaporation of toluene (3 \times 10 mL) and dissolved in CH_2Cl_2 (10 mL). Subsequently, cesium carbonate (0.2 mmol, 64 mg) and trichloroacetonitrile (6 mmol, 600 μL) were added. After stirring the resulting mixture for 1 h, TLC-analysis indicated that the starting material was completely converted into a higher running product. The reaction mixture was filtered, concentrated and the resulting oil was purified by silica gel chromatography (toluene/ethyl acetate/triethylamine, 100/0/0.5 \rightarrow 90/10/0.5, v/v/v) to give the *title compound* **31** (1.60 g, 86%) as a light yellow syrup; [Found: C, 57.1; H, 4.5. $\text{C}_{43}\text{H}_{42}\text{Cl}_3\text{NO}_{15}$ requires C, 57.31; H, 4.49%]; R_f (toluene/ethyl acetate/triethylamine, 90/10/1, v/v/v) 0.45; $[\alpha]_D^{20} +7.2^\circ$ (c 1, CHCl_3); δ_H (200 MHz, CDCl_3) 2.05, 2.07 (2 \times s, CH_3 , Ac), 3.85 (m, 3H, H-6a, H-6b, H-5), 3.95 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.12 (AB, 2H, H-4a', H-4b' or H-5a', H-5b'), 4.64 (s, 2H, CH_2 , Bn), 5.03 (d, 1H, H-2'), 5.37 (d, 1H, H-1', $J_{1',2'}$ 0.7 Hz), 5.41 (t, 1H, H-4, $J_{4,5}$ 9.7 Hz), 5.58 (dd, 1H, H-2, $J_{2,3}$ 9.6 Hz), 6.01 (t, 1H, H-3, $J_{3,4}$ 9.6 Hz), 6.78 (d, 1H, H-1, $J_{1,2}$ 3.7 Hz), 7.24–7.55 (m, 14H, Bz, Bn), 7.78–7.96 (m, 6H, Bz); δ_C (200 MHz), 20.2, 20.9 (2 \times CH_3 , Ac), 66.0, 69.1, 73.0 (C-4'', C-5'', C-6', CH_2 , Bn), 68.4, 69.9, 70.4, 71.7, 76.1 (C-2', C-3', C-4', C-5', C-2''), 84.9 (C-3''), 90.3 (CCl_3), 92.7 (C-1'), 106.2 (C-1''), 127.3–133.2 (CH, arom.), 129.2, 129.4 (Cq, Bz), 137.5 (Cq, Bn), 159.8 (C=NH), 164.7, 164.9 (C=O, Bz), 168.8, 169.5 (C=O, Ac).

3,4,5-Trimethoxyphenyl 6-O-(2,3-di-O-acetyl-5-O-benzyl- β -D-erythro-apiofuranosyl)-2,3,4-tri-O-benzoyl- β -D-glucopyranoside (32) and 1-(2,3,4-tri-O-benzoyl-6-O-(2,3-di-O-acetyl-5-O-benzyl- β -D-erythro-apiofuranosyl)-1-deoxy- β -D-glucopyranosyl)-2-oxo-4,5,6-trimethoxy-1,4-cyclohexadiene (33)

Trichloroacetimidate donor **31** (943 mg, 1.00 mmol) and 3,4,5-trimethoxyphenol (267 mg, 1.5 mmol) were dissolved in a mixture of CH_2Cl_2 and THF (11 mL, 10/1, v/v) and powdered molecular sieves (4 Å, 2 g) were added. The mixture was stirred for 30 min under an atmosphere of argon and then 1 mL of a 0.25 M solution of $\text{BF}_3 \cdot \text{OEt}_2$ in CH_2Cl_2 was slowly added over a period of 30 min. TLC analysis (20% $\text{EtOAc}/\text{toluene}$) showed the disappearance of the imidate **31** and the formation of two lower running products. The reaction mixture was neutralized with Et_3N , filtered and the filtrate was washed with 10% aq. NaHCO_3 and water. The organic phase was dried (MgSO_4), filtered

and concentrated *in vacuo*. The crude mixture was purified by silica gel column chromatography (0→1% MeOH/CH₂Cl₂) to afford homogeneous **32** (607 mg, 63%) as a colorless syrup; [Found: C, 64.4; H, 5.4 C₅₂H₅₂O₁₈ requires C, 64.72; H, 5.43%]; R_f (20% EtOAc/toluene) 0.45; [α]_D²⁰ –6.8° (c 0.5, CHCl₃); *m/z* 964.4 (M+H)⁺; δ_H (300 MHz, CDCl₃) 2.01 (s, 3H, CH₃, Ac), 2.02 (s, 3H, CH₃, Ac), 3.70 (s, 6H, 3-OMe, 5-OMe), 3.72 (m, 1H, H-6'a), 3.77 (s, 3H, 4-OMe), 3.85 (m, 1H, H-6'b), 3.97 (AB, 2H, CH₂, Bn), 4.00 (m, 2H, H-5'), 4.14 (AB, 2H, H-5''), 4.53 (AB, 2H, H-4''), 5.00 (d, 2H, H-2''), 5.26 (d, 1H, H-1', J_{1',2'} 7.8 Hz), 5.28 (d, 1H, H-1'', J_{1'',2''} 0.8 Hz), 5.55 (t, 1H, H-4', J_{4',5'} 9.6 Hz), 5.71 (dd, 1H, H-2', J_{2',3'} 9.6 Hz), 5.96 (t, 1H, H-3', J_{3',4'} 9.6 Hz), 6.26 (s, 1H, H-2, H-6), 7.27–7.38 (m, 17H, 3 × Bz, Bn), 7.85–8.00 (m, 6H, 3 × Bz). δ_C (200 MHz, CDCl₃) 20.3, 21.1 (2 × CH₃, Ac), 55.9 (3-OMe, 5-OMe), 60.7 (4-OMe), 65.9, 69.0, 73.1 (C-4'', C-5'', C-6', CH₂, Bn), 69.1, 71.6, 72.5, 73.7, 76.2 (C-2', C-3', C-4', C-5', C-2''), 85.0 (C-3''), 95.5 (C-2, C-6), 100.4 (C-1'), 105.8 (C-1''), 127.6–133.5 (CH, arom.), 128.8, 128.9 (Cq, Bz), 133.6 (C-4), 137.6 (Cq, Bn), 152.7 (C-1), 153.4 (C-3, C-5), 164.9, 165.6 (C=O, Bz), 169.0, 169.7 (C=O, Ac). Further elution of the column resulted in the isolation of compound **33** (38 mg, 4%) as a light yellow syrup; [Found: C, 64.7; H, 5.4 C₅₂H₅₂O₁₈ requires C, 64.72; H, 5.43%]; R_f (20% EtOAc/toluene) 0.15; [α]_D²⁰ –107.2° (c 1, CHCl₃); *m/z* 964.4 (M+H)⁺; δ_H (300 MHz, CDCl₃) 2.05, 2.21 (2 × s, 6H, CH₃, Ac), 2.91 (s, 3H, 5-OMe), 3.48 (m, 2H, H-6'a, H-6'b), 3.72, 3.80 (2 × s, 6H, 4-OMe, 6-OMe), 3.75 (m, 1H, H-5'), 3.86 (d, 1H, H-4a'), 4.05 (d, 1H, H-4b'), 4.12 (s, 2H, CH₂, Bn), 4.35 (d, 1H, H-1', J_{1',2'} 9.7 Hz), 4.53 (AB, 2H, CH₂, Bn), 4.84 (d, 2H, H-2''), 5.21 (t, 1H, H-4', J_{4',5'} 9.8 Hz), 5.34 (d, 1H, H-1'', J_{1'',2''} 0.8 Hz), 5.60 (d, 1H, H-3 or H-5, J_{3,5} 1.4 Hz), 5.63 (d, 1H, H-3 or H-5), 5.21 (t, 1H, H-3', J_{3',4'} 9.8 Hz), 5.21 (t, 1H, H-2', J_{2',3'} 9.8 Hz), 7.27–7.38 (m, 17H, 3 × Bz, Bn), 7.85–8.00 (m, 6H, 3 × Bz); δ_C (300 MHz, CDCl₃) 20.7, 21.2 (2 × CH₃, Ac), 52.1 (5-OMe), 55.9, 56.5 (4-OMe, 6-OMe), 66.6, 69.1 (C-4'', C-5'', C-6', CH₂, Bn), 73.0, 73.1, 75.1, 75.8, 78.3, 78.4 (C-1', C-2', C-3', C-4', C-5', C-2''), 79.8 (C-1), 85.3 (C-3''), 104.5, 105.4, 106.3 (C-1'', C-3, C-5), 128.0–133.4 (CH, Bz), 128.7, 129.0, 130.1 (Cq, Bz), 165.7, 165.1, 165.7 (C=O, Bz), 166.6, 167.7 (C-4, C-6), 169.0, 169.7 (C=O, Ac), 186.7 (C-2).

3,4,5-Trimethoxyphenyl 6-*O*-(5-*O*-benzyl-β-*D*-erythro-apiofuranosyl)-β-*D*-glucopyranoside (**34**)

Sodium methanolate (20 mg) was added to a solution of compound **32** (777 mg, 0.81 mmol) in a mixture of methanol and dichloromethane (5/1, v/v). After stirring for 2 h, the deacylation was complete, as judged by TLC-analysis. The reaction was neutralized with Dowex 50W X4 (H⁺-form), filtered and concentrated. The crude product was applied to a column of silica gel and eluted with ethyl acetate/methanol (100/0 → 95/5, v/v) to furnish the *title compound* **34** (405 mg, 88%) as a white amorphous solid; [Found: C, 57.2; H, 6.5 C₂₇H₃₆O₁₃ requires C, 57.04; H, 6.38%]; R_f (12% MeOH/CH₂Cl₂) 0.35; [α]_D²⁰ –57.7° (c 1, MeOH); δ_H (200 MHz, CDCl₃/CD₃OD) 3.65 (s, 3H, 4-OMe), 3.74 (s, 6H, 3-OMe, 5-OMe), 3.86 (d, 1H, H-2'', J_{2'',3''} 2.1 Hz), 4.76 (d, 1H, H-1', J_{1',2'} 7.6 Hz), 4.95 (d, 1H, H-1'', J_{1'',2''} 2.6 Hz), 6.38 (s, 1H, H-2, H-6), 7.32 (m, 5H, Bn); δ_C (200 MHz, CDCl₃) 56.0 (3-OMe, 5-OMe), 60.3 (4-OMe), 60.7, 70.3, 71.9, 73.3 (CH₂, Bn, C-6', C-5'', C-4''), 69.9, 75.7, 76.2, 76.9, 80.1 (C-2', C-3', C-4', C-5'', C-2''), 78.3 (C-3''), 95.2 (C-2, C-6), 101.3 (C-1'), 108.6 (C-1''), 127.5, 127.6 (CH, Bn), 133.7 (C-4), 137.2 (Cq, Bn), 153.4 (C-3, C-5), 154.7 (C-1).

3,4,5-Trimethoxyphenyl 6-*O*-(β-*D*-erythro-apiofuranosyl)-β-*D*-glucopyranoside (**1**)

Compound **34** (145 mg, 0.26 mmol) was dissolved in isopropanol/water (5.5 mL, 10/1, v/v) and, under a N₂ atmosphere, palladium on carbon was added. After applying a brief vacuum, the mixture was brought under a H₂-atmosphere for 12 h. The hydrogen gas was removed by application of a brief vacuum and the suspension was filtered, concentrated and the residue was purified on silica gel (CH₂Cl₂/MeOH, 85/15 → 80/20, v/v) to give the *title compound* **1** (113 mg, 91%) as a white amorphous solid; [Found: C, 50.2; H, 6.3 C₂₀H₃₀O₁₃ requires C, 50.21; H, 6.32%]; R_f (20% MeOH/CH₂Cl₂) 0.6; *m/z* 501.2 (M+Na)⁺; δ_H (600 MHz, CD₃OD) 3.25 (m, 2H, H-2', H-4'), 3.36 (t, 1H, H-3', J_{3',4'} ≈ J_{4',5'} 9.6 Hz), 3.48 (s, 2H, H-5''), 3.53 (m, 2H, H-6'a, H-5'), 3.63 (s, 3H, 4-OMe), 3.69 (d, 1H, H-4''b,

$J_{4'a,4'b}$ 9.6 Hz), 3.74 (s, 6H, 3-OMe, 5-OMe), 3.81 (d, 1H, H-2", $J_{2',3'} = 2.1$ Hz), 3.88 (d, 1H, H-4"a), 3.98 (dd, 1H, H-6'a, $J_{6'a,6'b} = 9.3$ Hz, $J_{6'a,5'} = 3.9$ Hz), 4.73 (d, 1H, H-1', $J_{1',2'} = 7.3$ Hz), 4.90 (d, 1H, H-1", $J_{1'',2''} = 2.4$ Hz), 6.39 (s, 1H, H-2, H-6); δ_C (600 MHz, CD_3OD) 55.7 (3-OMe, 5-OMe), 60.5 (4-OMe), 64.4 (C-5"), 66.7 (C-6'), 69.1 (C-4'), 72.8 (C-2'), 73.5 (C-4"), 74.8 (C-5'), 76.0 (C-2"), 76.4 (C-3'), 78.9 (C-3"), 95.0 (C-2, C-6), 101.4 (C-1'), 108.9 (C-1"), 133.2 (C-4), 153.0 (C-3, C-5), 154.7 (C-1); $[\alpha]_D^{20} -87^\circ$ (c 1.0, MeOH). Lit.^{1,2} $[\alpha]_D^{25} -99.8^\circ$ (c 0.5, MeOH)¹ and $[\alpha]_D^{21} -81.7^\circ$ (c 0.9, MeOH)². The title compound was acetylated according to Miyamura² to afford 3,4,5-trimethoxyphenyl 6-*O*-(2,3,5-tri-*O*-acetyl- β -D-erythro-apiofuranosyl)-2,3,4-tri-*O*-acetyl- β -D-glucopyranoside as white crystals, m.p. 138 °C; Lit.² m.p. 132–134 °C.

3,4,5-Trimethoxyphenyl 2,3,4-tri-*O*-phenoxyacetyl-6-*O*-(2,3-di-*O*-phenoxyacetyl-5-*O*-benzyl- β -D-erythro-apiofuranosyl)- β -D-glucopyranoside (35)

Phenoxyacetyl chloride (660 μ L, 4.75 mmol) was added dropwise in a period of 30 min to a stirred solution of 34 (416 mg, 0.732 mmol) and pyridine (680 μ L, 9 mmol) in 10 mL CH_2Cl_2 . After stirring for 1 h TLC analysis (toluene/ethyl acetate, 8/1, v/v) showed the formation of one major spot. The reaction was quenched by addition of methanol and diluted with dichloromethane and washed with water. The organic layer was dried ($MgSO_4$) and concentrated under reduced pressure. The resulting syrup was purified with silica gel column chromatography. Elution was performed with toluene/ethyl acetate (100/0 \rightarrow 80/20, v/v), to furnish, after concentration of the appropriate fractions, pure 35 (797 mg, 88%) as a light yellow oil; [Found: C, 64.8; H, 5.4 $C_{67}H_{66}O_{23}$ requires C, 64.94; H, 5.37%]; R_f (12.5% EtOAc/toluene) 0.5; $[\alpha]_D^{20} -23.2^\circ$ (c 1, $CHCl_3$); δ_H (300 MHz, $CDCl_3$) 3.43 (dd, 1H, H-6'a, $J_{5,6a'} = 3.1$ Hz, $J_{6a',6b'} = 12.1$ Hz), 3.49 (dd, 1H, H-6'b, $J_{5,6b'} = 6.2$ Hz), 3.75 (s, 6H, 3-OMe, 5-OMe), 3.78 (s, 3H, 4-OMe), 3.99 (dd, 2H, H-4"), 4.19 (s, 2H, CH_2 , Bn), 4.47 (s, 2H, CH_2 , PhOAc), 4.48 (s, 2H, CH_2 , PhOAc), 4.50 (s, 2H, CH_2 , PhOAc), 4.51 (s, 2H, CH_2 , PhOAc), 4.54 (s, 2H, CH_2 , PhOAc), 4.90 (d, 2H, H-2"), 5.03 (d, 1H, H-1', $J_{1',2'} = 7.7$ Hz), 5.25 (t, 1H, H-4', $J_{4',5'} = 9.6$ Hz), 5.29 (dd, 1H, H-2', $J_{2',3'} = 9.7$ Hz), 5.37 (d, 1H, H-1", $J_{1'',2''} = 1.7$ Hz), 5.46 (t, 1H, H-3', $J_{3',4'} = 9.6$ Hz), 6.19 (s, 1H, H-2, H-6), 6.81–6.88 (m, 20H, OPh, Bn), 7.22–7.28 (m, 10H, OPh); δ_C (200 MHz, $CDCl_3$) 56.1 (3-OMe, 5-OMe), 60.9 (4-OMe), 64.3, 64.6, 64.7, 65.4 ($5 \times CH_2$, PhOAc), 71.0, 71.6, 73.1, 74.4 (C-4", C-5", C-6', CH_2 , Bn), 69.0, 71.7, 72.6, 73.3, 77.2 (C-2', C-3', C-4', C-5', C-2"), 86.3 (C-3"), 95.2 (C-2, C-6), 99.0 (C-1'), 105.8 (C-1"), 114.3, 114.4, 114.5, 114.6 (CH , PhOAc), 121.7, 121.8, 121.9 (CH , PhOAc), 127.6–129.5 (CH , Bn, PhOAc), 133.6 (C-4), 137.3 (Cq, Bn), 152.7 (C-1), 153.6 (C-3, C-5), 157.3, 157.4 (Cq, PhOAc), 167.5, 167.6, 167.7, 167.8, 168.3 (C=O, PhOAc).

3,4,5-Trimethoxyphenyl 2,3,4-tri-*O*-phenoxyacetyl-6-*O*-(2,3-di-*O*-phenoxyacetyl- β -D-erythro-apiofuranosyl)- β -D-glucopyranoside (36)

Palladium on carbon (10%) was added to a solution of 34 (793 mg, 0.64 mmol) in a mixture of isopropanol/ethyl acetate/acetic acid (12/8/1, v/v/v, 15 mL). The mixture was vigorously stirred for 48 hours under hydrogen atmosphere. The reaction mixture was filtered and the filtrate was concentrated. The residual oil was applied onto a column of silica gel and elution was effected with toluene/ethyl acetate (100/0 \rightarrow 70/30, v/v) to give pure 36 (0.632 g, 86%) as an oil; [Found: C, 62.5; H, 5.3 $C_{60}H_{60}O_{23}$ requires C, 62.72; H, 5.26%]; R_f (4% MeOH/ CH_2Cl_2) 0.4; m/z 1150.2 ($M+H$)⁺, 1177.3 ($M+Na$)⁺; $[\alpha]_D^{20} -12.0^\circ$ (c 1.1, $CHCl_3$); δ_H (300 MHz, $CDCl_3$) 3.50 (m, 2H, H-6'a, H-6'b), 3.77 (s, 6H, 3-OMe, 5-OMe), 3.78 (s, 3H, 4-OMe), 4.05 (AB, 2H, H-4"), 4.45 (s, 2H, CH_2 , PhOAc), 4.52 (s, 2H, CH_2 , PhOAc), 4.58 (s, 2H, CH_2 , PhOAc), 4.68 (s, 2H, CH_2 , PhOAc), 4.75 (s, 2H, CH_2 , PhOAc), 4.96 (s, 2H, H-2"), 5.00 (d, 1H, H-1", $J_{1'',2''} = 1.6$ Hz), 5.09 (d, 1H, H-1', $J_{1',2'} = 7.5$ Hz), 5.19 (t, 1H, H-4', $J_{4',5'} = 9.6$ Hz), 5.36 (dd, 1H, H-2', $J_{2',3'} = 9.7$ Hz), 5.44 (t, 1H, H-3', $J_{3',4'} = 9.6$ Hz), 6.21 (s, 1H, H-2, H-6), 6.81–6.92 (m, 15H, OPh), 7.22–7.27 (m, 10H, OPh); δ_C (200 MHz, $CDCl_3$) 56.2 (3-OMe, 5-OMe), 60.9 (4-OMe), 64.5, 64.8, 64.9, 65.0, 65.6 ($5 \times CH_2$, PhOAc), 67.3, 74.1, 78.5 (C-4", C-5", C-6'), 68.9, 71.8, 72.9, 73.4, 78.7 (C-2', C-3', C-4', C-5', C-2"), 87.0 (C-3"), 95.3 (C-2,

C-6), 99.0 (C-1'), 106.1 (C-1''), 114.3, 114.4, 114.5, 114.6 (CH, PhOAc), 121.8, 122.0, 122.1 (CH, PhOAc), 129.6 (CH, PhOAc), 133.6 (C-4), 152.7 (C-1), 153.7 (C-3, C-5), 157.3, 157.4 (Cq, PhOAc), 167.6, 167.8, 168.4, 168.5, 169.1 (C=O, PhOAc).

3,4,5-Trimethoxyphenyl 2,3,4-tri-*O*-phenoxyacetyl-6-*O*-(2,3-di-*O*-phenoxyacetyl-5-*O*-(3,4-di-*O*-acetylcaffeoyl)- β -D-erythro-apiofuranosyl)- β -D-glucopyranoside (37)

To a solution of compound 36 (230 mg, 0.20 mmol) in CH_2Cl_2 (5 mL) and pyridine was added (50 μL , 0.60 mmol), was added a 1 mL of 0.4 M stock-solution of 3,4-di-*O*-acetylcaffeoyl chloride in CH_2Cl_2 . Monitoring the reaction by TLC-analysis showed the formation of a new spot. After 2 h the reaction mixture was diluted with CH_2Cl_2 and washed with 10% NaHCO_3 solution and water. The organic layer was separated and then dried (MgSO_4), filtered and concentrated. The crude product was purified by silica gel column chromatography (toluene/ethyl acetate, 8/2 \rightarrow 5/5, v/v) and after concentration of the appropriate fractions, 37 (215 mg, 77%) was obtained as a syrup; [Found: C, 62.7; H, 5.1 $\text{C}_{73}\text{H}_{70}\text{O}_{28}$ requires C, 62.84; H, 5.06%]; R_f (4% MeOH/ CH_2Cl_2) 0.4; $[\alpha]_D^{20}$ -33.2° (c 1, CHCl_3); δ_H (300 MHz, CDCl_3) 2.31 (s, 6H, 2 \times CH₃, Ac), 3.51 (dd, 1H, H-6'a, $J_{5,6a'}$ 6.0 Hz, $J_{6a',6b'}$ 12.1 Hz), 3.75 (m, 1H, H-6'b), 3.77 (s, 3H, 4-OMe), 3.78 (s, 6H, 3-OMe, 5-OMe), 3.85 (m, 1H, H-5'), 4.20 (dd, 2H, H-5'', J 10.8 Hz, J 18.3 Hz), 4.33 (s, 2H, CH₂, PhOAc), 4.50 (s, 2H, CH₂, PhOAc), 4.55 (d, 1H, H-4a'', J 12.6 Hz), 4.57 (s, 2H, CH₂, PhOAc), 4.58 (s, 2H, CH₂, PhOAc), 4.76 (dd, 2H, CH₂, PhOAc), 4.97 (s, 2H, H-2''), 5.09 (d, 1H, H-4''b), 5.12 (d, 1H, H-1', $J_{1',2'}$ 7.6 Hz), 5.28 (t, 1H, H-4', $J_{4',5'}$ 9.7 Hz), 5.36 (dd, 1H, H-2', $J_{2',3'}$ 9.7 Hz), 5.45 (t, 1H, H-3', $J_{3',4'}$ 9.7 Hz), 5.46 (s, 1H, H-1''), 6.21 (s, 1H, H-2, H-6), 6.31 (d, 1H, H-8'', $J_{7'',8''}$ 15.9 Hz), 6.73–6.96 (m, 16H, OPh, H-5'''), 7.16–7.27 (m, 12H, OPh, H-6'', H-2'''), 7.68 (d, 1H, H-7'''); δ_C (300 MHz, CDCl_3) 20.6 (CH₃, Ac), 56.2 (3-OMe, 5-OMe), 60.9 (4-OMe), 64.4, 64.7, 64.8, 64.9 (5 \times CH₂, PhOAc), 63.2, 65.3, 72.1 (C-4'', C-5'', C-6'), 69.0, 71.8, 72.7, 73.4, 76.0 (C-2', C-3', C-4', C-5', C-2''), 84.9 (C-3''), 95.3 (C-2, C-6), 99.0 (C-1'), 105.3 (C-1''), 114.3, 114.4, 114.5, 114.6 (CH, PhOAc), 117.5 (C-3'''), 121.6, 121.8, 121.9, 122.9, 124.0 (CH, PhOAc, C-2''', C-5''', C-6'''), 129.4, 129.6 (CH, PhOAc), 132.7 (C-1'''), 142.5 (C-3'''), 144.1 (C-4'''), 144.5 (C-7'''), 152.7 (C-1), 153.7 (C-3, C-5), 157.2, 157.3, 157.5 (Cq, PhOAc), 164.7 (C-9'''), 167.5, 167.6, 167.8 (C=O, PhOAc), 168.4, 168.9 (C=O, Ac).

3,4,5-Trimethoxyphenyl 6-*O*-(5-*O*-caffeoyl)- β -D-erythro-apiofuranosyl)- β -D-glucopyranoside (2)

To a stirred solution of compound 37 (181 mg, 0.13 mmol) in CH_2Cl_2 (2 mL) was added dropwise 1 mL of a 0.01 M K_2CO_3 solution in MeOH. Monitoring the deacylation by TLC-analysis showed that after adding 0.1 mL of the stock solution a new major spot occurred, in which both phenolic acetyl functions are cleaved as indicated by NMR-spectroscopy. After adding the total volume (1 mL) of K_2CO_3 solution TLC-analysis revealed the formation of a low running product. The solution was neutralized with a small amount of acetic acid and the solution was concentrated. The crude product was applied to a column of silica gel and eluted with dichloromethane/methanol (92/8 \rightarrow 80/20, v/v) to furnish the *title compound* (40 mg, 49%) as white amorphous solid; [Found: C, 54.6; H, 5.5 $\text{C}_{29}\text{H}_{36}\text{O}_{16}$ requires C, 54.73; H, 5.66%]; R_f (12% MeOH/ CH_2Cl_2) 0.30; m/z 663.0 ($\text{M}+\text{Na}$)⁺; δ_H (600 MHz, CD_3OD) 3.41 (t, 1H, H-4', $J_{4',5'}$ 9.6 Hz), 3.44 (dd, 1H, H-2', $J_{2',3'}$ 9.6 Hz), 3.47 (t, 1H, H-3', $J_{3',4'}$ 9.6 Hz), 3.60 (m, 1H, H-6'b), 3.65 (s, 3H, 4-OMe), 3.68 (m, 1H, H-5'), 3.80 (s, 6H, 3-OMe, 5-OMe), 3.82 (d, 1H, H-4a, $J_{4a',4b'}$ Hz), 3.98 (d, 1H, H-2'', $J_{1',2'}$ 2.1 Hz), 4.05 (d, 1H, H-4'a), 4.12 (dd, 1H, H-6'a, $J_{6'a,6'b'}$ 10.5 Hz, $J_{6'a,5'}$ 1.3 Hz), 4.25 (AB, 2H, H-5''), 4.99 (d, 1H, H-1', $J_{1',2'}$ 7.3 Hz), 5.01 (d, 1H, H-1'', $J_{1',2'}$ 2.1 Hz), 6.33 (d, 1H, H-8'', $J_{7'',8''}$ 15.9 Hz), 6.45 (s, 1H, H-2, H-6), 6.86 (d, 1H, H-5'', $J_{5'',6''}$ 8.1 Hz), 7.06 (dd, 1H, H-6'''), 7.20 (d, 1H, H-2''', $J_{7'',8''}$ 15.9 Hz), 7.70 (d, 1H, H-7'''); δ_C (600 MHz, CD_3OD) 55.5 (3-OMe, 5-OMe), 59.6 (4-OMe), 66.7 (C-5''), 67.2 (C-6'), 70.2 (C-4'), 73.4 (C-2'), 73.6 (C-4''), 75.6 (C-5'), 76.5 (C-2''), 76.9 (C-3'), 79.0 (C-3''), 95.3 (C-2, C-6), 101.4 (C-1'), 109.3 (C-1''), 114.0 (C-8'''), 114.5 (C-2''), 115.4 (C-5'''), 122.0 (C-6'''), 127.1 (C-1'''), 133.5 (C-4), 145.3 (C-3'''), 145.3 (C-7'''), 148.0 (C-4'''), 153.6 (C-3, C-5), 154.2 (C-1), 166.5 (C-9'''); $[\alpha]_D^{20}$ -74° (c 1.0, MeOH). Lit.³ $[\alpha]_D^{20}$ -70.3° (c 0.8, MeOH).

References and Notes

1. Shiraga, Y.; Okana, K.; Akira, T.; Fukaya, C.; Yokayama, K.; Tanaka, S.; Fukui, H.; Tubata, M. *Tetrahedron*, **1988**, *44*, 4703.
2. Miyamura, M.; Nohara, T.; Tomimatsu, T.; Nishioka, I. *Phytochemistry*, **1983**, *22*, 215.
3. Kitagawa, H.; Wei, H.; Nagao, S.; Mahmud, T.; Hori, K.; Kobayashi, M.; Uji, T.; Shibuya, H. *Chem. Pharm. Bull.*, **1996**, *44*, 1162.
4. Watson, R. R.; Orenstein, N. S. *Adv. Carbohydr. Chem. Biochem.*, **1975**, *31*, 135.
5. a) Mbaïraroua, O.; Ton-That, T.; Tapiéro, C. *Carbohydr. Res.* **1994**, *253*, 79. b) Suzuki, Y.; Yamaguchi, I.; Morofushi, N.; Takahashi, N.; Sugawara, F.; Yoshita, S.; Nukada, T.; Ogawa, T. *Agric. Biol. Chem.*, **1988**, *52*, 1261. c) Hettinger, P.; Schildknecht, H. *Liebigs Ann. Chem.*, **1984**, 1230.
6. a) Mahling, J.-A.; Schmidt, R. R. *Synthesis*, **1993**, 325. b) Mahling, J.-A.; Jung, K.-H.; Schmidt, R. R. *Liebigs Ann.*, **1995**, 461. c) Schmidt, R. R.; Hoffmann, M. *Tetrahedron Lett.*, **1982**, *23*, 409. d) Matsumoto, T.; Hosoya, T.; Suzuki, K. *Tetrahedron Lett.*, **1990**, *32*, 4629. e) Matsumoto, T.; Katsuki, M.; Suzuki, K. *Tetrahedron Lett.*, **1988**, *29*, 6935; f) Matsumoto, T.; Katsuki, M.; Jona, H.; Suzuki, K.; *J. Am. Chem. Soc.* **1991**, *113*, 6982; g) Suzuki, K.; *Pure & Appl. Chem.* **1994**, *66*, 1557.
7. Duynstee, H.I.; de Koning, M.C.; van der Marel, G.A.; van Boom, J.H. *Tetrahedron Lett.* **1998**, *39*, 4129.
8. a) Ho, P.-T. *Can. J. Chem.* **1979**, *57*, 381; b) Koos, M.; Mosher, H. S. *Carbohydr. Res.* **1986**, *146*, 335.
9. Nachman, R. J.; Hönel, M. H.; Williams, T. M.; Halaska, R. C.; Mosher, H. S. *J. Org. Chem.* **1986**, *51*, 4802.
10. Tipson, R. S. *Methods Carbohydr. Chem.* **1963**, *2*, 246.
11. a) Prepared by selective pivaloylation of methyl 2,3-di-*O*-benzyl- α -D-glucopyranoside;^{11b} b) Bernotas, R. C. *Tetrahedron Lett.* **1990**, *31*, 469.
12. Veeneman, G. H.; van Leeuwen, S. H.; van Boom, J. H. *Tetrahedron Lett.* **1990**, *31*, 1331.
13. a) Mootoo, D. R.; Konradsson, P.; Udodong, U.; Fraser-Reid, B. *J. Am. Chem. Soc.* **1988**, *110*, 5583; b) Veeneman, G. H.; van Boom, J. H. *Tetrahedron Lett.* **1990**, *31*, 275; c) Fraser-Reid, B.; Udodong, U. E.; Wu, Z.; Ottosson, H.; Merritt, J. R.; Rao, C. S.; Roberts, C.; Madsen, R. *Synlett* **1992**, 927.
14. Bochkov, A.F.; Snuatkova, V.I.; Voznyi Ya, V.; Kochetkov, N.K. *J. Gen. Chem. USSR*, **1971**, *41*, 2808.
15. a) Fraiser-Reid, B.; Wu, Z.; Andrews, C. W.; Skowronski, E.; Bowen, J. P. *J. Am. Chem. Soc.* **1991**, *113*, 1434; b) Boons, G.-J.; Grice, P.; Leslie, R.; Ley, S. V.; Yeung, L. L. *Tetrahedron Lett.* **1993**, *34*, 8523.
16. Ray, A.K.; Roy, N. *Carbohydr. Res.*, **1990**, *196*, 95.
17. Ethyl 2,3-di-*O*-acetyl-5-*O*-benzyl-1-thio- α / β -D-ribofuranoside (**19a**) was prepared from 2,3-*O*-isopropylidene- α / β -D-ribose in an identical way to that described for the synthesis of **4a** from **5**.
18. a) Roush, W.R.; Lin, X.-L. *J. Am. Chem. Soc.*, **1995**, *117*, 2236. b) Roush, W.R.; Lin, X.-L. *J. Org. Chem.*, **1991**, *56*, 5740. c) Kometani, T.; Kondo, H.; Fujimori, Y. *Synthesis*, **1988**, 1005.
19. Smits, E.; Engberts, J. B. F. N.; Kellogg, R. M.; van Doren, H. A. *J. Chem. Soc. Perkin Trans. 1* **1996**, 2873.
20. Smidt, R. R. *Angew. Chem. Int. Ed. Engl.* **1986**, *25*, 212.
21. Freudenberg, H.; *Chem. Ber.* **1953**, *86*, 190.