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Synthesis of 5-aminopentyl mono- to tri-saccharide haptens related to the species-specific glycopeptidolipids of *Mycobacterium avium-intracellulare* serovars 8 and 21

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ABSTRACT

The preparation of pyruvate acetal-containing 5-aminopentyl mono-, di-, and tri-saccharide fragments related to serovars 8 and 21 of the species-specific glycopeptidolipid of *Mycobacterium avium-intracellulare* is described. The saccharides were constructed by sequential coupling of the suitably protected 4,6-*O*-[(*S*)-1-methoxycarbonylethylidene]-D-glucopyranosyl trichloroacetimidates **6** and **7** to Z-protected 5-aminopentanol, to give the serovar 21 monosaccharide fragment **9** upon deblocking; and to ethyl 2-*O*-benzoyl-4-*O*-benzyl-1-thio-α-L-rhamnopyranoside (**18**), to give the corresponding ethyl 1-thio-disaccharides **21** and **23**, respectively. Subsequent *N*-iodosuccinimide-promoted coupling of the latter with Z-protected 5-aminopentanol followed by deblocking of the products afforded the corresponding disaccharide fragments **26** (serovar 8) and **27** (serovar 21), respectively. Condensation of **21** with Z-protected 5-aminopentyl 3,4-di-*O*-benzyl-6-deoxy-α-L-talopyranoside (**28**) and subsequent deblocking of the resulting trisaccharide gave the serovar 8 fragment 5-aminopentyl *O*-{4,6-*O*-[(*S*)-1-carboxyethylidene]-3-*O*-methyl-β-D-glucopyranosyl}-(1 → 3)-*O*-α-L-rhamnopyranosyl-(1 → 2)-6-deoxy-α-L-talopyranoside (**30**).

INTRODUCTION

Species of the *Mycobacterium avium* complex — the causative agent of "atypical" mycobacterioses and pulmonary infections — are distinguished by the highly species-specific glycopeptidolipids present in the outer integument of their cell walls[1]. Of the 31 serovars identified so far, the carbohydrate structure of the respective glycopeptidolipid of 12 serovars is known in detail[1,2]. These lipids are constructed out of the highly conserved *N*-fatty acyl tetrapeptide D-Phe-D-*allo*Thr-D-Ala-L-Alaninol, containing a 3,4-di-*O*-methyl-α-L-rhamnopyranosyl residue at the L-alaninol terminus and a 3-*O*-substituted α-L-rhamnopyranosyl-(1 → 2)-6-deoxy-α-L-talopyranosyl inner core which is glycosidically bound to the D-threonine residue of the glycopeptide backbone. The serologically distinguishable glycopeptidolipids are the consequence of the structural variability of an outer carbohydrate

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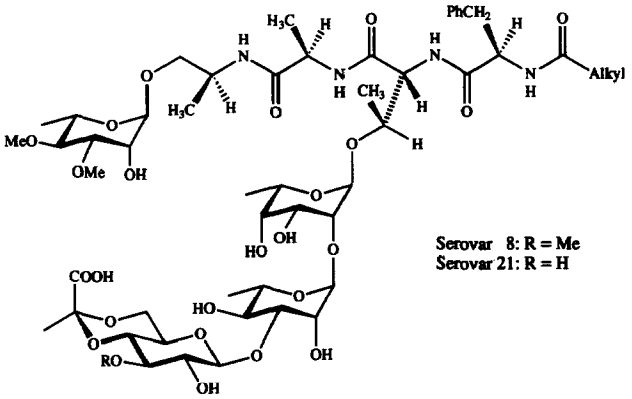


Fig. 1. Structure of the *Mycobacterium avium-intracellulare* glycopeptidolipids (serovar 8 and serovar 21)

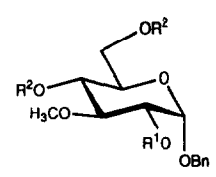
chain (mono-, di-, and tri-saccharide) that is attached to position 3 of the inner core[1–3] (Fig. 1).

Among the nontuberculous mycobacterioses caused by the *Mycobacterium avium-intracellulare* complex (MAI), infections by bacteria of the MAI serovar 8 are the most common[4,5]. For example, antibodies to MAI serovars 8 and 21 have been detected in the majority of serum specimens of healthy college students[5], whereas serovar 4 is described to be more common than the former in individuals suffering from AIDS[4,7]. For diagnostic purposes or for use as synthetic vaccines, there have therefore been considerable efforts to make the distinct haptenic oligosaccharides related to the common MAI serovars available. Thus, preparations of outer chain fragments corresponding to MAI serovars 2 and 4 (ref 8), and 25 and 26 (ref 9), as well as the complete serovar 4 tetrasaccharide[10,11], have been described *. Recently, an efficient synthesis of a pyruvate acetal-containing trisaccharide glycoconjugate related to the MAI serovar 21 has been developed in our laboratory[12] and ongoing studies toward pyruvated saccharides[13,14] prompted us to extend this approach to the MAI serovar 8. The synthesis of mono-, di-, and tri-saccharide fragments of the title serovars, both bearing 4,6-pyruvated β-D-glucopyranosyl units (Fig. 1), are now presented in detail.

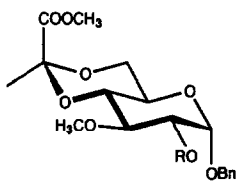
DISCUSSION

For the construction of the haptenic trisaccharide fragments related to MAI serovars 8 and 21, the pyruvated glucosyl trichloroacetimidates **6** and **7**, respectively, were needed. These donors exhibited superior properties with respect to

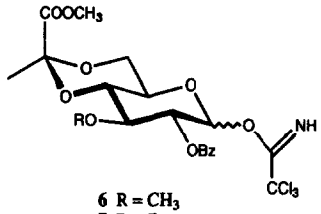
* During the editorial processing of this paper, a publication by J. Kerékgyártó, Z. Szurmai, and A. Lipták, *Carbohydr. Res.*, 245 (1993) 65–80, described the synthesis of the MAI serovar 20 tetrasaccharide.



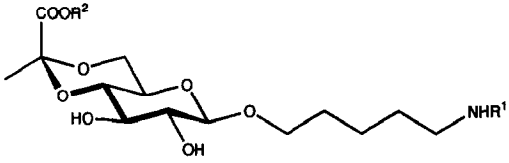
1 $R^1 = H$, $R^2 = PhCH$
2 $R^1 = ClCH_2CO$, $R^2 = PhCH$
3 $R^1 = ClCH_2CO$, $R^2 = H$



4 $R = ClCH_2CO$
5 $R = Bz$



6 $R = CH_3$
7 $R = Bz$



8 $R^1 = Z$, $R^2 = CH_3$
9 $R^1 = R^2 = H$

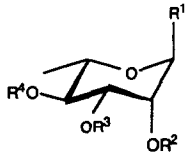
their reactivity and were easily prepared from benzyl 2-*O*-benzoyl-4,6-*O*-[(*S*)-1-methoxycarbonylethylidene]-3-*O*-methyl-α-D-glucopyranoside (**5**) and from the corresponding nonmethylated glucoside[14,15]. Compound **5** had previously been obtained in low yield, and contaminated by the corresponding *R*-diastereomer in one case, from benzyl 2-*O*-benzoyl-3-*O*-methyl-α-D-glucopyranoside[16] or from its 4,6-*O*-silylated counterpart[17] by acetalation with methyl pyruvate. Since the low overall yield was a consequence of side reactions at the anomeric center[15] (anomerisation and transacetalation), the 2-*O*-chloroacetyl-substituted diol **3** was used here for the pyruvation step. It was suspected[18,19] that a chloroacetyl substituent at position 2 would diminish the reactivity at the anomeric center and thus minimize side reactions. Indeed, treatment of the diol **3**, obtained via the sequence **1** → **2** (86%) and **2** → **3** (94%), with methyl pyruvate and boron trifluoride etherate[16] gave diastereoselectively compound **4** in 75% yield. Subsequent treatment of the latter with thiourea, followed by benzoyl chloride in pyridine, afforded **5** (97%) which was converted into the imidate **6** as recently described[14].

Previously, the MAI serovar 21 fragment *O*-[4,6-*O*-(1-carboxyethylidene)-β-D-glucopyranosyl]-(1 → 3)-*O*-α-L-rhamnopyranosyl-(1 → 2)-6-deoxy-α-L-talopyranoside was prepared using mono- and di-saccharide trichloroacetimidates exclusively for the entire construction of the oligosaccharide[12]. That approach allowed the effective coupling of the respective glycosyl donors and acceptors, but was expected to be ineffective for the synthesis of 5-aminopentyl saccharide fragments. This was because previous findings showed that trichloroacetimidates reacted rather slug-

gishly with 5-[(benzyloxycarbonyl)amino]pentanol[14], due to the presence of an amide bond in the alcohol. Similar problems have also been encountered with (benzyloxycarbonyl)aminoethanol[20] and were circumvented by the use of alkyl 1-thioglycosides as donors[14,21]. For example, the donor **6** previously gave the corresponding Z-protected aminopentyl 2-*O*-benzoyl-4,6-*O*-[(*S*)-1-methoxycarbonylethylidene]-3-*O*-methyl-β-D-glucopyranoside in a poor (48%) yield[14]. The latter compound afforded the MAI serovar 8 monosaccharide ligand upon deblocking. Unfortunately, 4,6-*O*-pyruvated alkyl 1-thioglucosides could not be used as glycosyl donors due to their unusually low reactivity[14]. Thus, donor **7** had to be used here and was condensed with 5-[(benzyloxycarbonyl)amino]pentanol to give the corresponding glucoside as crude material that had to be debenzoylated in order to obtain pure **8** (50%). Further deblocking of the latter then afforded the MAI serovar 21 monosaccharide ligand **9** (75%).

The MAI serovar 8 and 21 disaccharide ligands were prepared as follows. 2,3,4-Tri-*O*-acetyl-α-L-rhamnopyranosyl bromide (**10**) was first condensed with 5-[(benzyloxycarbonyl)amino]pentanol, to give compound **11** (87%), deblocking of which and subsequent treatment with acetone afforded **12** (81%). The latter partially protected rhamnopyranoside was benzoylated at position 4, to give **13** (82%) which afforded the diol **14** (73%) upon treatment with aq acetic acid. Regioselective acetylation of the axial hydroxyl group of **14** was achieved using the orthoester method[22,23] which gave the desired acceptor **15** in 91% yield. Originally, **15** was designed as the key intermediate for the construction of the desired disaccharide ligands. However, coupling of the latter and imidate **7** gave the target disaccharide **19** in an unacceptable (49%) yield. As was outlined above, the presence of an amide group in the acceptor **15** was thought to be the reason for the low yield in the coupling. Therefore, an alternative approach via thioglycosides was used. Starting from the known[21] ethyl 4-*O*-benzyl-1-thio-α-L-rhamnopyranoside (**16**), reaction with trimethyl orthoacetate or orthobenzoate, according to the improved procedure[24] of the original[25] acylation of 1-thio-L-rhamnosides, gave the known[21] acceptor **17** and the new compound **18** (93%), respectively. Coupling of the donor **6** with **18** and of donor **7** with **17** and **18**, respectively, proceeded smoothly, to give the corresponding disaccharides **21** (96%), **22** (80%), and **23** (92%).

Problems arose when the 2-*O*-acetylated disaccharide **22** was condensed with 5-[(benzyloxycarbonyl)amino]pentanol. The desired saccharide **20** (29%) was accompanied by the transesterification product 5-[(benzyloxycarbonyl)amino]pentyl acetate, isolated in 30% yield. Similar transesterifications of 2-*O*-acetyl groups have been previously observed in silver trifluoromethanesulfonate-promoted glycosylations of glycosyl halides[26] and it was recommended that benzoyl protecting groups should be used in order to avoid this side reaction. Indeed, when the *N*-iodosuccinimide-promoted condensation was performed with the thioglycosides **21** and **23**, respectively, the corresponding 5-[(benzyloxycarbonyl)amino]pentyl disaccharides **24** (72%) and **25** (74%) were obtained. Finally, deblocking of **24**



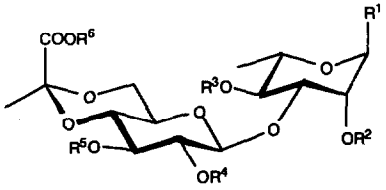
	R1	R2	R3	R4
10	Br	Ac	Ac	Ac
11	$O(CH_2)_5NHZ$	Ac	Ac	Ac
12	$O(CH_2)_5NHZ$	$(CH_3)_2C$		H
13	$O(CH_2)_5NHZ$	$(CH_3)_2C$		Bz
14	$O(CH_2)_5NHZ$	H	H	Bz
15	$O(CH_2)_5NHZ$	Ac	H	Bz
16	SEt	H	H	Bn
17	SEt	Ac	H	Bn
18	SEt	Bz	H	Bn

afforded the MAI serovar 8 disaccharide ligand **26** (77%) and deblocking of **25** afforded the corresponding serovar 21 ligand 27 (88%).

The MAI serovar 8 trisaccharide ligand was finally obtained by first coupling the disaccharide donor **21** to 5-[(benzyloxycarbonyl)amino]pentyl 3,4-di-*O*-benzyl-6-deoxy-α-L-talopyranoside[12] (**28**), to give the blocked trisaccharide **29** (72%). Deprotection of the latter afforded the free haptenic ligand **30** in 59% yield.

EXPERIMENTAL

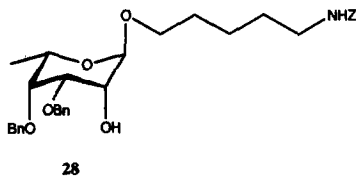
General methods.—NMR data (Tables I and II) were extracted from spectra measured for solutions in $CDCl_3$ for blocked compounds (with Me_4Si as internal standard) and in D_2O for deblocked compounds (with MeOH as internal standard) at 25°C with a Bruker AC 250F spectrometer. Data in the first row refer to the first sugar residue. Data in the second and third rows, if present, refer to the second and third sugar residues, respectively. ^{1}H-Assignments were made by first order analysis of the spectra. Of the two magnetically non-equivalent geminal protons at C-6, the one resonating at lower field was allocated H-6a and the one resonating at higher field H-6b. ^{13}C-Assignments were made by mutual comparison of the spectra, by DEPT spectra, and by comparison with spectra of related compounds. Optical rotations were measured at 25°C with a Perkin–Elmer automatic polarimeter, Model 241. Melting points were measured with a Büchi apparatus, Model SMP-20. Thin-layer chromatography (TLC) was performed on pre-



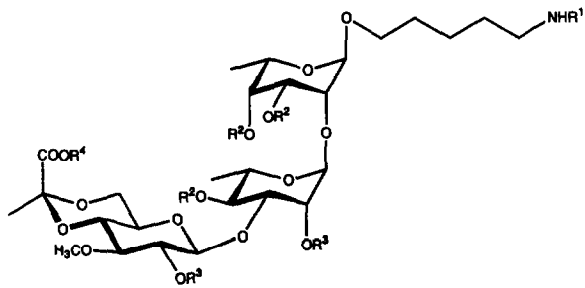
	R^1	R^2	R^3	R^4	R^5	R^6
19	$O(CH_2)_5NHZ$	Ac	Bz	Bz	Bz	CH_3
20	$O(CH_2)_5NHZ$	Ac	Bn	Bz	Bz	CH_3
21	SEt	Bz	Bn	Bz	CH_3	CH_3
22	SEt	Ac	Bn	Bz	Bz	CH_3
23	SEt	Bz	Bn	Bz	Bz	CH_3
24	$O(CH_2)_5NHZ$	Bz	Bn	Bz	CH_3	CH_3
25	$O(CH_2)_5NHZ$	Bz	Bn	Bz	Bz	CH_3
26	$O(CH_2)_5NH_2$	H	H	H	CH_3	H
27	$O(CH_2)_5NH_2$	H	H	H	H	H

coated plastic sheets, Polygram SIL UV_{254}, 40 × 80 mm (Macherey-Nagel), using appropriately adjusted mixtures of CCl_4–acetone. Detection was effected with UV light, where applicable, by I_2, and by charring with 5% H_2SO_4 in EtOH. Preparative chromatography was performed by elution from columns of Silica Gel 60 (Merck), using CCl_4–acetone. Solutions in organic solvents were dried with anhyd Na_2SO_4, and concentrated at 2 kPa, $\leq 40°C$.

Benzyl 4,6-O-benzylidene-2-O-chloroacetyl-3-O-methyl-α-D-glucopyranoside (**2**).—$NaHCO_3$ (1.0 g, 11.9 mmol) was added at room temperature to a solution of



28



29 $R^1 = Z$, $R^2 = Bn$, $R^3 = Bz$, $R^4 = CH_3$
30 $R^1 = R^2 = R^3 = R^4 = H$

1[17] (5.9 g, 15.8 mmol) and chloroacetic anhydride (6.0 g, 35.0 mmol) in DMF (25 mL), and the mixture was stirred for 4 h, poured into water, and extracted with CH_2Cl_2. The extracts were washed with aq $NaHCO_3$ and concentrated. Crystallization of the residue from EtOH afforded **2** (6.1 g, 86%); mp 142°C; $[\alpha]_D$ +17.9° (*c* 0.4, $CHCl_3$). Anal. Calcd for $C_{23}H_{25}ClO_7$: C, 61.54; H, 5.61; Cl, 7.90. Found: C, 61.25; H, 5.65; Cl, 8.09.

*Benzyl 2-O-chloroacetyl-3-O-methyl-α-*D*-glucopyranoside* (**3**).—A suspension of **2** (3.85 g, 8.58 mmol) in aq AcOH (80%, 100 mL) was stirred at 90°C until a clear solution was obtained (45 min). Concentration of the solution, coevaporation of toluene, and crystallization of the residue from acetone–hexane afforded **3** (2.91 g, 94%); mp 104°C; $[\alpha]_D$ +161.5° (*c* 0.6, $CHCl_3$). Anal. Calcd for $C_{16}H_{21}ClO_7$: C, 53.27; H, 5.87; Cl, 9.83. Found: C, 53.30; H, 5.90; Cl, 10.02.

*Benzyl 2-O-chloroacetyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-3-O-methyl-α-*D*-glucopyranoside* (**4**).—BF_3-etherate (1.24 mL, 10 mmol) was added at room temperature to a solution of **3** (1.81 g, 5 mmol) and methyl pyruvate (1.02 g, 10 mmol) in CH_2Cl_2 (5 mL). The mixture was stirred for 24 h, poured into aq $NaHCO_3$, and extracted with CH_2Cl_2. Concentration of the extracts and chromatography of the residue afforded **4** (1.66 g, 75%) as a colorless foam; $[\alpha]_D$ +143.2° (*c* 0.4, $CHCl_3$). Anal. Calcd for $C_{20}H_{25}ClO_9$: C, 54.00; H, 5.66; Cl, 7.97. Found: C, 54.24; H, 5.65; Cl, 8.11.

*Benzyl 2-O-benzoyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-3-O-methyl-α-*D*-glucopyranoside* (**5**).—A solution of **4** (1.88 g, 4.2 mmol) and piperidine thiocarbamide[27] (1.21 g, 8.4 mmol) in MeOH (20 mL) was stirred at room temperature for 36 h. Methyl chloroacetate (0.91 g, 8.4 mmol) was added and stirring was continued for 24 h. After concentration of the mixture, the residue was dissolved in CH_2Cl_2, and the solution was washed with satd aq NaCl and concentrated again. The residue was dissolved in pyridine (10 mL), benzoyl chloride (3 mL) was added, and the mixture was stirred at room temperature for 1 h, poured into water, and extracted with CH_2Cl_2. The extracts were washed with aq HCl and aq $NaHCO_3$, and concentrated. Chromatography of the residue with (25 : 1) toluene–acetone afforded **5** (1.92 g, 97%) as a colorless foam identical in all respects to the previously obtained compound[17].

*5-[(Benzyloxycarbonyl)amino]pentyl 4,6-O-[(S)-1-methoxycarbonylethylidene]-β-*D*-glucopyranoside* (**8**).—A solution of **7**[15] (0.82 g, 1.33 mmol) in CH_2Cl_2 (5 mL) was added at −20°C under Ar to a solution of 5-[(benzyloxycarbonyl)amino]pentanol[28] (0.33 g, 1.4 mmol) and trimethylsilyl trifluoromethanesulfonate (18 μL, 0.1 mmol) in CH_2Cl_2 (8 mL), and the mixture was stirred for 1 h. Pyridine (2 drops) was added, and the mixture was poured into aq $NaHCO_3$ and extracted with CH_2Cl_2. Concentration of the extracts and chromatography of the residue afforded the crude coupling product (0.49 g). A catalytic amount of NaOMe was added to a solution of the crude material in MeOH (10 mL) and the solution was stirred at room temperature for 15 h. Ion-exchange resin (Lewatit, H^+) was added until a neutral solution was obtained, the solution was filtered, and the filtrate was

concentrated. Chromatography of the residue with 10:1 CH_2Cl_2–MeOH afforded **8** (338.5 mg, 50%) as a colorless oil; $[\alpha]_D$ −23.7° (*c* 0.8, $CHCl_3$). Anal. Calcd for $C_{23}H_{33}NO_{10}$: C, 57.13; H, 6.89; N, 2.90. Found: C, 57.08; H, 6.97; N, 2.77.

5-Aminopentyl 4,6-O-[(S)-1-carboxyethylidene]-β-D-glucopyranoside (**9**).—Aq NaOH (0.1 M) was added to a solution of **8** (96.7 mg, 0.2 mmol) in MeOH (5 mL) until an alkaline solution was obtained, and the mixture was stirred at room temperature for 24 h and neutralized by addition of ion-exchange resin (Lewatit H^+). After filtration, a catalytic amount of Pd (10% on charcoal) was added to the filtrate, and the mixture was treated with H_2 at atmospheric pressure for 24 h, filtered, and concentrated. Chromatography of the residue with water on Bio Gel P2 and lyophilization of the carbohydrate-containing fractions afforded **9** (53 mg, 75%) as an amorphous solid; $[\alpha]_D$ −40.6° (*c* 0.2, H_2O). FABMS: *m/z* 336 $(MH)^+$. Anal. Calcd for $C_{14}H_{25}NO_8$: C, 50.14; H, 7.51; N, 4.18. Found: C, 49.87; H, 7.74; N, 3.86.

5-[(Benzyloxycarbonyl)amino]pentyl 2,3,4-tri-O-acetyl-α-L-rhamnopyranoside (**11**).—Mercuric cyanide (3.28 g, 13 mmol) and mercuric bromide (0.34 g, 0.93 mmol) were added at room temperature to a solution of **10**[29] (4.92 g, 13.9 mmol) and 5-[(benzyloxycarbonyl)amino]pentanol (3.56 g, 15 mmol) in MeCN (50 mL), and the mixture was stirred for 0.5 h, poured into water, and extracted with CH_2Cl_2. The extracts were washed with aq $NaHCO_3$ and concentrated. Chromatography of the residue afforded **11** (6.15 g, 87%) as a colorless oil; $[\alpha]_D$ −39.9° (*c* 0.9, $CHCl_3$). Anal. Calcd for $C_{25}H_{35}NO_{10}$: C, 58.93; H, 6.92; N, 2.75. Found: C, 59.27; H, 7.03; N, 2.88.

5-[(Benzyloxycarbonyl)amino]pentyl 2,3-O-isopropylidene-α-L-rhamnopyranoside (**12**).—A catalytic amount of NaOMe was added to a solution of **11** (5.09 g, 10 mmol) in MeOH (100 mL) and the solution was stirred at room temperature for 24 h. Ion-exchange resin (Lewatit, H^+) was added until a neutral solution was obtained, the solution was filtered, and the filtrate was concentrated. The oily residue was dissolved in acetone (100 mL), and dried $CuSO_4$ (10 g) and toluene-*p*-sulfonic acid (0.1 g) were added. The mixture was stirred at room temperature for 3 days, neutralized by addition of Et_3N, filtered through a layer of Celite, and concentrated. Chromatography of the residue afforded **12** (3.42 g, 81%) as a colorless oil; $[\alpha]_D$ −17.6° (*c* 0.5, $CHCl_3$). Anal. Calcd for $C_{22}H_{33}NO_7$: C, 62.39; H, 7.85; N, 3.31. Found: C, 62.53; H, 7.88; N, 3.22.

5-[(Benzyloxycarbonyl)amino]pentyl 4-O-benzoyl-2,3-O-isopropylidene-α-L-rhamnopyranoside (**13**).—Benzoyl chloride (10 mL) was added to a solution of **12** (2.25 g, 5.3 mmol) in pyridine (20 mL), and the mixture was stirred at room temperature for 2 h, poured into water, and extracted with CH_2Cl_2. The extracts were washed with aq HCl and aq $NaHCO_3$, and concentrated. Chromatography of the residue afforded **13** (2.29 g, 82%) as a colorless oil; $[\alpha]_D$ −2.8° (*c* 0.4, $CHCl_3$). Anal. Calcd for $C_{29}H_{37}NO_8$: C, 66.02; H, 7.07; N, 2.65. Found: C, 66.24; H, 7.09; N, 2.56.

5-[(Benzyloxycarbonyl)amino]pentyl 4-O-benzoyl-α-L-rhamnopyranoside (**14**).—A suspension of **13** (2.02 g, 3.83 mmol) in aq AcOH (80%, 50 mL) was stirred at 70°C until a clear solution was obtained (1 h), which was then concentrated. The residue was dissolved in CH_2Cl_2, and the solution was washed with aq $NaHCO_3$ and concentrated. Chromatography of the residue afforded **14** (1.36 g, 73%) as a colorless foam; $[\alpha]_D$ −68.3° (*c* 0.2, $CHCl_3$). Anal. Calcd for $C_{26}H_{33}NO_8$: C, 64.05; H, 6.82; N, 2.87. Found: C, 63.81; H, 6.91; N, 2.72.

5-[(Benzyloxycarbonyl)amino]pentyl 2-O-acetyl-4-O-benzoyl-α-L-rhamnopyranoside (**15**).—A solution of **14** (1.3 g, 2.6 mmol), trimethyl orthoacetate (0.6 g, 5 mmol), and a catalytic amount of toluene-*p*-sulfonic acid (10 mg) in DMF (10 mL) was stirred at 50°C until TLC revealed the complete conversion of the starting material into a single faster moving product (1 h). Triethylamine (5 drops) was added and the mixture was concentrated. The residue was dissolved in aq AcOH (80%, 50 mL) and the solution was stirred at room temperature for 0.5 h. Concentration and chromatography of the residue afforded **15** (1.25 g, 91%) as a colorless oil; $[\alpha]_D$ −24.0° (*c* 0.4, $CHCl_3$). Anal. Calcd for $C_{28}H_{35}NO_9$: C, 63.50; H, 6.66; N, 2.64. Found: C, 63.31; H, 6.73; N, 2.58.

Ethyl 2-O-benzoyl-4-O-benzyl-1-thio-α-L-rhamnopyranoside (**18**).—A catalytic amount of toluene-*p*-sulfonic acid (10 mg) was added to a solution of **16**[21] (1.67 g, 5.6 mmol) and trimethyl orthobenzoate (3.5 mL) in DMF (1 mL), and the mixture was stirred in vacuo at room temperature for 1 h. Workup and treatment with aq AcOH, as described for **15**, afforded **18** (2.1 g, 93%) as a colorless oil; $[\alpha]_D$ −50.9° (*c* 0.4, $CHCl_3$). Anal. Calcd for $C_{22}H_{26}O_5S$: C, 65.65; H, 6.51; S, 7.97. Found: C, 65.60; H, 6.49; S, 7.52.

5-[(Benzyloxycarbonyl)amino]pentyl O-{2,3-di-O-benzoyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-β-D-glucopyranosyl}-(1 → 3)-2-O-acetyl-4-O-benzoyl-α-L-rhamnopyranoside (**19**).—A solution of **7** (0.62 g, 1 mmol) in CH_2Cl_2 (2 mL) was added at −20°C under Ar to a solution of **15** (0.52 g, 1 mmol) and trimethylsilyl trifluoromethanesulfonate (36 μL, 0.2 mmol) in CH_2Cl_2 (5 mL), and the mixture was stirred for 0.5 h. Pyridine (5 drops) was added, and the mixture was poured into aq $NaHCO_3$ and extracted with CH_2Cl_2. Concentration of the extracts and chromatography of the residue afforded **19** (0.475 g, 49%) as a colorless foam; $[\alpha]_D$ +52.6° (*c* 0.6, $CHCl_3$). Anal. Calcd for $C_{52}H_{57}NO_{18}$: C, 63.47; H, 5.84; N, 1.42. Found: 63.42; H, 5.85; N, 1.33.

5-[(Benzyloxycarbonyl)amino]pentyl O-{2,3-di-O-benzoyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-β-D-glucopyranosyl}-(1 → 3)-2-O-acetyl-4-O-benzyl-α-L-rhamnopyranoside (**20**).—A solution of *N*-iodosuccinimide (78.8 mg, 0.35 mmol) and triflic acid (3.2 μL, 0.35 mmol) in 1:1 CH_2Cl_2–diethyl ether (3 mL) was added at −30°C under Ar to a suspension of **22** (252 mg, 0.32 mmol), 5-[(benzyloxycarbonyl)-amino]pentanol (83 mg, 0.35 mmol), and 3A molecular sieves (0.5 g) in CH_2Cl_2 (5 mL), and the mixture was stirred for 0.5 h. Pyridine (2 drops) was added, and the mixture was poured into aq $NaHCO_3$ and extracted with CH_2Cl_2. The extracts were washed with aq $Na_2S_2O_3$. Concentration and chromatography of the residue

TABLE I

^{1}H NMR data [a]

Compound	^{1}H Chemical shifts (δ), multiplicities, and coupling constants (Hz)								
	H-1 ($J_{1,2}$)	H-2 ($J_{2,3}$)	H-3 ($J_{3,4}$)	H-4 ($J_{4,5}$)	H-5 ($J_{5,6a}$)	H-6a ($J_{5,6b}$)	H-6b ($J_{6a,6b}$)	Aglycon	Other substituents
2 [b]	5.09d	4.79dd	3.51t	3.66t	3.91–3.75m	4.21dd	3.91–3.75m	4.74d, 4.53d (J – 12.2)	5.58s (PhCH), 3.55s (OMe)
	(3.8)	(9.6)	(9.3)	(9.3)	(4.3)	–	(– 10.0)		4.15d ($ClCH_2$)
3	5.12d	4.74dd	3.75–3.66m	3.75–3.66m	3.45bd	3.84–3.76m	3.75–3.66m	4.70d, 4.49d (J – 12.2)	3.48s (OMe)
	(3.7)	(9.0)	–	–	–	–	–		4.08d, 4.01d ($ClCH_2$, J 5.0)
4	5.06d	4.78dd	3.47t	3.77t	3.70–3.62m	3.97dd	3.93–3.79m	4.71d, 4.49d (J – 12.1)	3.84s (COOMe), 3.57s (OMe)
	(4.0)	(9.6)	(9.3)	(9.6)	(4.7)	–	(– 10.3)		1.55s (Me), 4.09d, 4.03d ($ClCH_2$)
8	4.33d	3.45–3.27m	3.45–3.27m	3.74–3.61m	3.74–3.61	4.04dd	3.45–3.27m	3.85dt, 3.52dt (OCH_2)	5.10s (Z), 1.68–1.42m (3 CH_2)
	(7.7)	–	–	–	(4.5)	–	(– 10.8)	3.19–3.11m (NCH_2)	3.82s (COOMe), 1.57s (Me)
11	4.71d	5.22dd	5.29dd	5.06t	3.85dq	1.22d		3.67dt, 3.41dt (OCH_2)	5.10s (Z), 4.87bs (NH)
	(1.5)	(3.5)	(10.1)	(9.7)	(6.3)	–		3.20bq(NCH_2)	2.14s, 2.04s, 1.98s (3 Me)
12	4.93bs	4.14–4.05m	4.14–4.05m	3.62t	3.47–3.35m	1.29d		3.60dt, 3.40dt (OCH_2)	5.09s (Z), 4.84bs (NH)
	(0.0)	–	–	(9.2)	(6.3)	–		3.19bq (NCH_2)	1.52s, 1.35s (2 Me)
13	5.03s	4.19d	4.34dd	5.13dd	3.87dq	1.20d		3.71dt, 3.44dt (OCH_2)	5.09s (Z), 5.04bs (NH)
	(0.0)	(5.4)	(7.8)	(10.1)	(6.3)	–		3.19bq (NCH_2)	1.62s, 1.35s (2 Me)
14	4.83bs	4.04–3.87m	4.04–3.87m	5.09dd	4.04–3.87m	1.26d		3.69dt, 3.41dt (OCH_2)	5.08s (Z), 4.92bs (NH)
	(0.0)	–	(9.2)	(9.7)	(6.3)	–		3.19bq(NCH_2)	
15	4.81d	5.16–5.08m	4.18ddd	5.16–5.08m	3.96dq	1.27d		3.69dt, 3.43dt (OCH_2)	5.09s (Z), 4.84bs (NH)
	(1.3)	(3.6)	(9.9)	(9.7)	(6.2)	–		3.21bq (NCH_2)	
18	5.33d	5.44dd	4.21–4.10m	3.51t	4.21–4.10m	1.40d		2.75–2.53m (SCH_2)	4.85d, 4.75d ($PhCH_2$)
	(1.1)	(3.4)	(9.4)	(9.4)	(6.3)	–		1.29t (SCH_2CH_3)	2.28bd (OH)
19	4.72d	5.22dd	3.83dd	4.23dd	3.72–3.61m	1.12d		3.65dt, 3.43dt (OCH_2)	5.11s (Z), 2.16s (Ac)
	(1.6)	(3.6)	(10.0)	(9.8)	(6.3)	–		3.22bq (NCH_2)	

	4.86d	5.27dd	5.47t	3.74t	3.72–3.61m	4.15dd	3.54dd		3.79s (COOMe)
	(7.6)	(9.3)	(9.3)	(9.4)	(4.8)	(4.6)	(−10.6)		1.46s (Me)
20	4.63d	5.15dd	3.85–3.77m	3.75–3.49m	4.14–4.01m	1.16d		3.75–3.30m (OCH_2)	5.10s (Z), 2.13s (Ac)
	(1.6)	(3.4)	–	–	(6.2)	–		3.19bq (NCH_2)	4.54d, 4.27 ($PhCH_2$)
	5.04d	5.45dd	5.61t	3.81t	3.75–3.49m	4.15dd	4.11dd		3.81s (COOMe)
	(7.7)	(9.3)	(9.3)	(9.5)	(4.8)	(3.5)	(−10.4)		1.48s (Me)
21	5.29d	5.39dd	4.14dd	5.55t	4.01dq	1.18d		2.70–2.45m (SCH_2)	4.64d, 4.38d ($PhCH_2$)
	(1.5)	(3.4)	(9.2)	(9.3)	(6.3)	–		1.28t (SCH_2CH_2)	
	4.90d	5.22bt	3.51t	3.46–3.38m	3.46–3.38m	4.06dd	3.54dd		3.77s (COOMe)
	(7.7)	(8.2)	(8.3)	–	(4.0)	(4.9)	(−10.0)		3.44s (OMe), 1.53s (Me)
22	5.12d	5.26dd	4.09dd	3.69bt	4.03–3.85m	1.17d		2.69–2.48m (SCH_2)	4.53d, 4.26d ($PhCH_2$)
	(1.3)	(3.4)	(9.4)	(10.4)	(6.3)	–		1.26t (SCH_2CH_3)	2.16s (Ac)
	5.03d	5.43dd	5.61t	3.37t	3.85–3.78m	4.15dd	3.55dd		3.82s (COOMe)
	(7.7)	(9.4)	(9.4)	(9.5)	(4.8)	(4.7)	(−10.6)		1.49s (Me)
23	5.31d	5.43dd	4.21dd	3.66–3.45m	4.05dq	1.19d		2.74–2.52m (SCH_2)	4.58d, 4.35d ($PhCH_2$)
	(1.4)	(3.4)	(9.3)	(9.4)	(6.2)	–		1.29t (SCH_2CH_3)	
	5.06d	5.42dd	5.60t	3.66–3.45m	3.75–3.68m	4.12dd	3.66–3.45m		3.75s (COOMe)
	(7.7)	(9.7)	(9.4)	–	(3.5)	–	(−9.7)		1.46s (Me)
24	4.78d	5.29dd	4.18dd	3.44–3.31m	3.44–3.31m	1.17d		3.44–3.31m (OCH_2 [a])	5.11s (Z), 4.81bs (NH)
	(1.6)	(3.4)	(9.2)	–	(6.1)	–		3.61dt (OCH_2 [b])	4.64d, 4.39d ($PhCH_2$)
	4.92d	5.23bt	3.57t	3.48t	3.44–3.31m	4.12–4.02m	3.68dd	3.20bq (NCH_2)	3.75s (COOMe)
	(7.7)	(8.2)	(8.6)	(9.2)	–	(6.0)	(−9.6)		3.44s (OMe), 1.52s (Me)
25	4.80d	5.32dd	4.24dd	3.70–3.36m	3.70–3.36m	1.18d		3.70–3.36m (OCH_2)	5.10s (Z), 4.83bs (NH)
	(1.4)	(3.5)	(9.2)	–	(6.2)	–		3.21bq (NCH_2)	4.59d, 4.36d ($PhCH_2$)
	5.08d	5.43dd	5.60t	3.60t	3.70–3.36m	4.12dd	3.70–3.36m		3.73s (COOMe)
	(7.7)	(9.3)	(9.3)	(9.9)	(4.0)	–	(−10.0)		1.46s (Me)

[a] For solutions in $CDCl_3$ unless otherwise indicated. Data in the 1st row refer to the first sugar residue. Data in the 2nd and 3rd rows, if present, refer to the 2nd and 3rd sugar residues, respectively. [b] For solution in Me_2SO-d_6.

TABLE II

^{13}C NMR data [a]

Compound	^{13}C Chemical shifts (δ)							
	C-1	C-2	C-3	C-4	C-5	C-6	Aglycon	Other substituents
2 [b]	100.3	79.3	82.3	85.1	67.5	75.9	73.3 (Bn)	106.1 (PhCH), 65.2 (OMe), 45.7 ($ClCH_2$)
3	95.0	71.3	80.8	75.2	69.8	61.7	69.9 (Bn)	61.3 (OMe), 40.7 ($ClCH_2$)
4	95.5	73.9	77.7	76.8	62.1	70.1	65.3 (Bn)	99.1 ($C_{quart.}$), 59.8 (OMe), 52.8 (COO*Me*), 40.6 ($ClCH_2$), 25.5 (Me)
8	103.1	73.2	74.4	76.3	65.7	66.5	64.9 (OCH_2), 40.7 (NCH_2), 70.0 (Z)	99.1 ($C_{quart.}$), 52.8 (COOMe), 25.2 (Me)
9 [c]	105.8	75.8	78.8	76.9	68.8	73.3	67.1 (OCH_2), 42.3 (NCH_2)	104.4 ($C_{quart.}$), 27.5 (Me)
11	97.4	71.2 [d]	69.9 [d]	69.2 [d]	66.3	17.4	66.6 (OCH_2), 40.9 (NCH_2), 68.0 (Z)	
12	96.9	78.4 [d]	75.8 [d]	74.4 [d]	65.9	17.5	66.7 (OCH_2), 41.0 (NCH_2), 67.4 (Z)	109.4 ($C_{quart.}$), 29.0 (Me), 28.0 (Me)
13	96.9	76.1 [d]	75.8 [d]	75.1 [d]	64.0	17.1	66.5 (OCH_2), 40.9 (NCH_2), 67.5 (Z)	109.5 ($C_{quart.}$), 27.7 (Me), 26.4 (Me)
14	99.5	76.6 [d]	75.9 [d]	71.1 [d]	65.8	17.6	67.6 (OCH_2), 40.9 (NCH_2), 70.3 (Z)	
15	97.3	75.3	67.9	72.9	66.1	17.5	66.6 (OCH_2), 40.9 (NCH_2), 68.6 (Z)	21.5 (Ac)
18	82.2 [d]	71.0 [e]	71.0 [e]	81.9 [d]	68.1 [e]	18.1	25.7 (SCH_2), 15.0 (SCH_2CH_3)	75.1 (Bn)
19	97.4	71.6	74.5	72.0	65.9	17.4	66.6 (OCH_2), 40.9 (NCH_2), 68.0 (Z)	21.1 (Ac)
	101.5	72.6 [d]	72.2 [d]	75.1	66.4	65.0	29.8, 29.0, 23.3 (3 CH_2)	99.3 ($C_{quart.}$), 52.7 (COO*Me*), 25.2 (Me)
20	97.1	71.8	77.9	79.9	65.0	17.8	66.0 (OCH_2), 40.9 (NCH_2), 67.6 (Z)	75.0 ($PhCH_2$), 21.1 (Ac)
	101.3	72.5 [d]	72.3 [d]	74.6	66.6	64.2	29.8, 28.9, 23.2 (3 CH_2)	99.3 ($C_{quart.}$), 52.7 (COO*Me*), 25.2 (Me)
21	82.1	74.6	79.3	80.5	68.4	18.0	25.9 (SCH_2), 15.2 (SCH_2CH_3)	75.1 ($PhCH_2$)
	101.7	66.0	80.1	72.8	76.1	65.1		99.2 ($C_{quart.}$), 58.6 (OMe), 52.9 (COO*Me*), 25.6 (Me)

22	82.0	74.6	78.0	80.2	68.2	17.7	25.5 (SCH_2), 14.9 (SCH_2CH_3)	75.0 ($PhCH_2$), 21.1 (Ac)
	101.5	72.5 [d]	72.2 [d]	73.7	66.1	65.0		99.4 ($C_{quart.}$), 52.7 (COO*Me*), 25.2 (Me)
23	81.9	74.9	78.6	80.1	68.2	17.8	25.2 (SCH_2), 15.0 (SCH_2CH_3)	74.9 ($PhCH_2$)
	101.5	72.5 [d]	72.2 [d]	74.9	66.0	65.0		99.3 ($C_{quart.}$), 52.7 (COO*Me*), 25.2 (Me)
24	97.0	65.7	79.0	79.6	67.3	17.9	66.6 (OCH_2), 40.9 (NCH_2)	75.0 ($PhCH_2$)
	101.4	72.4 [d]	80.4	72.7 [d]	76.0	64.9	29.8, 29.0, 23.3 (3 CH_2)	99.0 ($C_{quart.}$), 58.4 (OMe), 52.7 (COO*Me*), 25.4 (Me)
25	97.0	72.5 [d]	78.5	79.8	66.6	17.9	65.9 (OCH_2), 40.9 (NCH_2)	75.0 ($PhCH_2$)
	101.3	72.5 [d]	72.2 [d]	74.5	67.3	65.0	29.8, 29.0, 23.3 (3 CH_2)	99.3 ($C_{quart.}$), 52.6 (COO*Me*), 25.2 (Me)
26 [c]	99.6	71.2	80.5	70.1	68.6	16.8	67.7 (OCH_2), 39.6 (NCH_2)	
	104.6	65.9	81.6	72.9	75.1	64.5	28.2, 27.0, 22.7 (3 CH_2)	101.6 ($C_{quart.}$), 58.7 (OMe), 24.8 (Me)
27 [c]	99.8	71.4	80.7	70.3	68.8	17.0	67.8 (OCH_2), 39.7 (NCH_2)	
	104.8	74.5	73.1	76.3	66.2	64.6	28.4, 26.9, 22.8 (3 CH_2)	101.8 ($C_{quart.}$), 25.0 (Me)
29	99.5	72.7	77.2	76.1	72.4	17.0 [e]	66.6 (OCH_2), 40.9 (NCH_2), 67.4 (Z)	71.1 ($PhCH_2$), 72.9 ($PhCH_2$)
	98.2	67.4	79.1 [d]	79.5 [d]	65.1	18.0 [e]	29.7, 29.1, 23.3 (3 CH_2)	74.9 ($PhCH_2$)
	100.7	79.1	80.2	71.9	75.7	64.8		98.8 ($C_{quart.}$), 58.1 (OMe), 52.6 (COO*Me*), 25.5 (Me)
30 [c]	102.9	77.6	72.0	70.1	67.5	15.9	68.2 (OCH_2), 39.9 (NCH_2)	
	99.3	71.5	79.9	70.1	69.7	17.1	28.4, 27.2, 22.9 (3 CH_2)	
	104.6	66.2	81.9	73.2	75.4	64.8		102.0 ($C_{quart.}$), 59.0 (OMe), 25.0 (Me)

[a] For solutions in $CDCl_3$ unless otherwise indicated. Data in the 1st row refer to the first sugar residue. Data in the 2nd and 3rd rows, if present, refer to the 2nd and 3rd sugar residues, respectivcly. [b] For solution in Me_2SO-d_6. [c] For solution in D_2O. [d,e] Assignments may be reversed.

afforded first 5-[(benzyloxycarbonyl)amino]pentyl acetate (26.8 mg, 30%) as a colorless oil; ^{1}H NMR data: δ 7.44–7.29 (m, 5 H, Ar), 5.10 (s, 2 H, PhCH_2O), 4.78 (bs, 1 H, NH), 4.05 (t, 2 H, J 6.5 Hz, AcOCH_2), 3.20 (bdd, 2 H, J 6.6, −13.1 Hz, NCH_2), 2.04 (s, 3 H, CH_3), 1.70–1.31 (m, 6 H, 3 CH_2). Anal. Calcd for $C_{15}H_{21}NO_4$: C, 64.50; H, 7.58; N, 5.01. Found: C, 64.58; H, 7.57; N, 4.91.

Eluted second was **20** (89.5 mg, 29%) as a colorless foam; $[\alpha]_D$ +30.4° (*c* 0.3, $CHCl_3$). Anal. Calcd for $C_{52}H_{59}NO_{17}$: C, 64.39; H, 6.13; N, 1.44. Found: C, 64.44; H, 6.49; N, 1.39.

Ethyl O-*{2-O-benzoyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-3-O-methyl-β-*D*-glucopyranosyl}-(1 → 3)-2-O-benzoyl-4-O-benzyl-1-thio-α-*L*-rhamnopyranoside* (**21**). —A solution of **6**[14] (1.62 g, 3.15 mmol) in CH_2Cl_2 (2 mL) was added at −20°C under Ar to a solution of **18** (1.11 g, 2.7 mmol) and trimethylsilyl trifluoromethanesulfonate (57 μL, 0.32 mmol) in CH_2Cl_2 (10 mL), and the mixture was stirred for 0.5 h. Workup as described for **19** afforded **21** (1.99 g, 96%) as a colorless foam; $[\alpha]_D$ −69.6° (*c* 0.5, $CHCl_3$). Anal. Calcd for $C_{40}H_{46}O_{13}S$: C, 62.65; H, 6.05; S, 4.18. Found: C, 62.40; H, 6.00; S, 4.09.

Ethyl O-*{2,3-di-O-benzoyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-β-*D*-glucopyranosyl}-(1 → 3)-2-O-acetyl-4-O-benzyl-1-thio-α-*L*-rhamnopyranoside* (**22**).—A solution of **7** (0.62 g, 1 mmol) in CH_2Cl_2 (2 mL) was added at −20°C under Ar to a solution of **17**[21] (0.41 g, 1.2 mmol) and trimethylsilyl trifluoromethanesulfonate (18 μL, 0.1 mmol) in CH_2Cl_2 (4 mL), and the mixture was stirred for 0.5 h. Workup as described for **19** afforded **22** (0.636 g, 80%) as a colorless foam; $[\alpha]_D$ + 8.9° (*c* 0.7, $CHCl_3$). Anal. Calcd for $C_{41}H_{46}O_{14}S$: C, 61.95; H, 5.83; S, 4.03. Found: C, 61.92; H, 5.79; S, 3.99.

Ethyl O-*{2,3-di-O-benzoyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-β-*D*-glucopyranosyl}-(1 → 3)-2-O-benzoyl-4-O-benzyl-1-thio-α-*L*-rhamnopyranoside* (**23**).—A solution of **7** (0.8 g, 1.3 mmol) in CH_2Cl_2 (2 mL) was added at −20°C under Ar to a solution of **18** (0.52 g, 1.3 mmol) and trimethylsilyl trifluoromethanesulfonate (23 μL, 0.13 mmol) in CH_2Cl_2 (10 mL), and the mixture was stirred for 0.5 h. Workup as described for **19** afforded **23** (1.03 g, 92%) as a colorless foam; $[\alpha]_D$ −6.6° (*c* 0.6, $CHCl_3$). Anal. Calcd for $C_{46}H_{48}O_{14}S$: C, 64.47; H, 5.65; S, 3.74. Found: C, 64.65; H, 5.67; S, 3.39.

5-[(Benzyloxycarbonyl)amino]pentyl O-*{2-O-benzoyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-3-O-methyl-β-*D*-glucopyranosyl}-(1 → 3)-2-O-benzoyl-4-O-benzyl-α-*L*-rhamnopyranoside* (**24**).—A solution of *N*-iodosuccinimide (0.27 g, 1.2 mmol) and triflic acid (11 μL, 1.2 mmol) in 1:1 CH_2Cl_2–diethyl ether (10 mL) was added at −20°C under Ar to a suspension of **21** (766.9 mg, 1 mmol), 5-[(benzyloxycarbonyl)amino]pentanol (284.8 mg, 1.2 mmol), and 3A molecular sieves (1 g) in CH_2Cl_2 (15 mL), and the mixture was stirred for 0.5 h. Workup as described for **19** afforded **24** (0.69 g, 73%) as a colorless foam; $[\alpha]_D$ −39.7° (*c* 0.3, $CHCl_3$). Anal. Calcd for $C_{51}H_{59}NO_{16}$: C, 65.03; H, 6.31; N, 1.49. Found: C, 64.89; H, 6.30; N, 1.34.

5-[(Benzyloxycarbonyl)amino]pentyl O-*{2,3-di-O-benzoyl-4,6-O-[(S)-1-methoxy-*

carbonylethylidene]-β-D-glucopyranosyl}-(1 → 3)-2-O-benzoyl-4-O-benzyl-α-L-rhamnopyranoside (**25**).—A solution of *N*-iodosuccinimide (0.27 g, 1.2 mmol) and triflic acid (11 μL, 1.2 mmol) in 1:1 CH_2Cl_2–diethyl ether 10 mL) was added at −30°C under Ar to a suspension of **23** (1 g, 1.16 mmol), 5-[(benzyloxycarbonyl)amino]pentanol (284.8 mg, 1.2 mmol), and 3A molecular sieves (1 g) in CH_2Cl_2 (15 mL), and the mixture was stirred for 0.5 h. Workup as described for **19** afforded **25** (0.89 g, 74%) as a colorless foam; $[\alpha]_D$ +8.9° (*c* 0.5, $CHCl_3$). Anal. Calcd for $C_{57}H_{61}NO_{17}$: C, 66.33; H, 5.96; N, 1.36. Found: C, 66.30; H, 5.99; N, 1.24.

5-Aminopentyl O-{4,6-O-[(S)-1-carboxyethylidene]-3-O-methyl-β-D-glucopyranosyl}-(1 → 3)-α-L-rhamnopyranoside (**26**).—A solution of **24** (571.6 mg, 0.61 mmol) and a catalytic amount of NaOMe in MeOH (15 mL) was kept at room temperature for 24 h and at 50°C for 5 h. The mixture was neutralized by addition of ion-exchange resin (Lewatit, H^+-form), filtered, and concentrated. The residue was eluted with 15:1 CH_2Cl_2–MeOH from a column of silica gel in order to remove methyl benzoate. The carbohydrate-containing fractions were concentrated and the residue (379.9 mg) was redissolved in MeOH (12 mL). After addition of 0.1 M NaOH (7 mL), the mixture was stirred at room temperature for 24 h, neutralized with ion-exchange resin (Lewatit, H^+-form), and filtered. The filtrate was treated with a catalytic amount of Pd (10% on charcoal) and H_2 at 100 kPa for 24 h, filtered, and concentrated. The residue was eluted with water from a column of Bio-Gel P2 and the carbohydrate-containing fractions were lyophilized to give **26** (231.8 mg, 77%); $[\alpha]_D$ −55.8° (*c* 0.2, H_2O). FABMS: *m/z* 494 ($M - H^+$).

5-Aminopentyl O-{4,6-O-[(S)-1-carboxyethylidene]-β-D-glucopyranosyl}-(1 → 3)-α-L-rhamnopyranoside (**27**).—Compound **25** (753.4 mg, 0.73 mmol) was treated as described for the preparation of **26**, to give **27** (311.0 mg, 88%); $[\alpha]_D$ −64.0° (*c* 0.4, H_2O). Anal. Calcd for $C_{20}H_{35}NO_{12}$: C, 49.89; H, 7.33; N, 2.91. Found: C, 49.99; H, 7.12; N, 2.71.

5-[(Benzyloxycarbonyl)amino]pentyl O-{2-O-benzoyl-4,6-O-[(S)-1-methoxycarbonylethylidene]-3-O-methyl-β-D-glucopyranosyl}-(1 → 3)-O-(2-O-benzoyl-4-O-benzyl-α-L-rhamnopyranosyl)-(1 → 2)-3,4-di-O-benzyl-6-deoxy-α-L-talopyranoside (**29**).—A solution of *N*-iodosuccinimide (123.8 mg, 0.55 mmol) and triflic acid (5 μL, 0.55 mmol) in 1:1 CH_2Cl_2–diethyl ether (5 mL) was added at −30°C under Ar to a suspension of **21** (383.4 mg, 0.5 mmol), **28**[12] (238.7 mg, 0.43 mmol), and 3A molecular sieves (1 g) in CH_2Cl_2 (10 mL), and the mixture was stirred for 0.5 h. Workup as described for **19** afforded **29** (391 mg, 72%) as a colorless foam; $[\alpha]_D$ −47.0° (*c* 0.2, $CHCl_3$). Anal. Calcd for $C_{71}H_{81}NO_{20}$: C, 67.23; H, 6.44; N, 1.10. Found: C, 67.30; H, 6.45; N, 0.94.

5-Aminopentyl O-{4,6-O-[(S)-1-carboxyethylidene]-3-O-methyl-β-D-glucopyranosyl}-(1 → 3)-O-α-L-rhamnopyranosyl-(1 → 2)-6-deoxy-α-L-talopyranoside (**30**).—Compound **29** (208.5 mg, 0.16 mmol) was treated as described for the preparation of **26**, to give **30** (61.6 mg, 59%); $[\alpha]_D$ −67.7° (*c* 0.4, H_2O). FABMS: *m/z* 640 ($M - H^+$).

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REFERENCES

1 P.J. Brennan, S.W. Hunter, M. McNeil, D. Chatterjee, and M. Daffe, in E.M. Ayoub, G.H. Cassell, W.C. Branche, and T.J. Henry (Eds.), *Microbial Determinants of Virulence and Host Response*, Am. Soc. Microbiol., Washington, DC, 1990, pp 55–75.
2 M. McNeil, D. Chatterjee, S.W. Hunter, and P. Brennan, *Methods Enzymol.*, 179 (1989) 215–242.
3 P.J. Brennan, *Rev. Infect. Dis.*, 11 (1989) 420–430 (Suppl. 2).
4 J.K. McClatchy, *Rev. Infect. Dis.*, 3 (1981) 867–870.
5 R.C. Good, *Annu. Rev. Microbiol.*, 39 (1985) 347–369.
6 W.R. Thayer, C.M. Bozic, R.T. Camphausen, and M. McNeil, *J. Clin. Microbiol.*, 28 (1990) 714–718.
7 M. McNeil, A.Y. Tsang, and P.J. Brennan, *J. Biol. Chem.*, 262 (1987) 2630–2635.
8 G.O. Aspinall, A.M. Crane, D.W. Gammon, I.H. Ibrahim, N.K. Khare, D. Chatterjee, B. Rivoire, and P.J. Brennan, *Carbohydr. Res.*, 216 (1991) 337–355.
9 G.O. Aspinall, D.W. Gammon, R.K. Sood, D. Chatterjee, B. Rivoire, and P.J. Brennan, *Carbohydr. Res.*, 237 (1992) 57–77.
10 M.K. Gurjar and G. Viswanadham, *Tetrahedron Lett.*, 32 (1991) 6191–6194.
11 H.M. Zuurmond, G.H. Veeneman, G.A. van der Marel, and J.H. van Boom, *Carbohydr. Res.*, 241 (1993) 153–164.
12 T. Ziegler, *Angew. Chem.*, 104 (1992) 1369–1371; *Angew. Chem. Int. Ed. Engl.*, 31 (1992) 1358–1360.
13 T. Ziegler and E. Eckhardt, *Tetrahedron Lett.*, 33 (1992) 6615–6618.
14 T. Ziegler, E. Eckhardt, and V. Birault, *J. Org. Chem.*, 58 (1993) 1090–1099.
15 T. Ziegler, E. Eckhardt, and G. Herold, *Liebigs Ann. Chem.*, (1992) 441–451.
16 T. Ziegler, E. Eckhardt, and G. Herold, *Tetrahedron Lett.*, 31 (1992) 4413–4416.
17 T. Ziegler, E. Eckhardt, K. Neumann, and V. Birault, *Synthesis* (1992) 1013–1017.
18 T. Ziegler, *Liebigs Ann. Chem.*, (1990) 1125–1131.
19 T. Ziegler and G. Pantkowski, *J. Carbohydr. Chem.*, 12 (1993) 357–370.
20 M.I. Dawson and P.D. Hobbs, *Carbohydr. Res.*, 85 (1980) 121–129.
21 G.H. Veeneman, S.H. van Leeuwen, H. Zuurmond, and J.H. van Boom, *J. Carbohydr. Chem.*, 9 (1990) 783–796.
22 P.J. Garegg and H. Hultberg, *Carbohydr. Res.*, 72 (1979) 276–279.
23 D.R. Bundle and S. Josephson, *Carbohydr. Res.*, 80 (1980) 75–85.
24 V. Pozsgay, *Carbohydr. Res.*, 235 (1992) 295–302.
25 F.-I. Auzanneau and D.R. Bundle, *Carbohydr. Res.*, 212 (1991) 13–24.
26 T. Ziegler, P. Kováč, and C.P.J. Glaudemans, *Liebigs Ann. Chem.*, (1990) 613–615.
27 H. Hartmann and I. Reuther, *J. Prakt. Chem.*, 315 (1973) 144–148.
28 T. Suami, Jpn. Kokai Tokkyo Koho Jp 58 49, 395 (1983); *Chem. Abstr.*, 99 (1983) P 212875h.
29 E. Fischer, M. Bergmann, and A. Rabe, *Ber.*, 53 (1920) 2362–2388.