Synthetic Studies toward Pyruvate Acetal Containing Saccharides. Synthesis of the Carbohydrate Part of the *Mycobacterium smegmatis* Pentasaccharide Glycolipid and Fragments Thereof for the Preparation of Neoantigens[1]

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A series of 2,3-di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-D-glucopyranosyl donors (β-phenylthio **3**, bromide **4**, α-chloride **5**, β-fluoride **6**, and trichloroacetimidate **7**) were prepared from the corresponding α-allyl glucoside **1** via the deallylated glucose **2** and were tested in glycosylation reactions with methanol to give the pyruvylated methyl glucosides **8** and **9** and with methyl 2,4,6-tri-*O*-benzoyl-β-D-glucopyranoside **10** to give the disaccharide **11**. Best results with respect to yield and β-selectivity of the coupling were achieved with imidate **7**. Thus, the 2-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-D-glucopyranosyl trichloroacetimidate **14** was prepared from its benzyl glucoside **12** and used for the synthesis of fragments related to the *Mycobacterium smegmatis* lipopentasaccharide. Trimethylsilyl trifluoromethanesulfonate-mediated condensation of **14**, 5-[(benzyloxycarbonyl)amino]pentanol, and **10**, respectively, followed by deblocking of the products **15** and **17** gave the pyruvylated aminopentyl glucoside **16** and methyl laminaribioside **18**. Treatment of **17** with dichloromethyl methyl ether gave the laminaribiosyl chloride **19**, coupling of which with protected 5-aminopentanol gave **20** also obtained from **14** and the monosaccharide nucleophile **26**. The trisaccharide 5-aminopentyl glycoside fragment **42** was prepared by first coupling of **14** and benzyl 2-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-α-D-glucopyranoside **30** that was converted to the bispyruvylated laminaribiose imidate **33**, followed by condensation with thioglycoside **38** obtainable in four steps from 1,2,4,6-tetra-*O*-acetyl-3-*O*-benzyl-β-D-glucopyranose to give the trisaccharide ethyl thioglycoside **40**. Next, NIS-mediated condensation of **40** and 5-[(benzyloxycarbonyl)amino]pentanol followed by deblocking gave **42**. Pentasaccharide **45** was similarly prepared from **40** and hepta-*O*-benzoyltrehalose **43** to give first the blocked saccharide **44**, deblocking of which afforded the target pentasaccharide.

Introduction

Bacteria of the genus *Mycobacterium* display an astonishing structural variety of their membrane-associated saccharides.[3,4] In particular, the great diversity of lipooligosaccharides, phenolic glycolipids, and glycopeptidolipids found among the surface antigens of these bacteria has initiated considerable synthetic efforts during the past years.[4] Furthermore, the obligatory human pathogenicity of some Mycobacteria (i.e., *M. tuberculosis* and *M. leprae*) and the appearance of atypical mycobacterioses in immunocompromised persons, especially those suffering from AIDS,[5-7] caused by otherwise less pathogenic but ubiquitous Mycobacteria (*M. avium* and *M. intracellulare*) made the synthesis of these structures very attractive. This is because cell-surface glycolipids of Mycobacteria are often species-specific immunodeterminants that are thought to be suitable for the development of synthetic vaccines.[4,8] An efficient early treatment of atypical mycobacterioses also strongly demands highly specific diagnostical tools in order to differentiate unambiguously between *Mycobacterium* species. Especially when cultivating specimen for diagnostic purposes, contamination of the culture by other environmental Mycobacteria (for example, *M. smegmatis*) must be excluded. For that purpose it is desirable that synthetic derivatives related to distinct *Mycobacterium* species are available. Here, the synthesis of the species-specific carbohydrate part of the *M. smegmatis* acidic glycolipid A and aminopentyl mono to trisaccharide fragments thereof, allowing the preparation of neoantigens, is described.

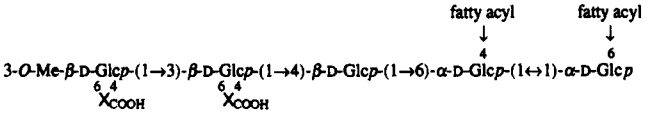

Figure 1. Structure of the acidic glycolipid A of *M. smegmatis*. The pyruvate acetals have the *S*-configuration. Fatty acyl groups are 2,4-dimethyl 2-eicosenoyl and tetra- or hexadecanoyl.

The chemical structure of the complex major α,α-trehalose-containing acidic oligosaccharide A (Figure 1) of the lipooligosaccharides isolated from *M. smegmatis* has been previously determined.[9,10] The most conspicuous

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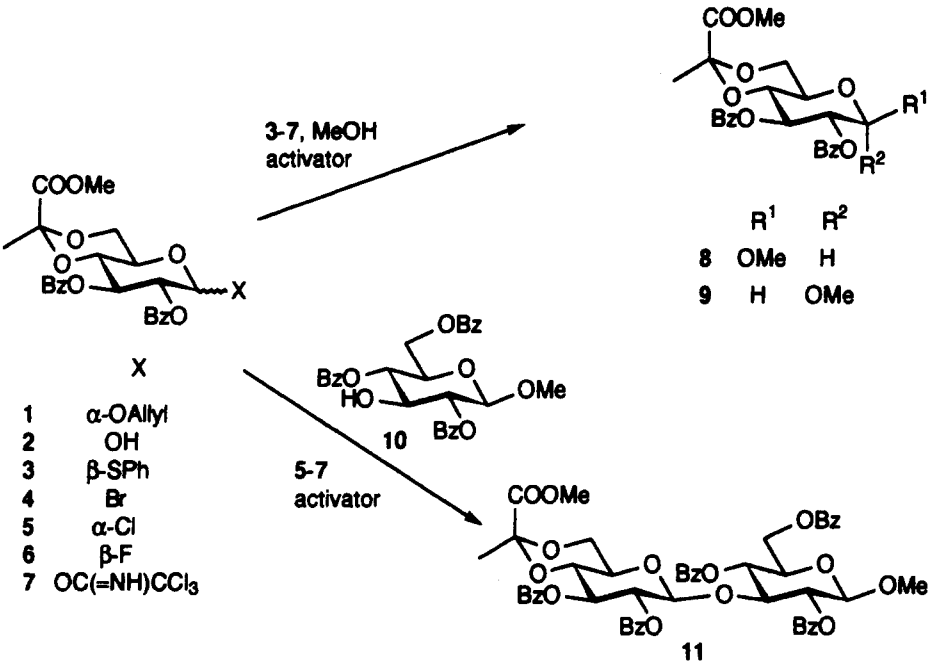
Scheme I



feature of the latter is the presence of two adjacent 4,6-*O*-((*S*)-1-carboxyethylidene) substituents at the laminaribiosyl part of the oligosaccharide. These pyruvic acid acetals are known from other bacteria to be immunodominant haptens of the carbohydrate backbone and may play an important role in infection mechanisms.[11-14] Two other acidic oligosaccharides (B_1 and B_2) also isolated from *M. smegmatis* and differing from oligosaccharide A only in the pyruvylated 3-*O*-methyl-β-D-glucosyl unit appeared to be biosynthetic precursors.[9] Similar oligosaccharides that contain two adjacent pyruvylated sugar residues are only known from *Rhizobium* species[15,16] where one of the two glycosyl units is, however, a pyruvylated D-galactosyl residue.

Results and Discussion

Previously, the synthesis of the *M. smegmatis* pentasaccharide part *without* the immunological important pyruvic acid acetals has been reported.[17] Since the stereoselective formation of the two glycosidic bonds of the 4,6-*O*-((*S*)-1-carboxyethylidene)-β-D-glucose units was expected to be most crucial in the construction of the pentasaccharide an approach was chosen here that started from pyruvylated monosaccharide building blocks and also allowed the preparation of mono to trisaccharide fragments containing a spacer-aglycon for subsequent conjugation with a protein. First, a suitable pyruvylated glucosyl donor had to be found that enabled the effective β-(1→3)-coupling to a respective pyruvylated glucosyl acceptor. This was recently achieved in a novel approach that applied pyruvylated glucosyl fluorides and TIPS-protected glucosides for the synthesis of saccharides related to *M. smegmatis*.[18] Here, a series of potential 4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-D-glucosyl donors **3–7** were first prepared as follows and tested in coupling reactions. The fully benzoylated pyruvate acetal-containing donors **3–7** were selected for these tests because of their convenient preparation and because the corresponding 3-*O*-methyl derivative, present in the naturally occurring saccharide, was expected to behave similarly. Pd-catalyzed deallylation[19] of readily prepared[20] **1** gave 4,6-pyruvylated 2,3-di-*O*-benzoyl-D-glucose **2** that was previously obtained from benzyl 2,3-di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)-ethylidene]-α-D-glucopyranoside.[21] Subsequent conver-

Table I. Reaction of the Pyruvylated Glycosyl Donors 3–7 with Methanol and Methoxytrimethylsilane To Give Methyl Glycosides 8 and 9 and with 10 To Give Dissaccharide 11

donor	acceptor	condns[a]	products	yield (%)	anomeric ratio (β:α)
3	methanol	DMTST,[b] 36 h	8 + 9	53	6:94
4	methanol	AgOTf, 4 h	8 + 9	80	81:19
5	methanol	AgOTf, 1 h	8	93	100:0
6	TMSOMe	BF_3OEt_2, 6 h	8	95	100:0
7	methanol	BF_3OEt_2, 1 h[c]	8	37	100:0
		BF_3OEt_2, 1 h[d]	8	89	100:0
5	10	AgOTf, 2 h	11	traces	
6	10[e]	BF_3OEt_2, 12 h	11	27	100:0
7	10	TMSOTf, −20 °C, 2 h[f]	11	95	100:0

[a] Unless otherwise stated, reactions were carried out at room temperature in dichloromethane. For further details, see Experimental Section. [b] Dimethyl(methylthio)sulfonium trifluoromethanesulfonate. [c] Addition of BF_3-OEt_2 to a mixture of **7** and methanol. [d] Addition of **7** to a mixture of methanol and BF_3-OEt_2. [e] The corresponding TMS ether of **10** did not react. [f] Addition of **7** to a mixture of **10** and TMSOTf.

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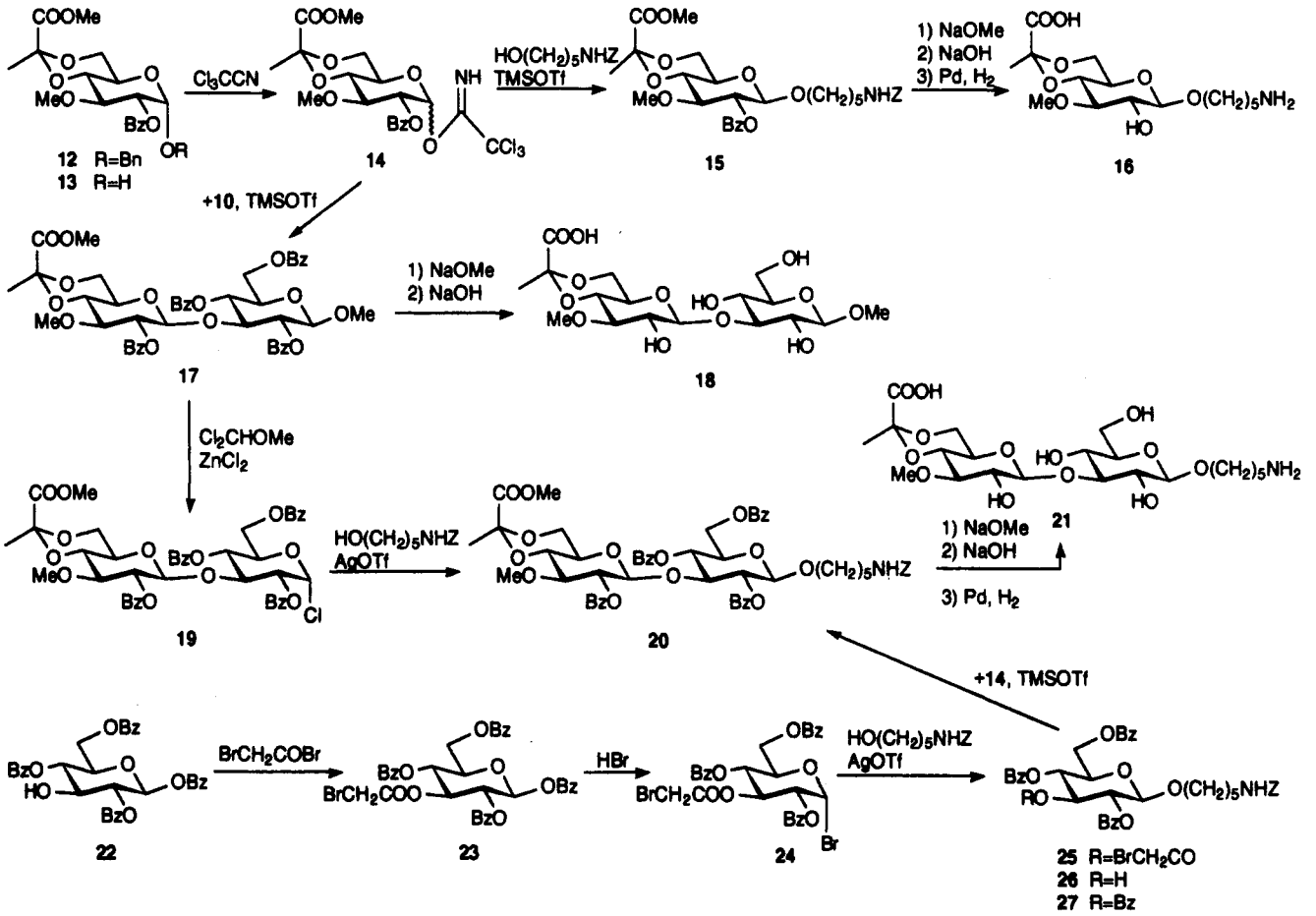
Scheme II



sion of **2** with (a) 1-chloro-*N*,*N*,2-trimethylpropenylamine[22] gave chloride **5**, (b) DAST gave the known[18] β-fluoride **6**, and (c) trichloroacetonitrile gave the known[21] imidate **7** (Scheme I). Phenyl 1-thio-D-glucoside[21] **3** was either activated by dimethyl(methylthio)sulfonium trifluoromethanesulfonate (DMTST) or converted in situ to the corresponding bromide **4** and reacted directly with silver trifluoromethanesulfonate (AgOTf) according to the previously described procedure.[23] The donor susceptibility of compounds **3**–**7** was then evaluated by reaction with methanol and methyl 2,4,6-tri-*O*-benzoyl-β-D-glucopyranoside[24] (**10**) (Table I). Surprisingly, all the donors **3**–**7** appeared to be relatively unreactive. For example, the glucosyl chloride **5**, originally planned in its 3-*O*-methyl form to be the key synthon for the construction of higher pyruvylated oligosaccharides, required under promotion by AgOTf 1 h at room temperature for complete reaction with methanol. In contrast, the corresponding pyruvylated galactosyl chloride reacted almost instantaneously under identical conditions.[21] This may be attributed to the conformally rigid skeleton of the pyruvylated glucose derivatives that resemble a *trans*-decalin system. The more flexible *cis*-decalin-like system of the pyruvylated galactosyl chloride may contrarily account for the significantly higher reactivity of the latter in glycosylation reactions. Similar results have been reported for other conformally restricted glycosyl donors.[25] The phenyl 1-thioglucoside **3** reacted with poor α/β-selectivity and a significant improvement of this situation could neither be achieved by activation with *N*-iodosuccinimide (NIS) nor by using the corresponding ethyl 1-thioglucoside[21] (no further details given). Best results with respect to yield and stereoselectivity of the coupling reaction of pyruvylated donors were obtained using the trichloroacetimidate **7** and the "inverse" addition procedure.[26] It should be also noted that TMSOTf as an activator for the latter procedure gave a shorter reaction time and a higher yield of the disaccharide methyl glycoside **11** than the previously used BF_3–etherate.[21]

For the construction of the *M. smegmatis* pentasaccharide and fragments thereof the key intermediate **14** was used. It allowed the sequential buildup of higher pyruvylated saccharide donors in an early stage of the synthesis. These oligosaccharides could then be applied either to prepare suitable ligands for protein conjugation or to the further extension of the sugar chain. This approach appeared to be more effective and flexible than the one that would introduce the pyruvylated glucosyl residues at a late stage of the synthesis (i.e., building up of the oligosaccharides beginning from the trehalose end). Starting from the pyruvylated benzyl 3-*O*-methyl-α-D-glucoside[20,27] **12** hydrogenolysis afforded first **13** that was

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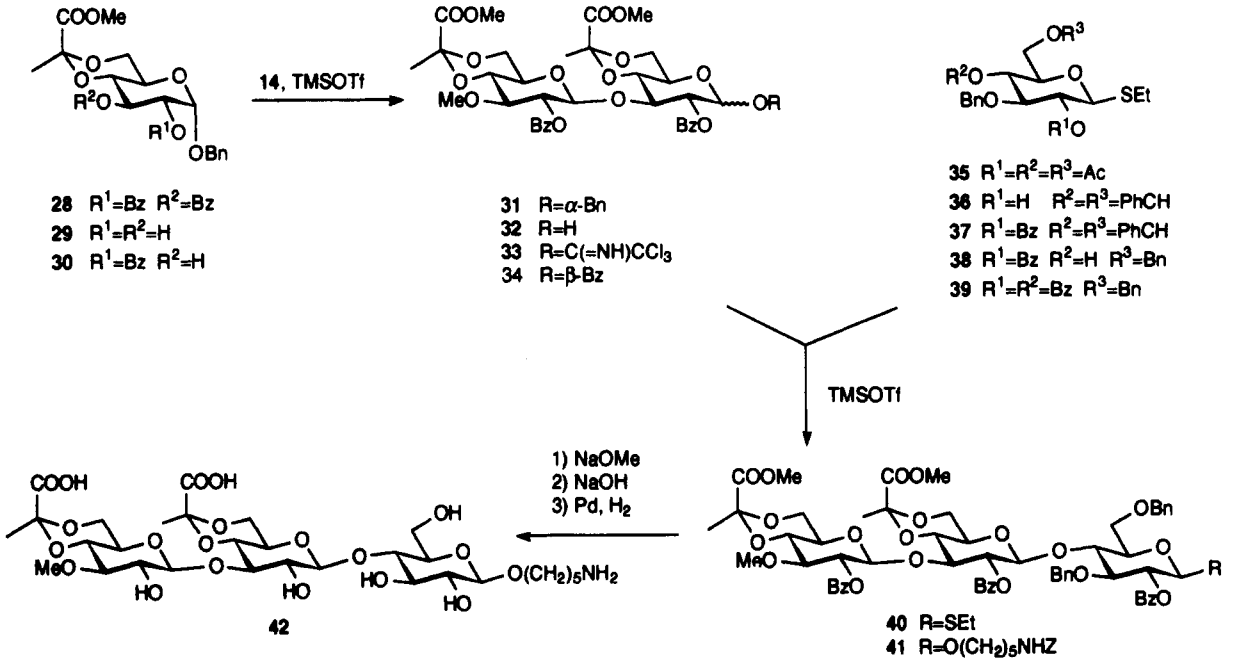
Scheme III



converted with trichloroacetonitrile to the building block **14** (Scheme II). In order to obtain the pyruvate acetal-containing monosaccharide ligand **16** that comprises not only a structural fragment of *M. smegmatis* but also of *M. avium* (serovar 8),[3,5] donor **14** was condensed with 5-[(benzyloxycarbonyl)amino]pentanol[28] to give first the blocked derivative **15** (49%). The somewhat low yield of this coupling step was due to the presence of an amide function in the nucleophile and was previously observed in similar glycosylations with [(benzyloxycarbonyl)amino]-ethanol.[29] The problem could be abolished when thioglycosides were used as donors.[30] However, as was concluded from the experiments described in Table I this was not feasible for pyruvylated thioglycosides due to their low reactivity and poor stereoselectivity in coupling reactions. Thioglycosides were thus restricted here solely to such glycosylations where nonpyruvylated residues were involved in the coupling step (see below). Next, compound **15** was sequentially deblocked by (a) removing the benzoyl residue (Zémplen), (b) saponification of the methyl ester, and (c) hydrogenation of the Cbz group affording **16** (98%).

Condensation of **14** and **10** proceeded smoothly to give exclusively the disaccharide methyl glycoside **17**, deblocking of which afforded glycoside **18**. The disaccharide aminopentyl glycoside **20** was prepared from **17** by first transforming the latter with dichloromethyl methyl ether[31] into the corresponding disaccharide chloride **19** followed by AgOTf-promoted coupling to 5-[(benzyloxycarbonyl)-amino]pentanol (Scheme II). Although the latter step afforded **20** in good yield, the conversion **17** → **19** gave only a poor yield (24%) due to extensive decomposition of the starting material. Therefore, this approach was not acceptable for preparative purposes, and an alternative strategy via the 3-*O*-unprotected aminopentyl glucoside **26** was chosen. Nucleophile **26** was prepared in four steps from the known[24,32] benzoate **22** using the bromoacetyl group for temporary protection of position 3 (Scheme II). TMSOTf-catalyzed glycosylation of compound **26** with imidate **14** then gave compound **20**, deblocking of which finally afforded the free ligand **21**.

The laminaribiosyl block **31** containing two adjacent pyruvic acid acetals and needed for the synthesis of the corresponding di- and trisaccharide fragments related to *M. smegmatis* was obtained in 92% yield by coupling of donor **14** and nucleophile **30** (Scheme III). The latter compound was available from the known[21] benzyl glucopyranoside **28** as follows. Debenzoylation of **28** afforded first the diol **29** that was selectively monobenzoylated at position 2 using in situ generated 1-(benzyloxy)benzotriazole[33] to give **30** in 89% yield. After hydrogenolytic cleavage of the benzyl aglycon of **31** to give first **32** as the α-anomer containing only traces of the β-anomer, treatment with trichloroacetonitrile afforded the complex disaccharide donor **33**, coupling of which to 5-[(benzyloxycarbonyl)amino]pentanol and subsequent deblocking has been recently described.[18] Since the condensation of both the pyruvylated trichloroacetimidates **14** and **33** with Cbz-protected aminopentanol proceeded rather unsatisfactory a strategy that used activation of a thioglycoside was chosen here for the more effective preparation of the trisaccharide fragments. As was outlined above, this was expected to be suitable because now a nonpyruvylated glucosyl residue was involved and the sluggish reactions of the imidates with the amino alcohol derivative were circumvented. Thus, acceptor **38** was constructed from **35** by conventional protective group manipulations as follows (Scheme III). It contained a benzoyl group at position 2 allowing further β-selective glycosylations and benzyl groups at positions 3 and 6 in order to compensate the notorious difficulties encountered for glycosylations of OH-4 in glucose derivatives. Starting from 1,2,4,6-tetra-

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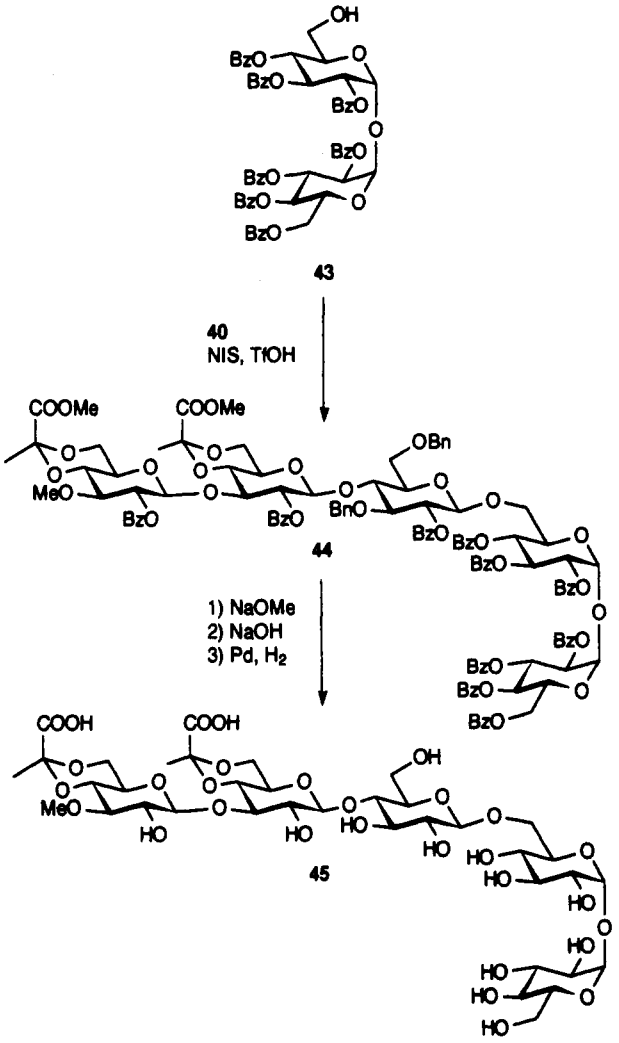
Scheme IV



O-acetyl-3-*O*-benzyl-β-D-glucose[34] treatment with ethyl mercaptan gave first the crystalline thioglucopyranoside **35**, deacetylation and benzylidenation of which afforded the crystalline compound **36**. The latter was converted to the corresponding 2-*O*-benzoate **37**, the benzylidene acetal of which was then diastereoselectively reduced with sodium cyanoborohydride[35] to give nucleophile **38**. TMSOTf-promoted coupling of **33** and **38** proceeded smoothly and gave the β-(1→4)-linked trisaccharide **40** in 71% yield. A minor faster moving byproduct, detected on TLC of the reaction mixture *prior* to the final benzoylation (see Experimental Section), was isolated and identified as the 4-*O*-benzoate **39** formed by transesterification[36] during glycosylation. The trisaccharide building block **40** was then condensed with 5-[(benzyloxycarbonyl)amino]pentanol under activation with NIS to give **41** (66%) deblocking of which afforded the free trisaccharide ligand **42**.

The trisaccharide 1-thioglycoside **40** served also for the preparation of the *M. smegmatis* related pentasaccharide **45** (Scheme IV). NIS-promoted addition of **40** to the selectively blocked α,α-trehalose **43** gave the fully blocked derivative **44** (71%). The trehalose derivative **43** was synthesized from the known[17] 2,3,4,2′,3′,4′,6′-hepta-*O*-acetyl-6-*O*-trityl-α,α-trehalose by removal of the acetyl groups, rebenzoylation, and detritylation with aqueous acetic acid. Detritylation employing iodotrimethylsilane[37] was not as effective as acetic acid due to the formation of considerable amounts of byproducts. Final sequential deblocking of **44** as described above for compound **16** then gave the target pentasaccharide **45** in 70% yield.

Conclusion

A series of benzoylated 4,6-*O*-pyruvylated D-glucosyl donors have been tested for glycosylation reactions, and it was found that the respective trichloroacetimidate **7** in combination with catalyst is by TMSOTf and inverse addition gave the highest yields of coupling products with exclusive β-selectivity. The poor reactivity of the donors was attributed to the conformally restricted skeleton. Thus, the easily obtained pyruvylated 3-*O*-methyl-D-glucosyl imidate **14** was used for the construction of the carbohydrate part of the lipopentasaccharide of *M. smegmatis* and mono to trisaccharide fragments thereof. These fragments were constructed to contain a 5-aminopentyl aglycon, the amino group of which is an excellent anchor for conjugation of the saccharides with a carrier protein[38] and thus result in neoantigens useful for immunological studies of pyruvylated saccharides[39,40] or, for example, for the attachment of fluorescence markers in order to get conjugates for histological studies. The combination of trichloroacetimidates and thioglycosides as donors proved here to be especially useful for the synthesis of the target saccharides. For the synthesis of the trisaccharide fragment **42** and the trehalose-containing pentasaccharide **45** the complex monosaccharide building block **38** was prepared. It allowed the effective glycosylation at position 4 and further β-selective coupling via thiophilic activation. Therefore, compound **38** should be useful for the synthesis of other oligosaccharides containing an internal 4-linked β-D-glucopyranosyl unit.

Experimental Section

General Methods. The general methods used in this section were essentially the same as previously described.[21] Unless otherwise stated, preparative chromatography was performed on silica gel by elution with solvent mixtures of CCl_4–acetone (20:1–5:1), NMR spectra were recorded for solutions in $CDCl_3$ for blocked derivatives and in D_2O for deblocked compounds. Assignments of NMR signals (ppm) described in this section and in Table II were made by mutual comparison of the spectra and by comparison with related compounds. *J* values are given in Hz. Sugar residues of oligosaccharides are numbered, beginning with the aglycon-bearing residue. Compounds **43**–**45** are numbered similarly, beginning with the terminal α-D-glucosyl residue of the trehalose residue. For carbon signals of oligosaccharides (Table II), the data presented in the first row of each compound refer to the first sugar residue, the data in the second to fifth row, if present, refer to the second to fifth sugar residue.

2,3-Di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-D-glucopyranose (2). A solution of compound **1**[20] (3

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Table II. ^{13}C NMR Chemical Shifts (δ)[a]

compd	C-1	C-2	C-3	C-4	C-5	C-6	C_{acetal}	Me	CO_2Me	OMe	OCH_2	NCH_2	CH_2	other subst	
5	90.9	68.8	72.1	74.4	64.8	65.1	99.6	25.1	52.7						
14 α	93.9	64.7	77.2	76.9	71.6	65.1	99.3	25.4	52.9	60.3[b]					
β	96.0	66.5	80.2	71.6	75.9	65.9	99.3	25.4	52.9	58.8[b]					
15	101.7	65.9	80.2	72.9	77.0	65.1	99.1	25.4	52.9	58.7	66.5	40.8	29.4	28.9 23.1	69.8 CH_2Ph
16	105.8	68.4	84.6	75.6	78.2	67.4	103.4	27.5		61.6	73.4	42.3	31.2	29.4 25.1	
17	101.4	73.2	78.5	70.3	72.7	63.4									56.6 OMe
	101.7	65.5	80.2	71.9	75.9	64.4	98.9	25.3	72.7	58.5					
18	106.3	71.0	87.3	76.1[b]	78.6[c]	63.6									60.2 OMe
	106.0	68.2	84.3	75.8[b]	78.3[c]	67.6	102.7	27.4		61.7					
19	90.7	73.3	77.2	70.7	68.4	62.3									
	101.8	65.6	80.1	72.7	75.9	64.3	98.9	25.3	52.7	58.5					
20	100.9	71.8	78.8	70.4	73.4	63.4					68.4	40.7	29.2	28.7 22.9	69.4 CH_2Ph
	101.5	65.5	80.2	72.8	75.9	64.3	98.8	25.2	52.9	58.5					
21	106.3	70.9	87.4	75.9[b]	78.6	63.6					73.1	42.3	31.1	29.4 25.0	
	104.9	68.5	84.4	75.8[b]	78.0	67.4	103.8	27.5		61.5					
23	92.6	70.5	73.1	68.9	74.0	62.6									24.4 CH_2Br
24	86.5	71.8	72.6	67.7	71.0	61.8									24.5 CH_2Br
25	101.1	71.6	72.1	69.5	74.1	63.0					66.5	40.8	29.4	28.9 23.9	24.5 CH_2Br 70.0 CH_2Ph
26	100.9	72.4	73.9	69.8	74.9	63.4					66.5	40.8	29.4	28.9 23.0	71.9 CH_2Ph
27	101.2	71.9	72.1	69.8	72.9	63.1					66.3	40.7	29.3	28.9 22.9	69.9 CH_2Ph
30	96.4	74.3	62.4	77.8	69.2	65.7	99.4	25.7	52.8						70.2 CH_2Ph
31	95.8	73.7[b]	77.2	74.6	62.4	66.2	99.2[c]	25.5[d]	52.8						69.9 CH_2Ph
	99.8	72.8[b]	80.4	75.9	65.8	65.2	99.1[c]	25.1[d]	52.8	58.1					
32	90.8	74.5[b]	80.4	74.0[b]	62.1	65.2	99.2[c]	25.5[d]	52.8						
	99.7	74.2[b]	76.0	65.8	72.8[b]	65.2	99.1[c]	25.1[d]	52.8	58.2					
34	90.5	73.6	77.6	75.9	71.9	65.0[b]	99.4[c]	25.5[d]	52.8						
	101.1	65.8	80.4	72.8	75.9	64.9[b]	99.1[c]	24.9[d]		58.3					
35	83.7	71.2	81.5	69.6	76.2	62.5									74.2 CH_2Ph
36	81.5[b]	73.0	81.2[b]	86.6	70.7	68.6									74.7 CH_2Ph 101.2 CHPh
37	81.7	71.9[b]	79.3	84.3	70.8[b]	68.7									74.3 CH_2Ph 101.3 CHPh
38	83.6[b]	72.3[c]	83.5[b]	78.2	72.0[c]	70.5									74.7 CH_2Ph 73.7 CH_2Ph
39	83.7	72.2	81.1	71.5	78.2	69.8									74.1 CH_2Ph 73.6 CH_2Ph
40	83.3	71.7	78.9	77.9	74.6	67.5									74.8 CH_2Ph 73.4 CH_2Ph
	99.7	65.7	80.4	73.7	76.3	65.3[b]	99.1	25.5[c]	52.8						
	100.7	65.7	81.6	72.8	75.9	64.8[b]	99.1	25.2[c]	52.8	58.1					
41	101.1	72.1[b]	77.9	76.7	74.6	67.4					66.4	40.7	29.3	28.7 23.0	74.5 CH_2Ph 73.4 CH_2Ph
	99.6	65.8[c]	80.1	73.6	74.6	65.3[d]	99.0[e]	25.5[e]	52.8[e]						69.3 CH_2Ph[f]
	100.7	65.7[c]	80.4	73.1[b]	75.9	64.7[d]	98.9[e]	25.2[e]	52.7[e]	58.1					
42	105.8	75.9	77.7[b]	81.3	77.1[b]	62.9					73.0	42.3	31.1	29.3 25.0	
	105.4	68.8[c]	82.6	76.7[b]	75.3	67.1	104.4[d]	27.5[e]							
	104.9	68.6[c]	84.2	76.7[b]	77.7[b]	67.1	104.3[d]	27.3[e]		61.0					
43	92.9[b]	70.5[c]	70.2[c]	68.7	68.4[e]	61.9									
	92.5[b]	71.4[d]	71.2[d]	68.7	69.9[e]	59.7									
44	91.7[b]	70.5[c]	70.3[c]	68.5	68.2	62.2									
	91.5[b]	71.1[d]	70.7[d]	68.8	69.1	67.2									
	101.2	72.8	77.9	76.5	75.9	66.4									74.5 CH_2Ph 73.2 CH_2Ph
	99.6	65.7	80.4[e]	73.6	74.7	65.3[e]	99.0	25.5[e]	52.8[e]						
	100.8	65.7	80.2[e]	72.8	75.9	64.7[e]	99.0	25.2[e]	52.7[e]	58.0					
45	96.2	73.9	75.4[b]	72.6	74.1	63.4									
	96.2	73.9	75.3[b]	72.2	75.1	71.1									
	105.8[c]	75.9	77.7	81.2	75.4[b]	62.8									
	105.8[c]	68.5	82.5	76.9	75.3[b]	67.3[d]	105.4[c]	27.4							
	105.4[c]	68.5	84.1	76.9	78.0	67.2[d]	105.4[c]	27.4		61.2					

[a] Spectra were taken at rt for solutions in $CDCl_3$ using tetramethylsilane as internal standard, except for compounds 16, 18, 21, 42, and 45 which were measured in D_2O with methanol as internal standard set to 49.0 ppm. [b-d] Assignment may be reversed. [e] Assignment in the same row of the respective compound may be reversed. [f] Benzyl group of the aglycon.

g, 5.8 mmol), sodium acetate (9.1 g, 110 mmol), and $PdCl_2$ (4 g, 22 mmol) in 95% aqueous acetic acid (200 mL) was stirred at 55 °C for 3 h. Allyl alcohol (8 mL) was added, and stirring was continued for an additional 0.5 h. The mixture was filtered and concentrated, and the residue was suspended in CH_2Cl_2 (500 mL), filtered, and concentrated again. Chromatography gave amorphous **2** (2.3 g, 84%), identical to the previously described substance.[21]

2,3-Di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-α-D-glucopyranosyl Chloride (5). 1-Chloro-*N*,*N*,2-trimethylpropenylamine[22] (0.31 mL, 2.2 mmol) was added to a solution of **2** (0.47 g, 1 mmol) in $CHCl_3$ (5 mL), and the mixture was stirred under reflux for 24 h and concentrated. Chromatography gave amorphous **5** (0.3 g, 61%), $[\alpha]_D$ +108° (*c* 4.4, $CHCl_3$). ^1H NMR: 6.42 (1 H, d, $J_{1,2}$ = 4.0, 1-H), 5.98 (1 H, t, $J_{2,3} = J_{3,4}$ = 9.7, 3-H), 5.32 (1 H, dd, 2-H), 4.30 (1 H, dt, $J_{4,5}$ = 9.8, $J_{5,6a}$ = 5.1, $J_{5,6b}$ = 10.4, 5-H), 4.15 (1 H, dd, $J_{6a,6b}$ = -10.6, 6a-H), 3.89 (1 H, t, 4-H), 3.83 (3 H, s, CO_2Me), 3.70 (1 H, t, 6b-H), 1.53 (3 H, s, Me).

EI-MS (20 eV, 400 K) *m*/*z*: calcd for $C_{22}H_{20}ClO_7$ ($M^+ - CO_2Me$) 431.0898, found 431.0899.

2,3-Di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-β-D-glucopyranosyl Fluoride (6). DAST (0.48 g, 3 mmol) was added under Ar at -30 °C to a stirred solution of **2** (1.21 g, 2.6 mmol) in THF (100 mL), and the mixture was gradually warmed to rt during 1 h. The yellow solution was cooled to -30 °C, methanol (1 mL) was added, and stirring was continued for 0.5 h. Concentration and chromatography gave material that was crystallized from acetone/*n*-hexane to give **6** (0.95 g, 76%), identical to the previously described substance.[18]

Anal. Calcd for $C_{24}H_{23}FO_9$ (479.48): C, 60.12; H, 5.89. Found: C, 59.92; H, 5.92.

Methyl 2,3-Di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-β- (8) and -α-D-glucopyranoside (9). (a) DMTST[41] (0.49 g, 1.9 mmol) was added at rt to a mixture of **3** (214 mg, 0.38 mmol), methanol (13 μL, 0.32 mmol), and 3-Å molecular sieves (0.2 g) in CH_2Cl_2 (4 mL), and the mixture was stirred for 36 h, diluted with CH_2Cl_2, and washed with aqueous $NaHCO_3$ solution. Concentration and filtration of the residue over a short column of silica gel gave a 6:94 mixture (^1H NMR) of **8** and **9** (92.6 mg, 53%), identical to the previously described substances.[21]

(b) A mixture of **3** (113 mg, 0.2 mmol), methanol (0.5 mL), 4-Å molecular sieves (0.5 g), 2,4,6-trimethylpyridine (24 μL, 0.18 mmol), and AgOTf (129 mg, 0.5 mmol) in CH_2Cl_2 (10 mL) was stirred at rt for 0.5 h. A solution of Br_2 (0.84 M) in CH_2Cl_2 (240 μL, 0.2 mmol) was added, and stirring at rt was continued for 6 h. The mixture was filtered, washed successively with aqueous $NaHCO_3$ and $Na_2S_2O_3$ solution, and concentrated. Chromatography gave first **9** (15 mg, 16%).

Eluted next was **8** (62.5 mg, 64%).

(c) A mixture of **5** (98.2 mg, 0.2 mmol), methanol (0.5 mL), 3-Å molecular sieves (0.2 g), and 2,4,6-trimethylpyridine (24 μL, 0.18 mmol) was stirred at rt for 0.5 h. AgOTf (129 mg, 0.5 mmol) was added, and stirring was continued for 1 h. Workup as described for (b) gave **8** (90 mg, 93%).

(d) BF_3–etherate (12.5 μL, 0.1 mmol) was added to a solution of **6** (41.9 mg, 0.09 mmol) and methoxytrimethylsilane (27 μL, 0.2 mmol) in CH_2Cl_2 (2 mL), the mixture was stirred at rt for 6 h, washed with aqueous $NaHCO_3$ solution, and concentrated. Chromatography gave **8** (40.2 mg, 95%).

(e) BF_3–etherate (12.5 μL, 0.1 mmol) was added to a solution of **7** (123.4 mg, 0.2 mmol) and methanol (0.5 mL) in CH_2Cl_2 (2 mL), and the mixture was stirred under Ar at rt for 1 h. Workup as described for d gave **8** (36 mg, 37%).

(f) A solution of **7** (123.4 mg, 0.2 mmol) in CH_2Cl_2 (1 mL) was added under Ar at rt to a solution of methanol (0.5 mL) and BF_3–etherate (12.5 μL, 0.1 mmol) in CH_2Cl_2 (1 mL), and the mixture was stirred for 1 h. Workup as described for d gave **8** (87.5 mg, 89%).

Methyl *O*-[2,3-Di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-β-D-glucopyranosyl]-(1→3)-2,4,6-tri-*O*-benzoyl-β-D-glucopyranoside (11). (a) AgOTf (128.5 mg, 0.5 mmol) was added at rt to a mixture of **5** (98.2 mg, 0.2 mmol), **10** (125 mg, 0.3 mmol), 2,4,6-trimethylpyridine (13 μL, 0.1 mmol), and 3-Å molecular sieves (0.1 g) in CH_2Cl_2 (5 mL), and the mixture was stirred for 3 h. Workup as described for compound **8** (b) gave **11** (<5 mg), identical to the previously described substance.[21]

(b) BF_3–etherate (0.63 mL, 5 mmol) was added under Ar to a solution of **6** (486 mg, 0.98 mmol), **10** (506 mg, 1 mmol), and triethylamine (140 μL, 1 mmol) in CH_2Cl_2 (15 mL), and the solution was stirred for 1 h. Workup as described for compound **8** (d) gave **11** (258.5 mg, 27%).

(c) A solution of **7** (0.2 g, 0.37 mmol) in CH_2Cl_2 (2 mL) was added at −20 °C under Ar to a solution of **10** (202 mg, 0.4 mmol) and TMSOTf (18 μL, 0.1 mmol) in CH_2Cl_2 (10 mL), and the solution was stirred for additional 2 h. Workup as described for compound **8** (d) gave **11** (336.4 mg, 95%).

2-*O*-Benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-D-glucopyranose (13). A suspension of **12**[20,27] (2.71 g, 5.73 mmol) and 10% Pd on charcoal (1 g) in acetic acid (50 mL) was treated with H_2 (101 kPa) at rt for 16 h, filtered through a layer of Celite, and concentrated. Chromatography gave **13** (2.19 g, 98%) as a crystalline α/β-mixture, identical to the previously described substance.[18]

Anal. Calcd for $C_{18}H_{22}O_9$ (382.36): C, 56.54; H, 5.80. Found: C, 56.39; H, 5.69.

2-*O*-Benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-D-glucopyranosyl Trichloroacetimidate (14). A mixture of **13** (1 g, 2.6 mmol), trichloroacetonitrile (0.62 mL, 3.6 mmol), and Na_2CO_3 (1.06 g, 10 mmol) in CH_2Cl_2 (5 mL) was stirred at rt for 16 h, filtered, and concentrated. Chromatography gave **14** (1.33 g, 99%) as an amorphous 1:1.7 α/β-mixture (^1H NMR), $[\alpha]_D$ +45° (*c* 0.5, $CHCl_3$). ^1H NMR: 6.53 (1 H, d, $J_{1,2}$ = 3.8, 1-Hα), 6.03 (1 H, d, $J_{1,2}$ = 7.5, 1-Hβ), 5.48 (1 H, t, $J_{2,3}$ = 7.5, 2-Hβ), 5.27 (1 H, dd, $J_{2,3}$ = 9.6, 2-Hα), 4.19 (1 H, dd, $J_{5,6a}$ = 5.7, $J_{6a,6b}$ = −10.3, 6a-Hβ), 4.10 (1 H, dd, $J_{5,6a}$ = 5.9, $J_{6a,6b}$ = −10.3, 6a-Hα), 3.98 (1 H, dd, $J_{5,6b}$ = 4.9, 6b-Hα), 3.97 (1 H, t, $J_{3,4}$ = 9.4, 3-Hα), 3.82–3.64 (6 H, m, 3-Hβ, 4-H, 5-H, 6b-Hβ), 3.87 (3 H, s, α-CO_2Me), 3.85 (3 H, s, β-CO_2Me), 3.61 (3 H, s, α-OMe), 3.56 (3 H, s, β-CO_2Me), 1.60 (3 H, s, α-Me), 1.58 (3 H, s, β-OMe).

Anal. Calcd for $C_{20}H_{22}Cl_3NO_9$ (528.73): C, 45.43; H, 4.19; N, 2.64; Cl, 20.12. Found: C, 45.47; H, 4.23; N, 2.66; Cl, 20.38.

5-[(Benzyloxycarbonyl)amino]pentyl 2-*O*-Benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-D-glucopyranoside (15). A solution of **14** (257 mg, 0.5 mmol) in CH_2Cl_2 (1 mL) was added under Ar at −20 °C to a solution of 5-[(benzyloxycarbonyl)amino]pentanol[28] (237 mg, 1 mmol) and TMSOTf (18 μL, 0.1 mmol) in CH_2Cl_2 (7 mL), and stirring was continued for 1 h. Workup as described for compound **8** (d) gave amorphous **15** (142.1 mg, 48%), $[\alpha]_D$ −0.5° (*c* 0.2, $CHCl_3$). ^1H NMR: 5.61 (2 H, bs, OCH_2Ph), 5.17 (1 H, bdt, $J_{1,2}$ = 7.8, $J_{2,3}$ = 9.0, 2-H), 4.56 (1 H, d, 1-H), 3.84 (3 H, s, CO_2Me), 4.11 (1 H, dd, $J_{5,6a}$ = 5.0, $J_{6a,6b}$ = −10.8, 6a-H), 3.84–3.78 (1, H, m, $J_{3,4}$ = 10.7, 4-H), 3.75 (1 H, bt, 3-H), 3.61 (1 H, dd, OCH_2^a), 3.52 (3 H, s, OMe), 3.46–3.37 (2 H, m, OCH_2^b, 6b-H), 2.90 (2 H, bdd, NCH_2), 1.57 (3 H, s, Me), 1.51–1.43 (2 H, m, CH_2), 1.30–1.15 (4 H, m, 2 CH_2).

EI-MS (70 eV, 400 K) *m/z*: calcd for $C_{29}H_{36}NO_9$ (M^+ − COOMe) 542.2390, found 542.2388.

5-Aminopentyl 4,6-*O*-((*S*)-1-Carboxyethylidene)-3-*O*-methyl-D-glucopyranoside (16). A solution of compound **15** (110.5 mg, 0.18 mmol) in methanol (10 mL) was treated with a catalytic amount of NaOMe at rt for 24 h. The solution was neutralized with ion-exchange resin (H^+), and concentrated BzOMe was removed by heating the residue at 60 °C for 24 h in vacuo. The residue was redissolved in 1:1 H_2O–methanol (10 mL) and treated with 1 M aqueous NaOH solution (1 mL) at rt for 24 h. The solution was neutralized as above and hydrogenolyzed in the presence of a catalytic amount of 10% Pd on charcoal. The mixture was filtered and concentrated, and the residue was eluted with H_2O from a column packed with Bio Gel P2. Carbohydrate-containing fractions were pooled and lyophilized to give amorphous **16** (55.9 mg, 81%), $[\alpha]_D$ −6.0° (*c* 0.25, H_2O).

Anal. Calcd for $C_{15}H_{27}NO_8 \cdot 2H_2O$ (385.41): C, 46.75; H, 8.10; N, 3.63. Found: C, 46.36; H, 8.02; N, 3.65.

Methyl *O*-[2,3-Di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-β-D-glucopyranosyl]-(1→3)-2,4,6-tri-*O*-benzoyl-β-D-glucopyranoside (17). A solution of **14** (0.8 g, 1.55 mmol) in CH_2Cl_2 (5 mL) was added at −20 °C under Ar to a solution of **10** (0.66 g, 1.3 mmol) and TMSOTf (180 μL, 1 mmol) in CH_2Cl_2 (15 mL), and the solution was stirred for an additional 2 h. Workup as described for compound **8** (d) gave amorphous **17** (792.5 mg, 70%), $[\alpha]_D$ +14.0° (*c* 0.3, $CHCl_3$). ^1H NMR: 5.35 (1 H, t, $J_{3,4}$ = 8.8, $J_{4,5}$ = 9.2, 4^1-H), 5.22 (1 H, dd, $J_{1,2}$ = 7.7, $J_{2,3}$ = 8.8, 2^1-H), 4.99 (1 H, dd, $J_{1,2}$ = 7.7, $J_{2,3}$ = 8.7, 2^2-H), 4.71 (1 H, d, 1^2-H), 4.60 (1 H, dd, $J_{5,6a}$ = 3.4, $J_{6a,6b}$ = −12.1, $6a^1$-H), 4.52 (1 H, d, 1^1-H), 4.40 (1 H, dd, $J_{5,6b}$ = 5.2, $6b^1$-H), 4.34 (1 H, t, 3^1-H), 4.09 (1 H, ddd, 5^1-H), 3.73 (3 H, s, CO_2Me), 3.63 (1 H, dd, $J_{5,6a}$ = 4.5, $J_{6a,6b}$ = −11.0, $6a^2$-H), 3.38–3.20 (2 H, m, $J_{3,4}$ = 9.0, 4^2, $6b^2$-H), 3.36 (3 H, s, OMe), 3.32 (3 H, s, OMe), 3.20–3.12 (1 H, m, 5^2-H), 1.26 (3 H, s, Me).

Anal. Calcd for $C_{46}H_{46}O_{17}$ (870.86): C, 63.44; H, 5.32. Found: C, 63.97; H, 5.31.

Methyl *O*-[4,6-*O*-((*S*)-1-Carboxyethylidene)-3-*O*-methyl-β-D-glucopyranosyl]-(1→3)-β-D-glucopyranoside (18). A solution of **17** (169.3 mg, 0.194 mmol) in methanol (10 mL) was treated with a catalytic amount of NaOMe as described for compound **16**. The residue (153.8 mg) was suspended in H_2O (~10 mL) and washed three times with Et_2O. The aqueous layer was concentrated and treated with 1 M aqueous NaOH solution (1.5 mL) at rt for 24 h, neutralized with ion-exchange resin (H^+), and concentrated. The residue was eluted with H_2O from a column of Bio Gel P2. Carbohydrate-containing fractions were pooled and lyophilized to give amorphous **18** (81 mg, 95%), as an extremely hygroscopic solid, $[\alpha]_D$ −17.5° (*c* 0.2, H_2O).

O-[2,3-Di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-β-D-glucopyranosyl]-(1→3)-2,4,6-tri-*O*-benzoyl-β-D-glucopyranosyl Chloride (19). A catalytic amount of $ZnCl_2$ was added to a solution of **17** (0.4 g, 0.46 mmol) and dichloromethyl methyl ether (3 mL) in $CHCl_3$ (2 mL), and the

(41) Ravenscroft, M.; Roberts, R. M. G.; Tilleft, J. G. *J. Chem. Soc., Perkin Trans. 1* **1982**, 1569–1572.

mixture was stirred at 70 °C for 3 h and concentrated. Chromatography gave amorphous **19** (96.7 mg, 24%), $[\alpha]_D$ +66.4° (*c* 0.3, $CHCl_3$). ^1H NMR: 6.38 (1 H, d, $J_{1,2}$ = 4.0, 1^1-H), 5.48 (1 H, t, $J_{3,4}$ = 9.6, $J_{4,5}$ = 9.8, 4^1-H), 5.12 (1 H, dd, $J_{2,3}$ = 9.7, 2^1-H), 5.02 (1 H, dd, $J_{1,2}$ = 7.8, $J_{2,3}$ = 8.9, 2^2-H), 4.82 (1 H, d, 1^2-H), 4.65–4.47 (2 H, m, $J_{5,6b}$ = 4.7, $J_{6a,6b}$ = −12.5, 5^1,$6a^1$-H), 4.59 (1 H, t, 3^1-H), 4.38 (1 H, dd, $6b^1$-H), 3.76–3.64 (2 H, m, 4^2,$6a^2$-H), 3.74 (3 H, s, CO_2Me), 3.44 (1 H, t, $J_{3,4}$ = 8.9, 3^2-H), 3.35 (3 H, s, OMe), 3.32–3.21 (2 H, m, 5^2,$6b^2$-H), 1.47 (3 H, s, Me).

Anal. Calcd for $C_{45}H_{43}ClO_{16}$ (875.28): C, 61.75; H, 4.95. Found: C, 61.31; H, 5.03.

5-[(Benzyloxycarbonyl)amino]pentyl *O*-[2,3-Di-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-β-D-glucopyranosyl]-(1→3)-2,4,6-tri-*O*-benzoyl-β-D-glucopyranoside (20). (a) AgOTf (52 mg, 0.2 mmol) was added to a suspension of **19** (78.8 mg, 0.09 mmol), 5-[(benzyloxycarbonyl)amino]pentanol (35.6 mg, 0.15 mmol), and 3-Å molecular sieves (0.1 g) in CH_2Cl_2 (5 mL), and the mixture was stirred at rt for 15 min. Workup as described for compound **8** (b) gave amorphous **20** (63.1 mg, 65%), $[\alpha]_D$ +9.2° (*c* 0.6, $CHCl_3$). ^1H NMR (significant peaks): 5.36 (1 H, t, $J_{3,4}$ = $J_{4,5}$ = 9.6), 5.23 (1 H, dd, $J_{1,2}$ = 7.4, $J_{2,3}$ = 9.5, 2^1-H), 5.06 (2 H, bs, OCH_2Ph), 5.00 (1 H, dd, $J_{1,2}$ = 7.1, $J_{2,3}$ = 9.0, 2^2-H), 4.69 (1 H, d, 1^1-H), 4.58 (1 H, d, 1^2-H), 3.72 (3 H, s, CO_2Me), 3.33 (3 H, s, OMe), 1.50 (3 H, s, Me).

Anal. Calcd for $C_{58}H_{61}NO_{19}$ (1076.11): C, 64.74; H, 5.71; N, 1.30. Found: C, 64.58; H, 5.86; N, 1.24.

(b) A solution of **14** (0.43 g, 0.6 mmol) in CH_2Cl_2 (10 mL) was added at −20 °C under Ar to a solution of **25** (0.31 g, 0.6 mmol, see below) and TMSOTf (11 μL, 0.06 mmol) in CH_2Cl_2 (3 mL), and the solution was stirred for additional 1 h. Pyridine (1 mL) and benzoyl chloride (0.5 mL) were added, and the mixture was stirred at rt for 16 h, washed with aqueous $NaHCO_3$ solution, and concentrated. Chromatography gave first amorphous **27** (0.24 g, 49%), $[\alpha]_D$ +11.4° (*c* 1.6, $CHCl_3$). ^1H NMR: 5.95 (1 H, t, $J_{3,4}$ = $J_{4,5}$ = 9.6, 4-H), 5.72 (1 H, t, $J_{2,3}$ = 9.7, 3-H), 5.56 (1 H, dd, $J_{1,2}$ = 7.8, 2-H), 5.06 (2 H, bs, CH_2OPh), 4.85 (1 H, d, 1-H), 4.67 (1 H, dd, $J_{5,6a}$ = 3.2, $J_{6a,6b}$ = −12.3, 6a-H), 4.52 (1 H, dd, $J_{5,6b}$ = 5.0, 6b-H), 4.16 (1 H, ddd, 5-H), 3.91 (1 H, dt, OCH_2^a), 3.51 (1 H, dt, OCH_2^b), 2.93 (2 H, bdd, NCH_2), 1.58–1.50 (2 H, m, CH_2), 1.31–1.21 (4 H, m, 2 CH_2).

Anal. Calcd for $C_{47}H_{45}NO_{12}$ (815.87): C, 69.19; H, 5.56; N, 1.72. Found: C, 69.42; H, 5.70; N, 1.76.

Eluted next was **20** (0.29 g, 46%).

5-Aminopentyl *O*-[4,6-*O*-((*S*)-1-Carboxyethylidene)-3-*O*-methyl-β-D-glucopyranosyl]-(1→3)-β-D-glucopyranoside (21). Deblocking of **20** (120 mg, 0.11 mmol) as described for compound **16** gave amorphous **21** (50.2 mg, 89%), $[\alpha]_D$ −24.0° (*c* 1.9, H_2O).

Anal. Calcd for $C_{21}H_{37}NO_{13}\cdot 2H_2O$ (547.55): C, 46.07; H, 7.55; N, 2.56. Found: C, 45.56; H, 7.43; N, 2.44.

1,2,4,6-Tetra-*O*-benzoyl-3-*O*-(bromoacetyl)-β-D-glucopyranose (23). Bromoacetyl bromide (2.22 g, 11 mmol) was added at 0 °C to a solution of **22**[24,32] (5.37 g, 9 mmol) and 2,4,6-trimethylpyridine (1.45 g, 12 mmol) in CH_2Cl_2 (100 mL), and the mixture was stirred at rt for 3 h, washed successively with aqueous HCl and $NaHCO_3$ solution, and concentrated. The residue was crystallized from acetone/*n*-hexane to give **23** (5.17 g, 80%), mp 195–198 °C (softening at 185 °C), $[\alpha]_D$ −3.1° (*c* 0.5, $CHCl_3$). ^1H NMR: 6.22 (1 H, d, $J_{1,2}$ = 7.7, 1-H), 6.20 (1 H, dd, $J_{2,3}$ = 9.9, 2-H), 5.83 (1 H, t, $J_{3,4}$ = $J_{4,5}$ = 9.3, 4-H), 5.75 (1 H, t, 3-H), 4.63 (1 H, dd, $J_{5,6a}$ = 3.9, $J_{6a,6b}$ = −12.3, 6a-H), 4.47 (1 H, dd, $J_{5,6b}$ = 4.6, 6b-H), 4.37–4.30 (1 H, m, 5-H), 3.62 (2 H, s, CH_2Br).

Anal. Calcd for $C_{36}H_{29}BrO_{11}$ (717.526): C, 60.26; H, 4.07. Found: C, 60.53; H, 4.05.

2,4,6-Tri-*O*-benzoyl-3-*O*-(bromoacetyl)-β-D-glucopyranosyl Bromide (24). A mixture of **23** (4.17 g, 5.8 mmol) and 30% HBr in acetic acid (60 mL) in CH_2Cl_2 (60 mL) was kept at rt for 1 h, poured on crushed ice, and extracted with CH_2Cl_2. The organic layers were washed with aqueous $NaHCO_3$ solution and concentrated. Chromatography gave amorphous **24** (3.16 g, 81%), $[\alpha]_D$ +121.8° (*c* 1.1, $CHCl_3$). ^1H NMR: 6.82 (1 H, d, $J_{1,2}$ = 4.0, 1-H), 6.03 (1 H, t, $J_{2,3}$ = 10.0, $J_{3,4}$ = 9.8, 3-H), 5.70 (1 H, t, $J_{4,5}$ = 9.7, 4-H), 5.23 (1 H, dd, 2-H), 5.09–4.61 (2 H, m, $J_{5,6b}$ = 4.9, $J_{6a,6b}$ = −12.9, 5,6a-H), 4.47 (1 H, dd, 6b-H), 3.63 (2 H, s, CH_2Br).

Anal. Calcd for $C_{29}H_{24}Br_2O_9$ (676.32): C, 51.5; H, 3.58; Br, 23.63. Found: C, 51.24; H, 3.62; Br, 24.16.

5-[(Benzyloxycarbonyl)amino]pentyl 2,4,6-Tri-*O*-benzoyl-3-*O*-(bromoacetyl)-β-D-glucopyranoside (25). A solution of **24** (2.77 g, 4 mmol) in CH_2Cl_2 (5 mL) was added at 0 °C to a suspension of 5-[(benzyloxycarbonyl)amino]pentanol (1.07 g, 4.5 mmol), 2,4,6-trimethylpyridine (0.42 g, 3.5 mmol), AgOTf (1.29 g, 5 mmol), and 3-Å molecular sieves (0.5 g) and stirred at 0 °C for 10 min. Workup as described for compound **8** (b) and chromatography gave amorphous **25** (2.81 g, 83%), $[\alpha]_D$ +4.1° (*c* 0.5, $CHCl_3$). ^1H NMR: 5.68 (1 H, t, $J_{3,4}$ = 9.7, $J_{4,5}$ = 9.5, 4-H), 5.56 (1 H, t, $J_{2,3}$ = 9.5, 3-H), 5.39 (1 H, dd, $J_{1,2}$ = 7.8, 2-H), 5.08 (2 H, bs, OCH_2Ph), 4.74 (1 H, d, 1-H), 4.61 (1 H, dd, $J_{5,6a}$ = 3.3, $J_{6a,6b}$ = −12.1, 6a-H), 4.46 (1 H, dd, $J_{5,6b}$ = 5.1, 6b-H), 4.06 (1 H, ddd, 5-H), 3.59 (2 H, s, CH_2Br), 3.49 (1 H, dt, OCH_2^a), 3.39 (1 H, dt, OCH_2^b), 2.93 (2 H, bdd, NCH_2), 1.55–1.50 (2 H, m, CH_2), 1.48–1.18 (4 H, m, 2 CH_2).

Anal. Calcd for $C_{42}H_{42}BrNO_{12}$ (832.70): C, 60.58; H, 5.08; N, 1.68; Br, 9.60. Found: C, 60.52; H, 5.06; N, 1.48; Br, 9.62.

5-[(Benzyloxycarbonyl)amino]pentyl 2,4,6-Tri-*O*-benzoyl-β-D-glucopyranoside (26). A solution of **25** (2 g, 2.4 mmol) and thiourea (0.38 g, 5 mmol) in 1:1 CH_2Cl_2–methanol (40 mL) was stirred at rt for 3 h, washed with aqueous $NaHCO_3$ solution, and concentrated. Chromatography and crystallization from acetone/*n*-hexane gave **26** (1.50 g, 88%), mp 144 °C $[\alpha]_D$ −17.7° (*c* 0.2, $CHCl_3$). ^1H NMR: 5.40 (1 H, t, $J_{3,4}$ = 9.3, $J_{4,5}$ = 9.5, 4-H), 5.21 (1 H, dd, $J_{1,2}$ = 7.8, $J_{2,3}$ = 9.3, 2-H), 5.06 (2 H, bs, OCH_2Ph), 4.69 (1 H, d, 1-H), 4.64 (1 H, dd, $J_{5,6a}$ = 3.0, $J_{6a,6b}$ = −12.1, 6a-H), 4.44 (1 H, dd, $J_{5,6b}$ = 5.4, 6b-H), 4.11 (1 H, dt, $J_{3,OH}$ = 6.0, 3-H), 4.02 (1 H, ddd, 5-H), 3.88 (1 H, dt, OCH_2^a), 3.49 (1 H, dt, OCH_2^b), 3.02 (1 H, d, OH), 2.94 (2 H, bdt, NCH_2), 1.56–1.48 (2 H, m, CH_2), 1.35–1.22 (4 H, m, 2 CH_2).

Anal. Calcd for $C_{40}H_{41}NO_{11}$ (711.76): C, 67.50; H, 5.81; N, 1.97. Found: C, 67.38; H, 5.78; N, 1.88.

Benzyl 4,6-*O*-[(*S*)-1-(Methoxycarbonyl)ethylidene]-α-D-glucopyranoside (29). A solution of **28**[21] (1.62 g, 2.9 mmol) in 2:1 methanol–toluene (30 mL) was treated with a catalytic amount of NaOMe at rt for 24 h, and the mixture was neutralized with ion-exchange resin (H^+) and concentrated. Chromatography (CH_2Cl_2–methanol (20:1)) gave amorphous **29** (0.87 g, 85%), identical to the previously described substance.[18]

Anal. Calcd for $C_{17}H_{22}O_8$ (354.36): C, 57.62; H, 6.26. Found: C, 57.38; H, 6.22.

Benzyl 2-*O*-Benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-α-D-glucopyranoside (30). Compound **29** (1.75 g, 4.9 mmol) was monobenzoylated with freshly prepared 1-(benzyloxy)benzotriazole according to the procedure described previously[33] to give amorphous **30** (2 g, 89%), $[\alpha]_D$ +115.8° (*c* 0.4, $CHCl_3$). ^1H NMR: 5.17 (1 H, d, $J_{1,2}$ = 3.8, 1-H), 5.00 (1 H, dd, $J_{2,3}$ = 9.6, 2-H), 4.72, 4.90 (2 H, 2 d, J = −12.3, OCH_2Ph), 4.32 (1 H, bt, $J_{3,4}$ = 9.4, 3-H), 4.02 (1 H, dd, $J_{5,6a}$ = 4.9, $J_{6a,6b}$ = −10.2, 6a-H), 3.94–3.86 (1 H, m, $J_{5,6b}$ = 10.3, 5-H), 3.84 (3 H, s, CO_2Me), 3.69 (1 H, t, 6b-H), 3.47 (1 H, t, $J_{4,5}$ = 9.4, 4-H), 2.68 (1 H, bs, OH), 1.58 (3 H, s, Me).

Anal. Calcd for $C_{24}H_{26}O_9$ (458.46): C, 62.88; H, 5.72. Found: C, 63.20; H, 5.84.

Benzyl *O*-[2-*O*-Benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-β-D-glucopyranosyl]-(1→3)-2-*O*-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-α-D-glucopyranoside (31). A solution of **14** (1.52 g, 2.9 mmol) in CH_2Cl_2 (5 mL) was added at −20 °C under Ar to a solution of **30** (3 g, 3 mmol) and TMSOTf (54 μL, 0.3 mmol) in CH_2Cl_2 (20 mL), and the solution was stirred for 2 h. Pyridine (4 mL) and benzoyl chloride (2 mL) were added, and the mixture was stirred at rt for 16 h, washed with aqueous $NaHCO_3$ solution, and concentrated. Chromatography gave amorphous **31** (2.2 g, 92%), $[\alpha]_D$ +70.7° (*c* 0.9, $CHCl_3$). ^1H NMR: 5.16 (1 H, d, $J_{1,2}$ = 7.5, 1^2-H), 5.09 (1 H, d, $J_{1,2}$ = 3.9, 1^1-H), 5.08 (1 H, bdd, $J_{2,3}$ = 9.6, 2^2-H), 4.92 (1 H, $J_{2,3}$ = 9.8, 2^1-H), 4.63, 4.40 (2 H, 2 d, J = −12.2, OCH_2-Ph), 4.35 (1 H, t, $J_{3,4}$ = 9.5, 3^1-H), 4.15 (1 H, dd, $J_{5,6a}$ = 4.9, $J_{6a,6b}$ = −11.0, $6a^1$-H), 3.96 (1 H, dd, $J_{5,6a}$ = 4.8, $J_{6a,6b}$ = −10.2, $6a^2$-H), 3.91–3.80 (1 H, m, $6b^1$-H), 3.86 (3 H, s, CO_2Me), 3.82 (3 H, s, CO_2Me), 3.76–3.67 (1 H, m, 5^1-H), 3.63 (1 H, t, $J_{4,5}$ = 9.2, 4^1-H), 3.50 (2 H, 2 t, $J_{3,4}$ = 9.0, $J_{4,5}$ = 9.5, 3^2,4^2-H), 3.44–3.38 (1 H, m, 5^2-H), 3.41 (3 H, s, OMe), 1.55 (3 H, s, Me), 1.46 (3 H, s, Me).

Anal. Calcd for $C_{42}H_{46}O_{17}$ (822.81): C, 61.31; H, 5.63. Found: C, 61.17; H, 5.68.

O-[2-O-Benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-3-O-methyl-β-D-glucopyranosyl]-(1→3)-2-O-benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-α-D-glucopyranose (32). A suspension of **31** (2 g, 2.4 mmol), 10% Pd on charcoal (50 mg), and acetic acid (10 mL) in ethyl acetate (100 mL) was treated with H_2 (101 kPa) at rt for 3 d, filtered through a layer of Celite, and concentrated. Chromatography gave amorphous **32** (1.3 g, 74%), $[\alpha]_D$ +57.8° (*c* 0.3, $CHCl_3$). ^1H NMR (significant peaks of the α-anomer): 5.42 (1 H, bt, $J_{1,2}$ = 3.7, 1^1-H), 5.14 (1 H, dd, $J_{1,2}$ = 7.3, $J_{2,3}$ = 7.8, 2^2-H), 5.06 (1 H, d, 1^2-H), 4.92 (1 H, dd, $J_{2,3}$ = 9.8, 2^1-H), 4.36 (1 H, t, $J_{3,4}$ = 9.6, 3^2-H), 4.32 (1 H, t, $J_{3,4}$ = 9.6, 3^1-H), 3.84 (3 H, s, CO_2Me), 3.80 (3 H, s, CO_2Me), 3.41 (3 H, s, OMe), 1.54 (3 H, s, Me), 1.43 (3 H, s, Me).

Anal. Calcd for $C_{35}H_{40}O_{17}$ (732.69): C, 57.38; H, 5.50. Found: C, 57.32; H, 5.29.

O-[2-O-Benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-3-O-methyl-β-D-glucopyranosyl]-(1→3)-2-O-benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-D-glucopyranose Trichloroacetimidate (33). A mixture of **32** (1.23 g, 1.68 mmol), trichloroacetonitrile (1 mL, 5.4 mmol), and K_2CO_3 (1.5 g, 10.85 mmol) in CH_2Cl_2 (20 mL) was stirred at rt for 5 h, filtered, and concentrated. Chromatography gave amorphous **33** (1.32 g, 90%) identical to the previously described substance.[18]

Anal. Calcd for $C_{37}H_{40}Cl_3NO_{17}$ (877.08): C, 50.67; H, 4.60; N, 1.60; Cl, 12.13. Found: C, 50.42; H, 4.62; N, 1.59; Cl, 12.00.

Ethyl 2,4,6-Tri-O-acetyl-3-O-benzyl-1-thio-β-D-glucopyranoside (35). A solution of 1,2,4,6-tetra-*O*-acetyl-3-*O*-benzyl-β-D-glucopyranose[34] (2.93 g, 6.7 mmol), ethyl mercaptan (0.43 g, 7 mmol), and BF_3–etherate (0.99 g, 7 mmol) in CH_2Cl_2 (20 mL) was stirred at rt for 2 h, washed with aqueous $NaHCO_3$ solution, and concentrated. Crystallization of the residue from acetone/*n*-hexane gave **35** (2.94 g, 100%), mp 88–90 °C, $[\alpha]_D$ −33.2° (*c* 0.2, $CHCl_3$). ^1H NMR: 5.11 (1 H, t, $J_{3,4}$ = 9.3, $J_{4,5}$ = 9.7, 4-H), 5.08 (1 H, dd, $J_{1,2}$ = 10.0, $J_{2,3}$ = 9.3, 2-H), 4.64, 4.58 (2 H, 2 d, J = −11.7, OCH_2Ph), 4.40 (1 H, d, 1-H), 4.20 (1 H, dd, $J_{5,6a}$ = 5.1, $J_{6a,6b}$ = −12.4, 6a-H), 4.10 (1 H, dd, $J_{5,6b}$ = 2.6, 6b-H), 3.71 (1 H, t, 3-H), 3.61 (1 H, ddd, 5-H).

Anal. Calcd for $C_{21}H_{28}O_8S$ (440.51): C, 57.26; H, 6.41; S, 7.28. Found: C, 57.27; H, 6.44; S, 7.63.

Ethyl 3-O-Benzyl-4,6-O-benzylidene-1-thio-β-D-glucopyranoside (36). Compound **35** (2 g, 4.5 mmol) in methanol (40 mL) was deblocked as described for compound **28**. The glasslike residue (1.42 g) was dissolved in benzaldehyde (10 mL), $ZnCl_2$ (3 g) was added, and the mixture was stirred at rt for 3 h until a clear solution was obtained. H_2O (50 mL) and *n*-hexane (100 mL) were added with stirring to the solution, and the crystalline material thus formed was isolated by filtration. Recrystallization from acetone/*n*-hexane gave **36** (1.6 g, 88%), mp 139 °C, $[\alpha]_D$ −46.2° (*c* 0.3, $CHCl_3$). ^1H NMR: 5.58 (1 H, s, PhCH), 4.97, 4.81 (2 H, 2 d, J = −11.7, OCH_2Ph), 4.46 (1 H, d, $J_{1,2}$ = 9.5, 1-H), 4.35 (1 H, dd, $J_{5,6a}$ = 4.9, $J_{6a,6b}$ = −10.3, 6a-H), 3.82–3.36 (5 H, m, 2,3,4,5,6b-H), 2.54 (1 H, bs, OH).

Anal. Calcd for $C_{22}H_{26}O_5S$ (402.51): C, 65.65; H, 6.51; S, 7.97. Found: C, 65.46; H, 6.50; S, 7.83.

Ethyl 2-O-Benzoyl-3-O-benzyl-4,6-O-benzylidene-1-thio-β-D-glucopyranoside (37). Benzoyl chloride (10 mL, 86 mmol) was added at 0 °C to a solution of **36** (0.82 g, 2 mmol) in pyridine (30 mL), and the mixture was stirred at rt for 1 h. H_2O (5 mL) was added at 0 °C followed by CH_2Cl_2 (100 mL), and the solution was washed with aqueous HCl and $NaHCO_3$ solution and concentrated. The residue was crystallized from acetone/*n*-hexane to give **37** (0.96 g, 95%), mp 127 °C, $[\alpha]_D$ −50.0° (*c* 0.1, $CHCl_3$). ^1H NMR: 5.61 (1 H, s, CHPh), 5.34 (1 H, dd, $J_{1,2}$ = 10.0, $J_{2,3}$ = 8.6, 2-H), 4.83, 4.69 (2 H, 2 d, J = −11.9, OCH_2Ph), 4.62 (1 H, d, 1-H), 4.40 (1 H, dd, $J_{5,6a}$ = 5.0, $J_{6a,6b}$ = −10.5, 6a-H), 3.90 (1 H, t, $J_{3,4}$ = 8.6, 3-H), 3.88–3.78 (2 H, m, 4,6b-H), 3.60–3.47 (1 H, m, 5-H).

Anal. Calcd for $C_{29}H_{30}O_6S$ (506.62): C, 68.75; H, 5.97; S, 6.33. Found: C, 68.56; H, 5.95; S, 6.58.

Ethyl 2-O-Benzoyl-3,6-di-O-benzyl-1-thio-β-D-glucopyranoside (38). A solution of HCl in diethyl ether was added in portions at rt to a stirred solution of **37** (1.3 g, 2.6 mmol) and $NaCNBH_3$ (1.45 g, 23 mmol) in THF (20 mL) until the evolution of H_2 stopped. Workup as described[35] and chromatography gave amorphous **39** (1.25 g, 95%), $[\alpha]_D$ −2.3° (*c* 0.4, $CHCl_3$). ^1H NMR: 5.57 (1 H, dt, $J_{4,5}$ = 9.4, $J_{5,6a}$ = $J_{5,6b}$ = 4.5, 5-H), 5.28 (1 H, dd, $J_{1,2}$ = 10.0, $J_{2,3}$ = 8.9, 2-H), 4.74, 4.67 (2 H, 2 d, J = −11.5, 3-OCH_2-Ph), 4.63, 4.55 (2 H, 2 d, J = −12.0, 6-OCH_2Ph), 4.55 (1 H, d, 1-H), 3.86–3.78 (3 H, m, 4,6a,6b-H), 3.69 (1 H, t, $J_{3,4}$ = 8.8, 3-H), 2.84 (1 H, bs, OH).

Anal. Calcd for $C_{29}H_{32}O_6S$ (508.63): C, 68.48; H, 6.34; S, 6.30. Found: C, 68.72; H, 6.36; S, 6.15.

O-[2-O-Benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-3-O-methyl-β-D-glucopyranosyl]-(1→3)-1,2-di-O-benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-β-D-glucopyranose (34), Ethyl 2,4-Di-O-benzoyl-3,6-di-O-benzyl-1-thio-β-D-glucopyranoside (39), and Ethyl O-[2-O-Benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-3-O-methyl-β-D-glucopyranosyl]-(1→3)-O-[2-O-benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-β-D-glucopyranosyl]-(1→4)-2-O-benzoyl-3,6-di-O-benzyl-1-thio-β-D-glucopyranoside (40). A solution of **33** (0.61 g, 0.7 mmol) in CH_2Cl_2 (5 mL) was added under Ar at −20 °C to a solution of **38** (0.51 g, 1 mmol) and TMSOTf (18 μL, 0.1 μmol) in CH_2Cl_2 (5 mL). The mixture was stirred for 1 h at −20 °C, whereupon TLC revealed the formation of a faster moving byproduct. Pyridine (5 mL) and benzoyl chloride (1 mL) were added, and stirring was continued at rt for 16 h. Workup as described for compound **20** (b) gave first **39** (0.14 g, 23% relative to **38**), mp (*n*-hexane) 84 °C, $[\alpha]_D$ +19.4° (*c* 0.2, $CHCl_3$). ^1H NMR: 5.45–5.37 (2 H, m, 2,4-H), 4.65 (1 H, d, $J_{1,2}$ = 10.0, 1-H), 4.60–4.45 (4 H, m, $2OCH_2Ph$), 4.04 (1 H, t, $J_{2,3}$ = $J_{3,4}$ = 9.2, 3-H), 3.84 (1 H, dt, $J_{4,5}$ = 9.1, $J_{5,6a}$ = $J_{5,6b}$ = 4.6, 5-H), 3.66 (2 H, bd, 6a,6b-H).

Anal. Calcd for $C_{36}H_{36}O_7S$ (612.74): C, 70.57; H, 5.92; S, 5.23. Found: C, 70.53; H, 5.88; S, 5.40.

Eluted next was amorphous **34** (57.8 mg, 10%), $[\alpha]_D$ +38.0° (*c* 0.1, $CHCl_3$). ^1H NMR (significant peaks): 6.53 (1 H, d, $J_{1,2}$ = 3.8, 1^1-H), 5.31 (1 H, dd, $J_{2,3}$ = 9.9, 2^1-H), 4.50 (1 H, d, $J_{1,2}$ = 7.2, 1^2-H), 4.46 (1 H, t, $J_{3,4}$ = 9.7, 3-H), 3.82 (3 H, s, CO_2Me), 3.81 (3 H, s, CO_2Me), 3.44 (3 H, s OMe), 1.55 (3 H, s, Me), 1.40 (3 H, s, Me).

Anal. Calcd for $C_{42}H_{44}O_{18}$ (836.80): C, 60.28; H, 5.30. Found: C, 60.02; H, 5.53.

Eluted next was amorphous **40** (0.61 g, 71%), $[\alpha]_D$ +31.7° (*c* 0.2, $CHCl_3$). ^1H NMR (significant peaks): 5.05 (1 H, d, $J_{1,2}$ = 7.8, 1^2-H), 4.90 (1 H, d, $J_{1,2}$ = 7.1, 1^3-H), 4.73, 4.52 (2 H, 2 d, J = −11.2, OCH_2Ph), 4.61, 4.27 (4 H, J = −11.7, OCH_2Ph), 4.59 (1 H, d, $J_{1,2}$ = 8.3, 1^1-H), 3.83 (3 H, s, CO_2Me), 3.82 (3 H, s, CO_2Me), 3.38 (3 H, s, OMe), 1.54 (3 H, s, Me), 1.46 (3 H, s, Me).

Anal. Calcd for $C_{64}H_{70}O_{22}S$ (1223.31): C, 62.84; H, 5.77. Found: C, 62.63; H, 5.74.

5-[(Benzyloxycarbonyl)amino]pentyl O-[2-O-Benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-3-O-methyl-β-D-glucopyranosyl]-(1→3)-O-[2-benzoyl-4,6-O-[(S)-1-(methoxycarbonyl)ethylidene]-β-D-glucopyranosyl]-(1→4)-2-O-benzoyl-3,6-di-O-benzyl-β-D-glucopyranoside (41). A solution of NIS (50 mg, 0.22 mmol) and trifluoromethanesulfonic acid (2 μL, 0.023 μmol) in 1:1 CH_2Cl_2–diethyl ether (2.5 mL) was added under Ar at −40 °C to a solution of **40** (0.23 g, 0.19 mmol), 5-[(benzyloxycarbonyl)amino]pentanol (52.2 mg, 0.22 mmol), and 4-Å molecular sieves (0.25 g) in CH_2Cl_2 (5 mL), and the mixture was stirred at −30 °C for 1.5 h. Workup as described for compound **8** (b) gave amorphous **41** (0.17 g, 66%), $[\alpha]_D$ −7.5° (*c* 0.2, $CHCl_3$). ^1H NMR (significant peaks): 5.04 (2 H, bs, OCH_2Ph), 4.90 (1 H, d, $J_{1,2}$ = 7.1, 1^2-H), 4.71, 4.53 (2 H, 2 d, J = −11.3, OCH_2Ph), 4.60, 4.25 (2 H, 2 d, J = −12.3, OCH_2Ph), 4.58 (1 H, d, $J_{1,2}$ = 7.0, 1^3-H), 4.27 (1 H, d, $J_{1,2}$ = 7.0, 1^1-H), 3.82 (3 H, s, CO_2Me), 3.81 (3 H, s, CO_2Me), 3.38 (3 H, s, OMe), 1.54 (3 H, s, Me), 1.46 (3 H, s, Me).

Anal. Calcd for $C_{75}H_{85}NO_{24}$ (1384.49): C, 65.07; H, 6.19; N, 1.01. Found: C, 64.18; H, 6.02; N, 0.94.

5-Aminopentyl O-[4,6-O-((S)-1-Carboxyethylidene)-3-O-methyl-β-D-glucopyranosyl]-(1→3)-O-[4,6-O-((S)-1-carboxyethylidene)-β-D-glucopyranosyl]-(1→4)-β-D-glucopyranoside (42). Deblocking of **41** (0.15 mg, 0.11 mmol) as described for compound **16** gave amorphous **42** (51.3 mg, 64%), $[\alpha]_D$ −75.7° (*c* 0.1, H_2O). FABMS *m/z*: 744 $(M + H)^+$.

O-(2,3,4-Tri-O-benzoyl-α-D-glucopyranosyl)-(1→1)-2,3,4,6-tetra-O-benzoyl-α-D-glucopyranoside (43). A catalytic amount of NaOMe was added to a solution of 2,3,4,2′,3′,4′,6′-hepta-*O*-acetyl-6-*O*-trityl-α,α-trehalose[17] (1 g, 1.2 mmol) in methanol (30 mL), and the mixture was stirred at rt for 24 h and concentrated. The residue was dissolved in pyridine (10 mL), benzoyl chloride

(2.5 mL) was added, and the mixture was stirred at rt for 12 h. Workup as described for compound **37** gave material that was dissolved in 90% aqueous acetic acid (50 mL) and stirred at 70 °C for 2 h. Concentration of the solution and chromatography gave amorphous **43** (0.97 g, 78%), $[\alpha]_D$ +208.3° (*c* 0.4, $CHCl_3$). ^1H NMR: 6.35, 6.31 (2 H, 2 t, $J_{3,4}$ = 9.8, 10.0, $J_{4,5}$ = 10.0, 10.1, 4^1,4^2-H), 5.76, 5.74 (2 H, 2 d, $J_{1,2}$ = 3.4, 3.3, 1^1,1^2-H), 5.69, 5.50 (2 H, 2 t, $J_{2,3}$ = 9.8, 10.0, 3^1,3^2-H), 5.49, 5.44 (2 H, 2 dd, 2^1,2^2-H), 4.33 (1 H, ddd, $J_{5,6a}$ = 2.7, $J_{5,6b}$ = 4.3, 5^1-H), 3.99 (1 H, dd, $J_{6a,6b}$ = −12.5, $6a^1$-H), 3.92–3.85 (2 H, m, 5^2,$6b^1$-H), 3.21 (1 H, dd, $J_{5,6a}$ = 1.8, $J_{6a,6b}$ = −13.8, $6a^2$-H), 2.99 (1 H, dd, $J_{5,6b}$ = 2.5, $6b^2$-H), 2.34 (1 H, bs, OH).

Anal. Calcd for $C_{61}H_{50}O_{18}$ (1071.05): C, 68.41; H, 4.71. Found: C, 68.19; H, 4.76.

***O*-[2-*O*-Benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-3-*O*-methyl-β-D-glucopyranosyl]-(1→3)-*O*-[2-benzoyl-4,6-*O*-[(*S*)-1-(methoxycarbonyl)ethylidene]-β-D-glucopyranosyl]-(1→4)-*O*-(2-*O*-benzoyl-3,6-di-*O*-benzyl-β-D-glucopyranosyl)-(1→6)-*O*-(2,3,4-tri-*O*-benzoyl-α-D-glucopyranosyl)-(1→1)-2,3,4,6-tetra-*O*-benzoyl-α-D-glucopyranose (44).** A solution of NIS (45 mg, 0.2 mmol) and trifluoromethanesulfonic acid (1.8 μL, 0.02 μmol) in 1:1 CH_2Cl_2–diethyl ether (2 mL) was added under Ar at −30 °C to a solution of **40** (0.2 g, 0.16 mmol), **43** (0.21 g, 0.2 mmol), and 4-Å molecular sieves (0.25 g) in CH_2Cl_2 (5 mL), and the mixture was stirred at −30 °C for 0.5 h. Workup as described for compound **8** (b) gave amorphous **44** (0.26 g, 71%), $[\alpha]_D$ +110.2° (*c* 0.5, $CHCl_3$). ^1H NMR (significant peaks): 6.14 (1 H, t, $J_{3,4}$ = $J_{4,5}$ = 9.8, 4^1-H), 6.12 (1 H, t, $J_{3,4}$ = $J_{4,5}$ = 9.8, 4^2-H), 5.54 (1 H, t, $J_{2,3}$ = 9.9, 3^1-H), 5.47 (1 H, d, $J_{1,2}$ = 4.0, 1^1-H), 5.45 (1 H, d, $J_{1,2}$ = 4.0, 1^2-H), 5.32 (1 H, dd, 2^1-H), 5.31 (1 H, t, $J_{2,3}$ = 10.0, 3^2-H), 5.17, (1 H, dd, 2^2-H), 5.04–5.16 (3 H, m, 2^3,2^4,5^2-H), 4.89 (1 H, d, $J_{1,2}$ = 7.1, 1^4-H), 4.69, 4.54 (2 H, 2 d, J = −11.1, OCH_2Ph), 4.53 (1 H, d, $J_{1,2}$ = 7.3, 1^5-H), 4.49, 4.18 (2 H, 2 d, J = −12.4, OCH_2Ph), 4.19 (1 H, d, $J_{1,2}$ = 7.3, 1^3-H), 3.83 (3 H, s, CO_2Me), 3.81 (3 H, s, CO_2Me), 3.38 (3 H, s, OMe), 1.54 (3 H, s, Me), 1.45 (3 H, s, Me).

Anal. Calcd for $C_{123}H_{114}O_{40}$ (2232.23): C, 66.18; H, 5.15. Found: C, 65.97; H, 5.22.

***O*-[4,6-*O*-((*S*)-1-Carboxyethylidene)-3-*O*-methyl-β-D-glucopyranosyl]-(1→3)-*O*-[4,6-*O*-((*S*)-1-carboxyethylidene)-β-D-glucopyranosyl]-(1→4)-*O*-β-D-glucopyranosyl-(1→6)-*O*-α-D-glucopyranosyl-(1→1)-α-D-glucopyranose (45).** Deblocking of **44** (0.21 g, 0.09 mmol) as described for compound **16** gave amorphous **45** (69.2 mg, 70%) as a hygroscopic solid, $[\alpha]_D$ +31.4° (*c* 0.2, H_2O).

Anal. Calcd for $C_{37}H_{58}O_{30}\cdot 7H_2O$ (1108.95): C, 40.07; H, 6.57. Found: C, 40.10; H, 6.23.

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