Synthesis of a derivative of a pentasaccharide repeating unit of the O-antigenic polysaccharide of the bacterium *Klebsiella pneumoniae* O3 as a benzoylated 2-methoxycarbonylethyl thioglycoside*

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Block synthesis of a fully benzoylated derivative of the pentasaccharide α-D-Man*p*-(1→3)-α-D-Man*p*-(1→2)-α-D-Man*p*-(1→2)-α-D-Man*p*-(1→2)-α-D-Man*p*-$SCH_2CH_2CO_2Me$, the glycoside of the repeating unit of the O-antigenic polysaccharide of the bacterium *Klebsiella pneumoniae* O3, was performed.

Key words: pentasaccharide, mannooligosaccharides, repeating unit of the O-antigenic polysaccharide of the bacterium *Klebsiella pneumoniae* O3, block synthesis, NMR spectroscopy.

Covalent bonding of mono- or oligosaccharide fragments of natural high-molecular-weight carbohydrates to natural or synthetic polymers is a popular method for the synthesis of neoglycoconjugates that combine specific biological activity of the carbohydrate component and high molecular weight of the carrier.[1] If immobilization is to be performed for a synthetic oligosaccharide, it is desirable to use its glycoside containing a certain function, for example, a carboxy group, in the aglycone.

Oligosaccharide glycosides of 9-hydroxynonanoic acid (as the methyl ester) have become popular.[2] The conjugates were prepared by converting the ester to hydrazide and then to reactive acyl azide, which was employed to acylate free amino groups of a protein. Glycosides of lower and higher homologs of this spacer (4-hydroxy-C_4-, 7-hydroxy-C_7-, 12-hydroxy-C_{12}-, 15-hydroxy-C_{15}-acid,[3] 6-hydroxy-C_6-acid[4]) and its heteroatomic analogs, esters of 10-hydroxy-5,8-dioxadecanoic, 9-hydroxy-6-oxo-7-azanonanoic, 8-hydroxy-3,6-dioxaoctanoic, and 6-hydroxy-4-thiahexanoic acid,[3—7] were also synthesized. The latter were obtained by the reaction of 2-bromoethyl glycosides with methyl 3-mercaptopropionate. Glycosylation of the proper 3-mercaptopropionic acid with fully acetylated mono- and disaccharides in the presence of Lewis acids gave the corresponding thioglycosides,[8,9] which were used as thioglycoside donors for the construction of neoglycopeptides using automated solid-phase peptide synthesis[10,11] and glycodendrimers with the polypropyleneimine core and peripheral galactose sulfate residues.[12] An attractive feature of *S*-glycosides is their higher hydrolytic stability compared to *O*-glycosides in a living organism. However, no data on the possible use of 3-mercaptopropionic acid glycosides as glycosyl acceptors have been reported.

Here we describe the synthesis of a derivative of linear mannopentaoside having the structure of the repeating unit of the O-antigenic polysaccharide of *Klebsiella pneumoniae* O3 as the *S*-glycoside of 3-mercaptopropionic acid for its subsequent transformation to neoglycoconjugates.

Lipopolysaccharide of the bacterium *K. pneumoniae* O3 (see Ref. 13) is an effective adjuvant (compound that enhance the immune response of the organism to antigens). The O-specific polysaccharide of this lipopolysaccharide responsible for the adjuvant effect is a linear regular α-D-mannan composed of pentasaccharide repeating units with the 1→2 and 1→3 linkages.[14] The same structure is inherent in O-antigenic polysaccharides of *Escherichia coli* O9 (see Ref. 15) and *Hafnia alvei* PCM 1223 (see Ref. 16); as regards the adjuvant action, the lipopolysaccharide from *E. coli* O9 is comparable with the *Klebsiella* O3 lipopolysaccharide (see Ref. 17).

The synthesis of the repeating unit of the O-antigenic polysaccharide of *K. pneumoniae* O3 as a reducing pentasaccharide (**A**) was reported in the literature.[18]

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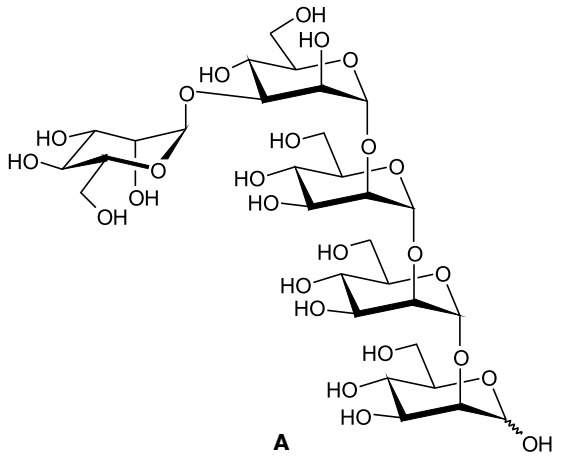


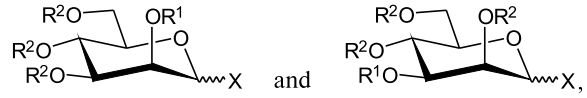
A

This synthesis was based on the use of partly O-benzylated derivatives of mono- and oligosaccharides as glycosyl donors and glycosyl acceptors; the final synthetic stage is the removal of *O*-benzyl protecting groups by catalytic hydrogenolysis. This is inapplicable to thioglycosides, hence, the route to pentasaccharide derivative that we propose should not include hydrogenolysis. Hence, other protecting groups for monosaccharides should be used.

A number of publications describe the targeted preparation of linear and branched oligomannosides, mainly as methyl and allyl glycosides (see, for example, a review[19]). Recently,[20] oligomannosides with an aglycone containing a free amino group were synthesized; they were effectively converted to conjugates with bovine serum albumin.

Retrosynthetic analysis of the target pentasaccharide derivative suggests the following synthetic route: stepwise construction of the 1→2-linked trisaccharide and 1→3-linked disaccharide and their coupling (Scheme 1).

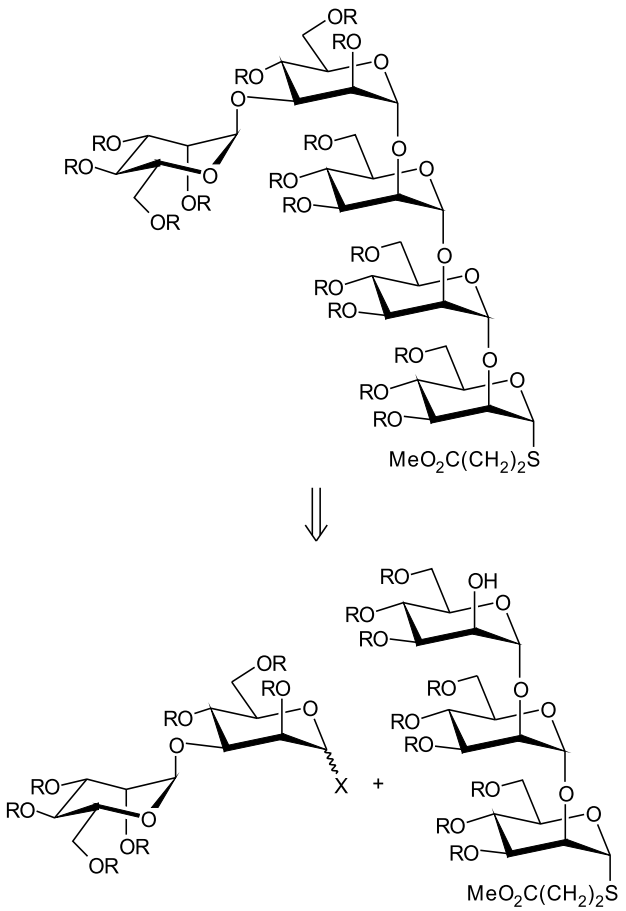
The presence of 1→2 and 1→3 intermonomer bonds in the pentasaccharide molecule allows the use of two types of building blocks for the synthesis



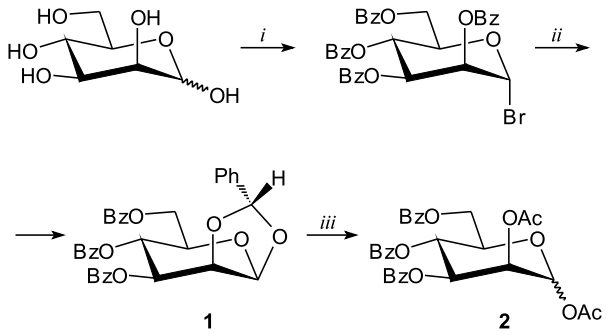
where R^1 is a "temporary" protecting group at O(2) or O(3), R^2 is a "permanent" protecting group, and X is a leaving group of the glycosyl donor or an aglycone in the glycosyl acceptor. Since the *O*-acetyl protecting group in carbohydrates can selectively be removed in the presence of *O*-benzoyl groups by mild acid methanolysis,[21] we decided to use this combination of protecting groups for the assembly of oligosaccharide structures.

Thus a possible precursor of the 2-substituted mannose residue in oligosaccharides is 1,2-di-*O*-acetyl-3,4,6-tri-*O*-benzoyl-D-mannopyranose, which is easily obtained from D-mannose (Scheme 2).

Scheme 1



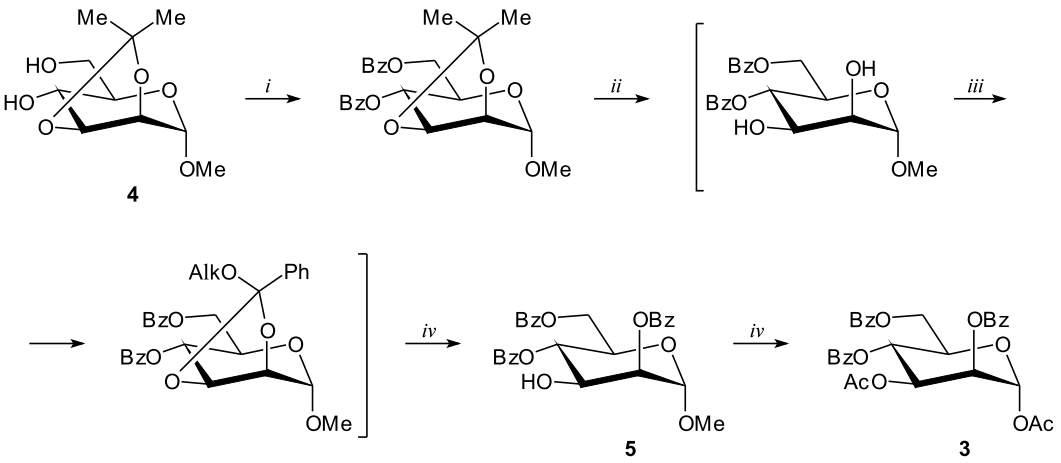
Scheme 2



Reagents: *i*. 1) BzCl, pyridine; 2) HBr/AcOH; *ii*. $NaBH_4$/MeCN; *iii*. 1) 90% CF_3CO_2H; 2) Ac_2O, pyridine.

The key step of this route, namely, the conversion of readily accessible per-*O*-benzoyl-α-D-mannopyranosyl bromide to 1,2-*O*-benzylidene derivative by treatment with sodium borohydride in acetonitrile at room temperature, *i.e.*, under conditions described previously,[22] or on heat-

Scheme 3



Reagents: *i*. BzCl, pyridine; *ii*. 80% AcOH, reflux; *iii*. $PhC(OAlk)_3$ (Alk = Me or Et), TsOH, MeCN; *iv*. 90% CF_3CO_2H; *v*. Ac_2O—AcOH, H_2SO_4.

ing,[23] smoothly gave crystalline benzylidene derivative **1** in high yield. The structure of this previously unknown compound followed unambiguously from ^1H and ^{13}C NMR spectra. A comparison of the chemical shifts of the acetal H atoms in the ^1H NMR spectra of compound **1** (δ_H 6.03), 3,4-di-*O*-acetyl-1,2-*O*-[(*R*)-benzylidene]-β-L-rhamnopyranose (δ_H 5.91),[22] and 3,4-di-*O*-acetyl-1,2-*O*-[(*S*)-benzylidene]-β-L-rhamnopyranose (δ_H 6.36)[22] provides the conclusion of (*S*)-configuration of the new chiral center, *i.e.*, the *exo*-position of the acetal H atom. Data from the difference 1D ROESY spectrum confirm this conclusion: pre-irradiation of the proton signal at δ_H 6.03 (acetal H atom) induces enhancement of the proton signal at δ_H 4.74 (H(2)). Judging by the spin—spin coupling constants of the ring H atoms, the pyranose ring has the $^4C_1$-conformation.

Acid hydrolysis of acetal **1** and acetylation of 1,2-diol thus formed (Ac_2O in pyridine) gave the target diacetate **2** as an anomeric mixture (~2.5 : 1, ^1H and ^{13}C NMR data). The major component is the α-anomer, as the signals of its C(3) and C(5) atoms are located in the higher field than the signals of the same atoms of the minor β-anomer *(cf.* Ref. 24). The spin—spin coupling constants of the vicinal H atoms of compound **2** (and other mono- and oligosaccharide derivatives) have standard values: H(1) resonates as a broadened singlet or doublet with $J_{1,2} \approx 2$ Hz, the H(2) atom resonates as a broadened singlet or broadened doublet, H(3) forms a doublet of doublets with $J_{2,3} \approx 3$, $J_{3,4} \approx 10$ Hz, and H(4) is a triplet with $J_{4,3} = J_{4,5} \approx 10$ Hz.

The α-anomer of the same compound was reported.[25] It was synthesized by a longer route that comprised the preparation of D-mannopyranose pentaacetate, its conversion to glycosyl bromide and then to 1,2-*O*-ethylidene derivative by a known procedure,[22] saponification of the *O*-acetyl groups, O-benzoylation, acid-induced deacetalation, and O-acetylation of 1,2-diol.

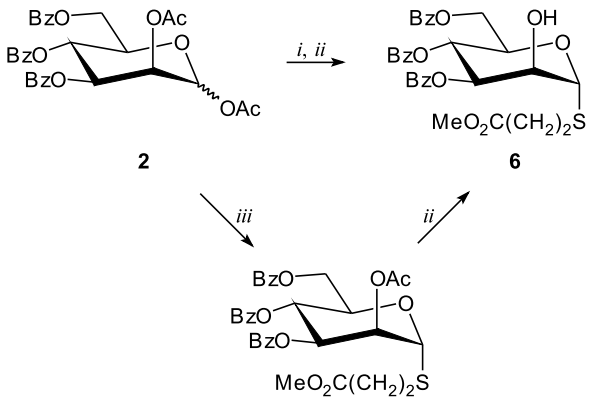
It was decided to use isomeric 1,3-di-*O*-acetyl-2,4,6-tri-*O*-benzoyl-D-mannopyranose (**3**) for introducing 3-substituted D-mannose residue. Known[26] methyl 2,3-*O*-isopropylidene-α-D-mannopyranoside (**4**) served as the starting compound for its synthesis. By simple operations (benzoylation, deacetonation, trans-orthoesterification, and regiospecific[27] hydrolysis), this compound was converted to methyl 2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (**5**), which was then subjected to acetolysis (Scheme 3). The structure of the acetolysis product (**3**) was established unambiguously by spectroscopic and analytical data.

The proposed route to tribenzoate **5** appears more effective than the approaches comprising selective benzoylation, with benzoyl cyanide (see Refs 28, 29), of methyl 4,6-*O*-benzylidene-α-D-mannopyranoside or methyl 2,4-di-*O*-benzoyl-α-D-mannopyranoside whose synthesis was reported previously.[30]

Acetolysis of the last-mentioned methyl glycoside was also investigated.[30] Treatment with an Ac_2O—AcOH—H_2SO_4 mixture (100 : 50 : 3) at room temperature resulted only in 3,6-di-O-acetylation; at 40 °C, smooth replacement of the MeO group by the AcO group in high yield took place. Under the same conditions, acetolysis of methyl glycoside **5** gave 1,3-diacetate **3** in ~90% yield.

1,2-Diacetate **2** was made to react with 3-mercaptopropionic acid in the presence of $BF_3 \cdot Et_2O$ under thermodynamic control (16 h, ~20 °C) and the thiolysis product was treated with hydrogen chloride in methanol.

Scheme 4



Reagents: *i*. $HSCH_2CH_2CO_2H$, $BF_3 \cdot Et_2O$; *ii*. HCl/MeOH; *iii*. $HSCH_2CH_2CO_2Me$, $BF_3 \cdot Et_2O$

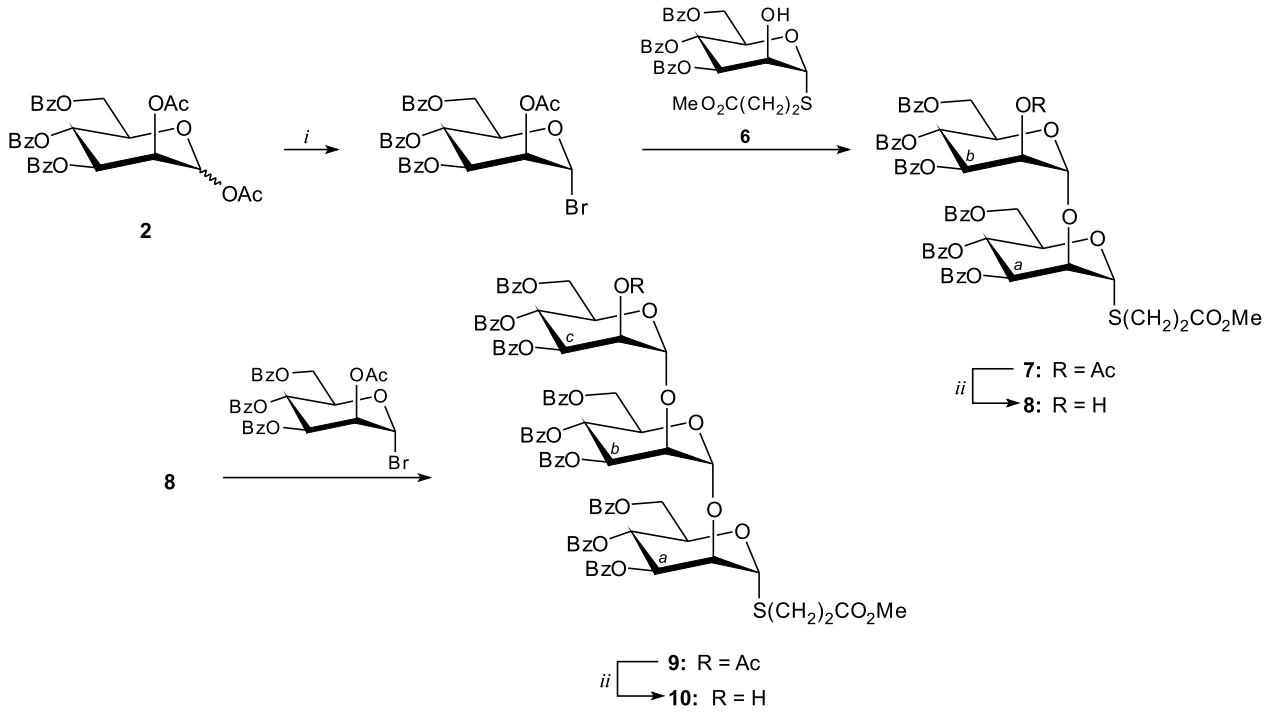
This resulted in esterification of the carboxyl group and selective O-deacetylation. The target thioglycoside **6** (primary glycosyl acceptor) was isolated by column chromatography in 42% yield (Scheme 4). The same product was obtained in the reaction of diacetate **2** with methyl 3-mercaptopropionate followed by O-deacetylation.

Data from NMR spectra unambiguously prove the structure of this compound. In particular, the relatively high-field position of the H(2) signal in the ^1H NMR spectrum ($\delta_{H(2)}$ 4.44, *cf.* $\delta_{H(2)}$ 5.55 in the spectrum of the acetate) attested to the presence of a free hydroxy group at O(2), while low-field signals for H(3), H(4), and H(6) implied that the benzoyl groups at the corresponding oxygen atoms have been retained. The anomeric C atom of thiomannoside **6** appeared as a higher-field signal (δ_C 84.7) than the C(1) atom of *O*-mannosides (δ_C ~100); we used this feature in interpreting the NMR spectra of the thioglycosides of the oligosaccharides obtained subsequently. The spectra exhibited also signals for the CO_2CH_3 group (δ_H 3.70, δ_C 171.9 and 51.8).

1,2-Diacetate **2** was converted to the corresponding mannosyl bromide by the conventional route. This product was used as the glycosyl donor in the glycosylation of acceptor **6** in the presence of silver trifluoromethanesulfonate (triflate), the yield of disaccharide **7** was ~70%. The *O*-acetyl group of the disaccharide was removed selectively; however, the yield of product **8** was rather low (~40%).

Glycosylation of acceptor **8** under the same conditions as in the synthesis of disaccharide **7** afforded fully protected trisaccharide **9** in a relatively high yield (82%). O-Deacetylation gave the target trisaccharide glycosyl acceptor, compound **10** (Scheme 5).

Scheme 5



Reagents: *i*. HBr/AcOH; *ii*. HCl/MeOH.

The glycosylation pattern (the formation of 1→2-glycosidic bonds) followed from NMR data, in particular, from the downfield shift of the C(2) and C(2′) signals in the ^{13}C NMR spectra and the high-field position of the H(2) and H(2′) signals in the ^{1}H NMR spectra of disaccharide **7** and trisaccharide **9**, respectively. Deacetylation of the glycosylation products (**7** → **8**; **9** → **10**) was accompanied by an upfield shift of the signals of H(2′) and H(2″) in the ^{1}H NMR spectra and a downfield shift of the signals of C(2′) and C(2″) in the ^{13}C NMR spectra of di- and trisaccharide glycosyl acceptors **8** and **10**. It was found[31] that the signals for the carbon atoms of *O*- and *S*-mannosides with the same pattern of substitution (except for the signals for the anomeric carbons) occur in similar spectral regions. Analysis of the ^{13}C NMR spectra of di- and trisaccharides showed similarity of the chemical shifts of the characteristic C(3) and C(5) atoms, which is indicative of the same α-configuration of the anomeric centers.

For constructing the 1→3-linked disaccharide fragment of the pentasaccharide, 1,3-diacetate **3** was converted to *p*-methoxyphenyl α-glycoside (**11**), the 3-*O*-acetyl group was selectively removed (→ **12**), and the second mannopyranose residue was introduced. The oxidative removal of the aglycone, *p*-methoxyphenyl group, in the glycoside of disaccharide **13** by treatment with cerium ammonium nitrate resulted in reducing disaccharide **14**, which was converted to disaccharide glycosyl donor (→ **15** → **16**) by a standard procedure (Scheme 6).

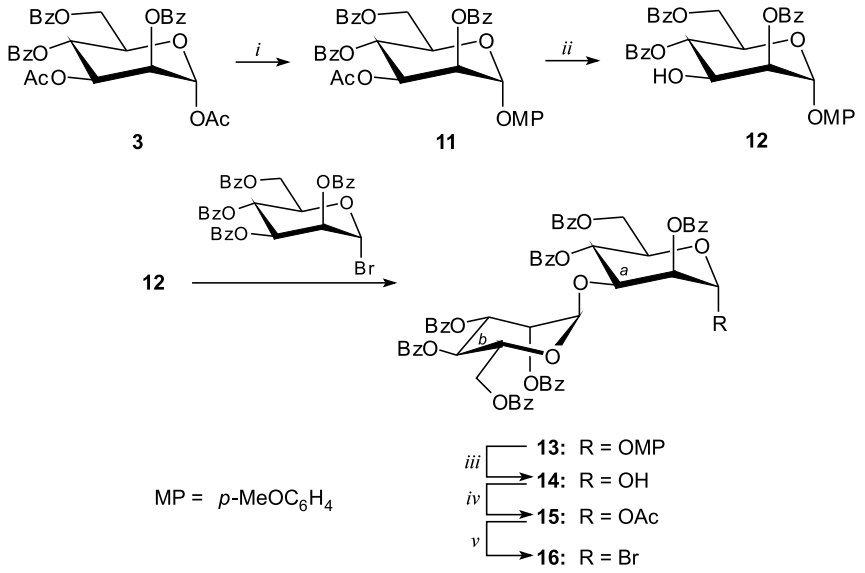
Compound **12** has been obtained previously[32] by deallylation of 4-methoxyphenyl 3-*O*-allyl-2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside under the action of $PdCl_2$ in MeOH; the ^{1}H NMR spectral data for the compound we synthesized are similar to those reported. The same publication[32] gives characterization of disaccharide derivative **13**. The $[\alpha]_D$ value of our glycoside **13** (−34.6) is similar to the reported value (−42.6). Relying on the analysis of the COSY spectrum (Fig. 1), we changed the earlier[32] assignment of the signals of H(1a,b), H(2a,b), and H(4a,b) protons in the ^{1}H NMR spectrum (Table 1).

The final step of the synthesis was coupling of glycosyl acceptor **10** (trisaccharide) with glycosyl donor **16** (disaccharide). This reaction was carried out in the presence of silver triflate to give the target pentasaccharide derivative **17** in 43% yield (Scheme 7).

The structure of the condensation product (**17**) followed from spectroscopic data. The ESI mass spectrum exhibited an ion peak with m/z 1320.9, which corresponded to $[M + 2\ Na]^{2+}$ of the protected pentasaccharide (calculated for $z = 2$, $C_{146}H_{122}O_{43}SNa_2$ (2594.71 + + 2 • 22.99) : 2 = 1320.345).

The ^{1}H and ^{13}C NMR signals were assigned (see Tables 1 and 2) by means of 2D NMR spectroscopy (COSY, TOCSY, HSQC); the HMBC and ROESY procedures provided unambiguous proof for the types of linkage (one 1→3- and three 1→2-linkages) and the sequence of monosaccharide units in the chain. Thus the assumed sequence is supported by the presence of δ_H/δ_C correlation peaks between the monosaccharide residues in the HMBC spectrum (δ): 5.33 (H(1*e*))/75.67 (C(3*d*)), 5.00 (H(1*d*))/77.48 (C(2*c*)), 5.33 (H(1*c*))/76.50 (C(2*b*)) и 5.45

Scheme 6



Reagents: *i*. *p*-$MeOC_6H_4OH$, $BF_3 \cdot Et_2O$; *ii*. HCl/MeOH; *iii*. $(NH_4)_2Ce(NO_3)_6$, MeCN-H_2O; *iv*. Ac_2O/pyridine; *v*. HBr/AcOH.

Scheme 7

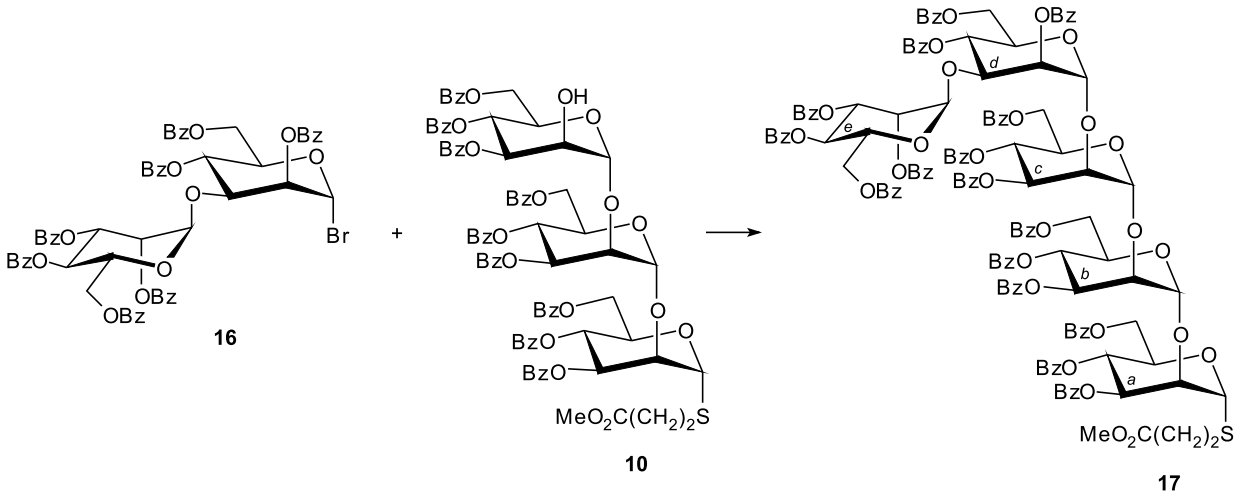


Table 1. Data of the ^{1}H NMR spectra of derivatives of di- and trisaccharides **7—10**, **13—15** and pentasaccharide **17**

Compound	Residue	δ						
		H(1)	H(2)	H(3)	H(4)	H(5)	H(6)	H(6′)
7	*a*	5.70 (br.s)	4.51 (m)	5.79 (dd)	6.03 (t)	4.79 (ddd)	4.66 (dd)	4.60 (m)
	b	5.13 (br.s)	5.70 (br.s)	5.91 (m)	5.90 (t)	4.60 (m)	4.51 (m)	
8	*a*	5.66 (br.s)	4.51 (m)	5.70 (dd)	5.98 (t)	4.75 (ddd)	4.59 (m)	
	b	5.14 (br.s)	4.46 (br.s)	5.77 (dd)	5.91 (t)	4.55 (m)	4.58 (m)	4.51 (m)
9	*a*	5.71 (br.s)	4.55 (br.s)	5.73 (m)	6.00 (m)	4.81 (ddd)		4.68 (m)
	b	5.49 (br.s)	4.53 (br.s)	6.01 (m)	6.07 (t)	4.65 (m)	4.62 (m)	
	c	4.96 (br.s)	5.64 (br.t)	5.87 (dd)	5.83 (t)	4.46 (m)	4.29 (dd)	4.16 (dd)
10	*a*	5.63 (br.s)	4.46 (br.s)	5.67 (dd)	5.96 (t)	4.75 (ddd)	4.62 (m)	
	b	5.44 (br.s)	4.51 (br.s)	5.89 (dd)	5.99 (t)	4.57 (m)	4.58 (m)	
	c	4.93 (br.s)	4.37 (br.s)	5.68 (dd)	5.78 (t)	4.37 (m)	4.19 (dd)	4.06 (dd)
13	*a*	5.68 (br.s)	5.86 (br.s)	4.84 (dd)	6.03 (t)	4.44 (m)	4.62 (m)	4.46 (m)
	*	5.42	5.36	4.84	6.01			
	b	5.41 (br.s)	5.35 (br.s)	5.72 (dd)	5.99 (t)	4.52 (br.dt)	4.59 (br.d)	4.36 (dd)
	*	5.69	5.87	5.72	6.05			
14	*a*	5.50 (br.s)	5.72 (br.s)	4.73 (br.d)	6.08 (t)	4.52 (m)	4.73 (br.d)	4.39 (dd)
	b	5.33 (br.s)	5.41 (br.s)	5.70 (dd)	5.98 (t)	4.52 (m)	4.62 (br.d)	4.34 (dd)
15	*a*	6.38 (d)	5.70 (m)	4.65 (dd)	6.11 (t)	4.35 (m)	4.69 (dd)	4.48 (m)
	b	5.37 (br.s)	5.35 (d)	5.70 (m)	6.01 (t)	4.51 (m)	4.56 (m)	4.42 (dd)
17	*a*	5.72 (br.s)	4.58 (m)	5.74 (dd)	5.99 (t)	4.79 (m)	4.65 (m)	4.61 (dd)
	b	5.45 (br.s)	4.63 (br.d)	5.85 (dd)	6.02 (t)	4.65 (m)	4.58 (m)	
	c	5.33 (br.s)	4.52 (br.s)	5.84 (dd)	5.98 (t)	4.41 (m)	4.35 (dd)	4.23 (dd)
	d	5.00 (br.s)	5.72 (m)	4.65 (m)	5.97 (t)	4.25 (m)	4.19 (br.s)	
	e	5.33 (br.s)	5.38 (br.s)	5.70 (dd)	6.10 (t)	4.44 (m)	4.52 (br.d)	4.33 (dd)

* Data from Ref. 32.

Note. Other signals, δ: 2.1 (s, CH_3CO), 2.6 (m, SCH_2), 2.9 (m, $C\underline{H}_2COOMe$), 3.7 (s, $C_6H_4OC\underline{H}_3$, $CO_2C\underline{H}_3$). Spin—spin coupling constants: $J_{1,2} \approx 2$ Hz, $J_{2,3} \approx 3$ Hz, $J_{3,4} \approx 10$ Hz, $J_{4,5} \approx 10$ Hz, $J_{5,6} \approx 3$ Hz, $J_{5,6'} \approx 4$ Hz, and $J_{6,6'} \approx 12$ Hz.

(H(1*b*))/78.00 (C(2*a*)). The spin—spin coupling constants $^1J_{H(1),C(1)O} = 175$ Hz and $^1J_{H(1),C(1)S} = 169$ Hz (see Ref. 33) pointed to the α-configuration of all anomeric centers. The same conclusion follows from the presence of intense $\delta_{H(1)}/\delta_{C(3)}$ and $\delta_{H(1)}/\delta_{C(5)}$ correlation peaks of particular monosaccharide residues [5.72/71.00 and 5.72/69.46 (unit *a*), 5.45/71.26 and 5.45/69.89 (unit *b*), 5.33/70.69 and 5.33/69.73 (unit *c*), 5.00/75.67 and 5.00/69.53 (unit *d*)]

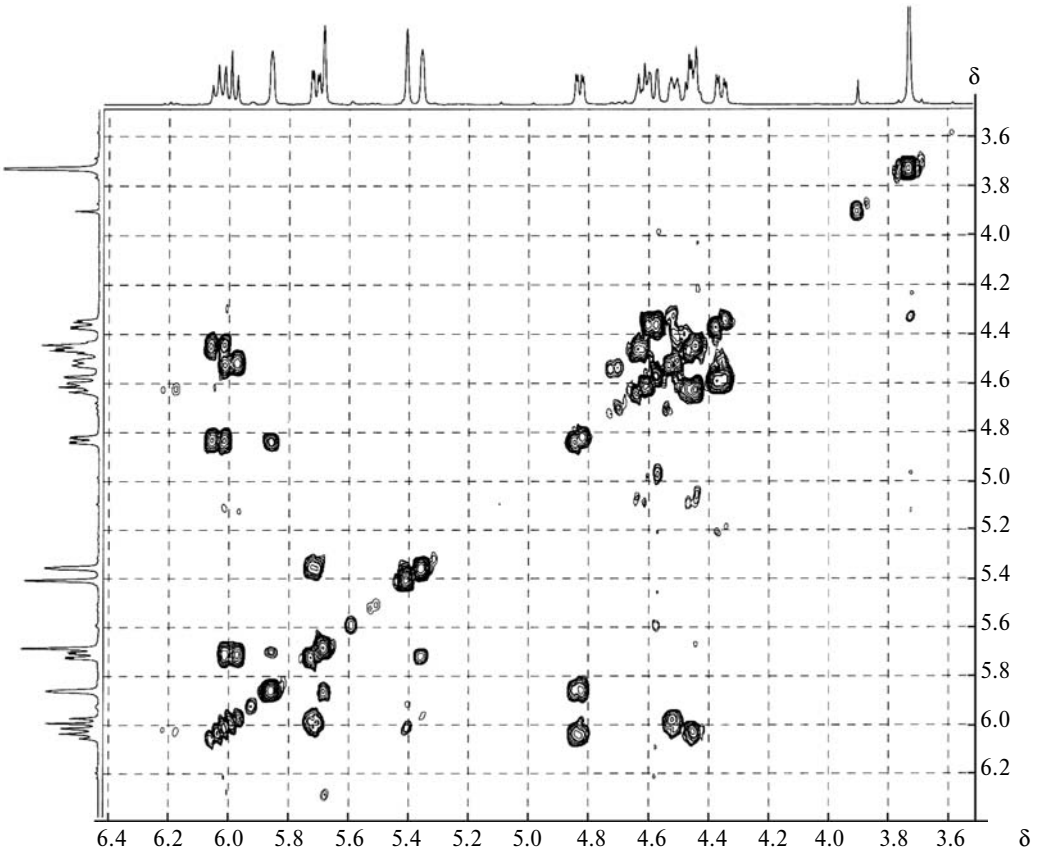


Fig. 1. Fragment of the COSY spectrum of disaccharide derivative **13**.

Table 2. ^{13}C NMR data for derivatives of di- and trisaccharides **7—10**, **13—15** and pentasaccharide **17**

Compound	Residue	δ					
		C(1)	C(2)	C(3)	C(4)	C(5)	C(6)
7	*a*	84.25	77.85	71.12	67.60	69.49	63.56
	b	99.50	69.48	69.49	67.23	69.88	63.44
8	*a*	84.27	77.73	71.20	67.52	69.33	63.58
	b	101.52	69.38	71.59	67.03	69.82	63.58
9	*a*	84.13	77.42	71.20	67.56	69.22	63.43
	b	99.86	77.42	70.25	67.36	69.60	63.73
	c	99.56	69.32	69.42	66.91	69.42	63.21
10	*a*	84.32	77.39	72.19	67.69	69.36	63.58
	b	100.08	77.39	70.76	67.41	69.46	63.89
	c	101.72	69.68	71.26	66.85	69.25	63.46
13	*a*	96.44	71.72	76.23	68.37	69.78	62.99
	b	99.66	70.23	69.32	66.51	69.48	62.64
14	*a*	92.21	72.21	75.62	68.48	68.86	62.79
	b	99.44	70.19	69.34	66.59	69.59	62.66
15	*a*	91.8	72.2	77.3	69.3	72.1	64.1
	b	100.9	71.7	71.0	67.7	71.5	64.1
17	*a*	84.17	78.00	71.00	67.29*	69.46	63.72
	b	100.37	76.50	71.26	67.23*	69.89	63.72
	c	100.43	77.48	70.69	67.90**	69.73	63.54
	d	99.55	71.34	75.67	67.95**	69.53	62.62
	e	99.34	70.10	69.46	66.11	69.46	62.00

* The assignment may be opposite. ** The assignment may be opposite.
Note. Other signals, δ: 26.6 (SCH_2), 34.6 ($\underline{C}H_2CO_2CH_3$), 55.6 ($C_6H_4O\underline{C}H_3$), 51.8 ($CO_2C\underline{H}_3$).

in the HMBC spectrum (the H(1)—C(1)—C(2)—C(3) and H(1)—C(1)—O—C(5) dihedral angles are 180°).

Thus, we synthesized a functionalized thioglycoside of the protected pentasaccharide with the structure of the chemical repeating unit of the O-antigenic polysaccharide of the bacterium *Klebsiella pneumoniae* O3.

Experimental

Optical rotation was measured in CH_2Cl_2 on a PU-07 polarimeter (Russia) at ~20 °C. The melting points were measured on a Koffler hot stage. ESI mass spectrum was recorded on an LCQ Finnigan MAT instrument. NMR spectra were measured on Bruker AC-200, Bruker AM-300, Bruker DRX-500, and Avance II 600 spectrometers in $CDCl_3$. The ^{1}H NMR chemical shifts were referred to the residual $CHCl_3$ signal (δ_H 7.27), $^{13}C\{^1H\}$ NMR chemical shifts were referred to the $CDCl_3$ signal (δ_C 77.0); the most important signals are presented. Data of the NMR spectra of di- and trisaccharide and pentasaccharide derivatives are summarized in Tables 1 and 2. Column chromatography was carried out using silica gel Merck (type 9385, 230—400 mesh, 60 Å); elution was carried out with toluene—ethyl acetate solvent mixtures with increasing concentration of the latter, TLC was performed on DC-Alufolien Kieselgel 60 F_{254} plates (Merck); the compounds were visualized under UV light and/or by wetting the plates with an ethanol—85% H_3PO_4 mixture (9 : 1 v/v) followed by heating on a hot plate at ~150 °C. Anhydrous solvents were prepared by conventional procedures. Acylmannopyranosyl bromides were prepared by treating the corresponding fully acylated derivatives with a solution of HBr in AcOH according to a previously reported procedure.[34]

1,2-*O*-[(*S*)-Benzylidene]-3,4,6-tri-*O*-benzoyl-β-D-mannopyranose (1). A solution of tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (3.71 g, 5.3 mmol) in anhydrous MeCN (10 mL) was stirred with $NaBH_4$ (0.311 g, 8.18 mmol) for 48 h at ~20 °C. The reaction mixture was diluted with chloroform and washed with water, the organic layer was concentrated, and the residue was crystallized from an ethyl acetate—light petroleum mixture to give 2.4 g (77%) of benzylidene derivative **1**, m.p. 173—174 °C, $[\alpha]_D$ −3.4 (*c* 0.8). Found (%): C, 70.13; H, 4.96. $C_{34}H_{28}O_9$. Calculated (%): C, 70.34; H, 4.86. ^{1}H NMR, δ: 6.20 (t, 1 H, H(4), J = 9.9 Hz); 6.03 (s, 1 H, Ph—C—H); 5.78 (dd, 1 H, H(3), $J_{3,2}$ = 3.9 Hz, $J_{3,4}$ = 10.0 Hz); 5.66 (d, 1 H, H(1), $J_{1,2}$ = 2.0 Hz); 4.77 (dd, 1 H, H(6), $J_{6,5}$ = 2.6 Hz, $J_{6,6'}$ = 12.2 Hz); 4.74 (dd, 1 H, H(2), $J_{2,1}$ = 2.1 Hz, $J_{2,3}$ = 3.8 Hz); 4.50 (dd, 1 H, H(6′), $J_{6',5}$ = 3.7 Hz, $J_{6,6'}$ = 12.2 Hz); 4.16 (br.dt, 1 H, H(5)). ^{13}C NMR, δ: 107.17 (Ph—C—H); 96.53 (C(1)); 78.36 (C(2)); 71.70 (C(3)); 71.64 (C(5)); 66.43 (C(4)); 62.68 (C(6)).

1,2-Di-*O*-acetyl-3,4,6-tri-*O*-benzoyl-D-mannopyranose (2). A solution of benzylidene derivative **1** (0.93 g, 1.6 mmol) in 90% CF_3CO_2H (9 mL) was kept for 1 h at ~20 °C. After completion of the reaction (TLC monitoring, toluene—ethyl acetate, 20 : 1), the reaction mixture was diluted with chloroform, washed with water and a saturated aqueous solution of $NaHCO_3$, filtered through cotton, and concentrated *in vacuo*. The 1,2-diol thus obtained was acetylated with Ac_2O (0.82 g, 8 mmol) in pyridine (5 mL) at ~20 °C. After 14 h, the excess of Ac_2O was quenched by adding water (0.2 mL), the reaction mixture was diluted with chloroform, the solution was washed with water, 1 *M* HCl, and a saturated aqueous solution of $NaHCO_3$, and the solvent was evaporated. Chromatography gave 0.895 g (97%) of 1,2-diacetate **2**. ^{1}H NMR, δ: 6.25 (d, 0.72 H, H(1α), $J_{1,2}$ = 1.4 Hz); 6.15 (br.s, 0.28 H, H(1β)); 6.05 (t, 0.72 H, H(4α), $J_{4,3}$ = $J_{4,5}$ = 9.9 Hz); 5.85 (t, 0.28 H, H(4β), $J_{4,3}$ = $J_{4,5}$ = 9.9 Hz); 5.80 (dd, 0.72 H, H(3α), $J_{3,2}$ = 3.3 Hz, $J_{3,4}$ = 10.2 Hz); 5.75 (br.d, 0.28 H, H(2β), J = 2.7 Hz); 5.65 (dd, 0.28 H, H(3β), $J_{3,2}$ = 3.1 Hz, $J_{3,4}$ = 9.9 Hz); 5.55 (br.d, 0.72 H, H(2α), J = 2.1 Hz); 4.64 (m, 1 H, H(6α), H(6β)); 4.53 (dd, 0.28 H, H(6′β), $J_{6\beta,5}$ = 5.4 Hz, $J_{6\beta,6\alpha}$ = 12.2 Hz); 4.55—4.45 (m, 1.44 H, H(5α), H(6′α)); 4.25 (ddd, 0.28 H, H(5β), $J_{5,6\alpha}$ = 3.1 Hz). ^{13}C NMR, δ: 90.59 (C(1α, 1β)); 73.28 (C(5β)); 71.24 (C(3β)); 70.84 (C(5α)); 69.49 (C(3α)); 68.70 (C(2α)); 68.37 (C(2β)); 66.51 (C(4β)); 66.43 (C(4α)); 63.06 (C(6β)); 62.82 (C(6α)).

2-Methoxycarbonylethyl 3,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (6). ***A.*** 3-Mercaptopropionic acid (6.1 g, 5.7 mL, 57.6 mmol) (Fluka) was dissolved in MeOH (10 mL), AcCl (0.4 mL) was added, and the mixture was kept for ~14 h at ~20 °C. The solution was diluted with dichloromethane and washed with an aqueous solution of $NaHCO_3$, and the solvent was evaporated at 30 °C. The residue was distilled *in vacuo* to give methyl 3-mercaptopropionate, b.p. 70 °C (20 Torr) (lit.:[35] b.p. 54—55 °C (14 Torr); lit.:[36] b.p. 79—80 °C (27 Torr)), yield 3.8 g (55%). At 0 °C, $HSCH_2CH_2CO_2Me$ (2.6 mL, 23.3 mmol) and $BF_3 \cdot OEt_2$ (1.7 mL, 13.4 mmol) were added to a solution of 1,2-diacetate **2** (4 g, 6.9 mmol) in CH_2Cl_2 (20 mL). The reaction mixture was kept for 48 h at ~20 °C. After completion of the reaction (TLC monitoring, toluene—ethyl acetate, 1 : 1), the reaction mixture was diluted with chloroform, washed with water and a saturated aqueous solution of $NaHCO_3$, filtered through cotton, and concentrated *in vacuo*. Column chromatography gave 3.55 g (83%) of **2-methoxycarbonylethyl 2-*O*-acetyl-3,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside**, $[\alpha]_D$ +69.4 (*c* 1.43). ^{1}H NMR, δ: 5.92 (t, 1 H, H(4), $J_{4,3}$ = $J_{4,5}$ = 10.0 Hz); 5.67 (dd, 1 H, H(3), $J_{3,2}$ = 3.2 Hz, $J_{3,4}$ =10.0 Hz); 5.55 (br.d, 1 H, H(2)); 5.42 (br.s, 1 H, H(1)); 4.73 (ddd, 1 H, H(5), $J_{5,6}$ = 2.6 Hz, $J_{5,6'}$ = 5.2 Hz, $J_{5,4}$ = 9.5 Hz); 4.60 (dd, 1 H, H(6), $J_{6,5}$ = 2.6 Hz, $J_{6,6'}$ = 12.1 Hz); 4.50 (dd, 1 H, H(6′), $J_{6',5}$ = 5.4 Hz, $J_{6,6'}$ = 12.1 Hz); 3.65 (s, 3 H, OCH_3); 2.95 (m, 2 H, SCH_2); 2.70 (t, 2 H, CH_2COO); 2.12 (s, 3 H, CH_3COO). ^{13}C NMR, δ: 82.72 (C(1)); 71.28 (C(2)); 70.20 (C(3)); 69.46 (C(5)); 67.17 (C(4)); 63.19 (C(6)); 51.84 (OCH_3); 34.48 (SCH_2); 26.47 ($\underline{C}H_2COO$); 20.72 ($\underline{C}H_3CO$).

The whole amount of obtained 2-acetate (3.55 g, 5.58 mmol) was dissolved in CH_2Cl_2 (10 mL), and a solution of HCl in MeOH (obtained by adding acetyl chloride (1 mL) to methanol (50 mL) at 0 °C) was added. The solution was kept for 14 h at ~20 °C, and, after completion of the reaction (TLC monitoring, toluene—ethyl acetate, 1 : 1), an aqueous solution of $KHCO_3$ was added, and the mixture was stirred for 30 min. Then the reaction mixture was concentrated, diluted with chloroform, and washed with water, and the solvent was evaporated. Crystallization from an ether—petroleum ether mixture gave 2.5 g (75%) of compound **6**, m.p. 114—116 °C, $[\alpha]_D$ +85.4 (*c* 0.69). Found (%): C, 63.04; H, 5.01. $C_{31}H_{30}O_{10}S$. Calculated (%): C, 62.62; H, 5.09. ^{1}H NMR, δ: 5.96 (t, 1 H, H(4), $J_{4,3}$ = $J_{4,5}$ = = 9.9 Hz); 5.59 (dd, 1 H, H(3), $J_{3,2}$ = 3.1 Hz, $J_{3,4}$ = 9.9 Hz); 5.48 (br.s, 1 H, H(1)); 4.76 (ddd, 1 H, H(5), $J_{5,6}$ = 2.8 Hz, $J_{5,6'}$ = 5.4 Hz, $J_{5,4}$ = 9.5 Hz); 4.61 (dd, 1 H, H(6), $J_{6,5}$ = 2.7 Hz, $J_{6,6'}$ = 12.1 Hz); 4.54 (dd, 1 H, H(6′), $J_{6',5}$ = 5.6 Hz, $J_{6,6'}$ = 12.2 Hz); 4.44 (br.s, 1 H, H(2)); 3.70 (s, 3 H, OCH_3);

3.00 (m, 2 H, SCH_2); 2.71 (t, 2 H, CH_2COO). ^{13}C NMR, δ: 84.76 (C(1)); 72.82 (C(3)); 70.49 (C(2)); 69. 30 (C(5)), 67.15 (C(4)); 63.41 (C(6)).

B. 1,2-Diacetate **2** (1.17 g, 2 mmol) was dissolved in CH_2Cl_2 (2 mL), and $HSCH_2CH_2CO_2H$ (0.7 mL, 8 mmol) and $BF_3 \cdot OEt_2$ (0.17 mL) were added at 0 °C. After 14 h at ~20 °C (TLC monitoring in the toluene—ethyl acetate system, 1 : 1), the reaction mixture was diluted with $CHCl_3$, washed with water and 1 *M* HCl, and filtered through cotton, and the solvent was evaporated. The product thus obtained was dissolved in 10 mL of a 0.6 *M* solution of HCl in MeOH (prepared by adding acetyl chloride (0.4 mL) to methanol (10 mL) at 0 °C). The solution was kept for 14 h at ~20 °C. Evaporation of the solvent and chromatography gave 0.5 g (42%) of product **6** identical to that obtained by procedure *A*.

2-Methoxycarbonylethyl 2-*O*-(2-*O*-acetyl-3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-3,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (7). Calcined molecular sieves 4 Å were added to a solution of glycosyl acceptor **6** (0.43 g, 0.72 mmol) and 2-*O*-acetyl-3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl bromide (obtained from 1.09 mmol of diacetate **2**) in CH_2Cl_2 (10 mL) (here and below, the weight of molecular sieves is approximately equal to the sum of weights of the glycosyl acceptor and the glycosyl donor), the mixture was stirred for 1 h at 0 °C, a solution of AgOTf (0.334 g, 1.3 mmol) in toluene (5 mL) was added, and the mixture was stirred for an additional 40 min. The reaction mixture was diluted with chloroform, filtered through a layer of Celite HyFlo, and washed with a solution of $Na_2S_2O_3$, and the solvent was evaporated. Column chromatography gave disaccharide **7**, yield 0.53 g (66%), $[\alpha]_D$ +29 (*c* 2.08). Found (%): C, 65.00; H, 4.69. $C_{60}H_{54}O_{19}S$. Calculated (%): C, 64.86; H, 4.90.

2-Methoxycarbonylethyl 2-*O*-(3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-3,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (8). Mono-*O*-acetate 7 (0.65 g, 0.59 mmol) was dissolved in 3 mL of a 0.6 *M* solution of HCl in MeOH (prepared by adding acetyl chloride (0.4 mL) to methanol (10 mL) at 0 °C). The solution was kept for 14 h at ~20 °C. Evaporation of the solvent and chromatography in a toluene—ethyl acetate system gave 0.12 g of unreacted disaccharide **7** and 0.22 g of glycosyl acceptor **8** (43% relative to the converted disaccharide **7**), $[\alpha]_D$ +27.2 (*c* 0.93). Found (%): C, 65.37; H, 4.95. $C_{58}H_{54}O_{18}S$. Calculated (%): C, 65.16; H, 4.90.

2-Methoxycarbonylethyl (2-*O*-acetyl-3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (9). The condensation of disaccharide glycosyl acceptor **8** (0.156 g, 0.146 mmol) with 2-*O*-acetyl-3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl bromide (prepared from 0.218 mmol of diacetate **2**) in the presence of AgOTf (0.057 g, 0.22 mmol) and molecular sieves 4 Å in a CH_2Cl_2—toluene mixture was carried out similarly to the above described synthesis of protected disaccharide **7** to give trisaccharide **9** (0.19 g, 82%), $[\alpha]_D$ +4.7 (*c* 1.0).

2-Methoxycarbonylethyl (3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (10). The prepared trisaccharide **9** (0.17 g, 0.11 mmol) was treated with 3 mL of a 0.6 *M* solution HCl in MeOH as described above. Evaporation of the solvent and chromatography gave 0.06 g of the initial trisaccharide and its deacetylation product **10** (0.07 g, 64% relative to the converted trisaccharide acetate), $[\alpha]_D$ −10 (*c* 0.58).

Methyl 4,6-di-*O*-benzoyl-α-D-mannopyranoside. Benzoyl chloride (9 mL, 78 mmol) was added with stirring to a solution of methyl 2,3-*O*-isopropylidene-α-D-mannopyranoside[26] (3.7 g, 15.6 mmol) in pyridine (10 mL). After 40 min, TLC analysis ($CHCl_3$—MeOH, 19 : 1) showed the absence of the starting compound. The excess of BzCl was decomposed by dropwise addition of water to the reaction mixture, and the reaction mixture was diluted with chloroform, washed with water, 1 *M* HCl, and a saturated aqueous solution of $NaHCO_3$, and concentrated to give **methyl 4,6-di-*O*-benzoyl-2,3-*O*-isopropylidene-α-D-mannopyranoside**, yield 6.1 g (91%), $[\alpha]_D$ +28.0 (*c* 1.45), m.p. 87—88 °C (from ethanol). Found (%): C, 65.26; H, 5.98. $C_{24}H_{26}O_8$. Calculated (%): C, 65.15; H, 5.92. ^1H NMR, δ: 5.42 (dd, 1 H, H(4), $J_{4,3}$ = 7.6 Hz, $J_{4,5}$ = 10.2 Hz); 5.03 (s, 1 H, H(1)); 4.55 (dd, 1 H, H(6), $J_{6,5}$ = 3.0 Hz, $J_{6,6'}$ = 12.0 Hz); 4.43 (m, 2 H, H(3), H(6′)); 4.23 (d, 1 H, H(2), $J_{2,3}$ = 5.5 Hz); 4.15 (sept, 1 H, H(5), $J_{5,6}$ = 3.0 Hz, $J_{5,6'}$ = 6.2 Hz, $J_{5,4}$ = 9.8 Hz), 3.45 (s, 3 H, OCH_3), 1.65, 1.38 (both s, 3 H each, 2 CH_3). ^{13}C NMR, δ: 110.12 ($\underline{C}(CH_3)_2$, 98.26 (C(1)); 75.99 (C(3)); 75.77 (C(2)); 70.68 (C(4)); 66.35 (C(5)); 63.67 (C(6)); 55.09 (OCH_3); 27.66, 26.29 ($C(\underline{C}H_3)_2$).

The resulting isopropylidene derivative was dissolved in 80% AcOH (50 mL), the solution was refluxed for 1 h, the solvent was evaporated *in vacuo*, and the remaining AcOH was co-evaporated with toluene. Column chromatography in a $CHCl_3$—MeOH system (methanol concentration gradient from 5 to 10%) gave **methyl 4,6-di-*O*-benzoyl-α-D-mannopyranoside**, yield 4.95 g (80%), $[\alpha]_D$ +72.1 (*c* 0.70), m.p. 84-85 °C (from an ether—petroleum ether mixture). Found (%): C, 62.89; H, 5.65. $C_{21}H_{22}O_8$. Calculated (%): C, 62.68; H, 5.51. ^1H NMR, δ: 5.41 (t, 1 H, H(4), $J_{4,3} = J_{4,5}$ = 9.8 Hz); 4.80 (s, 1 H, H(1)); 4.53 (dd, 1 H, H(6), $J_{6,5}$ = 2.7 Hz, $J_{6,6'}$ = 12.0 Hz); 4.44 (dd, 1 H, H(6′), $J_{6',5}$ = 6.1 Hz, $J_{6,6'}$ = 12.0 Hz); 4.16 (sept, 1 H, H(5), $J_{5,6}$ = 2.6 Hz, $J_{5,6'}$ = 6.0 Hz, $J_{5,4}$ = 9.6 Hz); 4.07 (br.d, 1 H, H(3)); 4.00 (br.s, 1 H, H(2)); 3.38 (s, 3 H, OCH_3). ^{13}C NMR, δ: 100.62 (C(1)); 71.04 (C(4)); 70.64 (C(2)); 70.27 (C(3)); 67.96 (C(5)); 63.82 (C(6)); 55.10 (OCH_3).

Methyl 2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (5). ***A.*** A solution of methyl 2,4-di-*O*-benzoyl-α-D-mannopyranoside[30] (0.55 g, 1.35 mmol) and BzCN (0.18 g, 1.35 mmol) in MeCN (2 mL) was stirred for 30 min at ~20 °C in the presence of catalytic amount of Et_3N. After completion of the reaction (TLC monitoring, toluene—ethyl acetate, 4 : 1), anhydrous MeOH (5 mL) was added, the mixture was stirred for 30 min, and the solvents were evaporated. Column chromatography gave methyl 2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (327 mg, 48%), $[\alpha]_D$ +6.2 (*c* 0.42). Found (%): C, 66.39; H, 5.24. $C_{28}H_{26}O_9$. Calculated (%): C, 66.39; H, 5.17. ^1H NMR, δ: 5.68 (t, 1 H, H(4), $J_{4,3} = J_{4,5}$ = 10 Hz); 5.41 (dd, 1 H, H(2), $J_{2,1}$ = 1.6 Hz, $J_{2,3}$ = 3.3 Hz); 4.93 (d, 1 H, H(1), $J_{1,2}$ = 1.5 Hz); 4.67 (dd, 1 H, H(6), $J_{6,5}$= 2.5 Hz, $J_{6,6'}$ = 12.0 Hz); 4.50 (dd, 1 H, H(6′), $J_{6',5}$ = 4.7 Hz, $J_{6,6'}$ = 12.1 Hz); 4.39 (br.d, 1 H, H(3)); 4.27 (ddd, 1 H, H(5), $J_{5,6}$ = 2.5 Hz, $J_{5,6'}$ = 4.4 Hz, $J_{5,4}$ = 10 Hz); 3.48 (s, 3 H, OCH_3). ^{13}C NMR, δ: 98.51 (C(1)), 72.75 (C(2)), 70.39 (C(4)), 68.91 (C(3)), 60.88 (C(5)), 62.99 (C(6)), 55.44 (OCH_3).

B. A solution of methyl 4,6-di-*O*-benzoyl-α-D-mannopyranoside (1.034 g, 2.5 mmol), $PhC(OMe)_3$ (2 mL, 10.278 mmol), and $TsOH \cdot H_2O$ (0.05 g) in anhydrous MeCN (8 mL) was stirred at ~20 °C. After 1 h (TLC monitoring, $CHCl_3$—MeOH, 19 : 1),

90% CF_3COOH (2 mL) was added to the obtained bicyclic orthoester. After 30 min, the solvents were evaporated, the remaining acid was co-evaporated with toluene. Column chromatography gave 0.849 g (67%) of tribenzoate **5** identical to that obtained by method *A*, $[\alpha]_D$ + 4.5 (lit[28]: $[\alpha]_D$ +4.9).

1,3-Di-*O*-acetyl-2,4,6-tri-*O*-benzoyl-α-D-mannopyranose (3). A cooled solution of conc. H_2SO_4 (0.08 mL) in Ac_2O (1.9 mL) was added to a cooled (0 °C) solution of glycoside **5** (0.307 g, 0.61 mmol) in AcOH (1.9 mL) and Ac_2O (1.9 mL). The mixture was heated for 2 h at 40 °C. After completion of the reaction (TLC monitoring, toluene—ethyl acetate, 4 : 1), the solution was cooled to 20 °C, cold water was added dropwise, and the solution was concentrated *in vacuo* to ~1 mL. The residue was diluted with chloroform, and the solution was washed with a saturated aqueous solution of $NaHCO_3$ to give diacetate **3**, yield 0.32 g (91%). Found (%): C, 64.76; H, 4.86. $C_{31}H_{28}O_{11}$. Calculated (%): C, 64.58; H, 4.90. ^{1}H NMR (200 MHz), δ: 6.33 (d, 1 H, H(1), $J_{1,2}$ = 1.9 Hz); 6.01 (t, 1 H, H(4), $J_{4,3} = J_{4,5}$ = = 10.1 Hz); 5.72 (dd, 1 H, H(3), $J_{3,2}$ = 3.3 Hz, $J_{3,4}$ = 10.2 Hz); 5.61 (dd, 1 H, H(2), $J_{2,1}$ = 2.0 Hz, $J_{2,3}$ = 3.2 Hz); 4.69 (dd, 1 H, H(6), $J_{6,5}$ = 2.6, $J_{6,6'}$ = 12.2); 4.47—4.36 (m, 2 H, H(5), H(6′)); 1.93, 2.28 (both s, 3 H each, 2 CH_3COO). 13C NMR (δ: 90.82 (C(1)); 70.92 (C(5)); 69.06 (C(2)); 68.75 (C(3)); 66.30 (C(4)); 62.50 (C(6)).

4-Methoxyphenyl 3-*O*-acetyl-2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (11). 4-Methoxyphenol (0.24 g, 1.94 mmol) and $BF_3 \cdot Et_2O$ (0.28 g, 0.25 mL, 1.94 mmol) were added at ~20 °C to a solution of 1,3-diacetate **3** (0.56 g, 0.97 mmol) in anhydrous CH_2Cl_2 (3 mL). After 14 h, the reaction mixture was diluted with chloroform and washed with water and a saturated aqueous solution of $NaHCO_3$. Column chromatography gave glycoside **11**, yield 0.44 g (70%), $[\alpha]_D$ −11.5 (*c* 0.46). ^{1}H NMR, δ: 5.94—5.93 (m, 2 H, H(3), H(4)); 5.78 (br.s, 1 H, H(2)); 5.63 (br.s, 1 H, H(1)); 4.62 (dd, 1 H, H(6), $J_{6,5}$ = 2.0 Hz, $J_{6,6'}$ = 12.0 Hz); 4.52 (m, 1 H, H(5)); 4.45 (dd, 1 H, H(6′), $J_{6',5}$ = 5.0 Hz, $J_{6,6'}$ = 12.0 Hz); 3.76 (s, 3 H, OCH_3); 1.93 (s, 3 H, CH_3COO). ^{13}C NMR, δ: 96.70 (C(1)); 70.18 (C(2)); 69.39 (C(5)); 69.10 (C(3)); 67.05 (C(4)); 62.94 (C(6)); 55.59 (OCH_3); 20.69 ($\underline{C}H_3COO$).

4-Methoxyphenyl 2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (12). Glycoside **11** (0.41 g, 0.65 mmol) was dissolved in 7 mL of a 0.6 *M* solution of HCl in MeOH (prepared by adding acetyl chloride (0.4 mL) to methanol (10 mL) at 0 °C). The solution was kept for 14 h at ~20 °C. Evaporation of the solvent and column chromatography gave 0.3 g (77%) of glycosyl acceptor **12**, $[\alpha]_D$ +46 (*c* 0.46) (lit.:[32] $[\alpha]_D$ +10.3 (*c* 1.0, $CHCl_3$)). ^{1}H NMR, δ: 5.71 (t, 1 H, H(4), $J_{4,3} = J_{4,5}$ = 9.8 Hz) ; 5.64 (d, 1 H, H(1), $J_{1,2}$ = 1.7 Hz); 5.60 (dd, 1 H, H(2), $J_{2,3}$ = 3.2 Hz, $J_{2,1}$ = 1.7 Hz); 4.63—4.60 (m, 2 H, H(3), H(6)); 4.49—4.43 (m, 2 H, H(5), H(6′)); 3.75 (s, 3 H, OCH_3). ^{13}C NMR, δ: 96.47 (C(1)); 72.67 (C(2)); 70.30 (C(4)); 69.01 (C(5)), 68.90 (C(3)); 63.05 (C(6)); 55.60 (OCH_3).

4-Methoxyphenyl 3-*O*-(2,3,4,6-tetra-*O*-benzoyl-α-D-mannopyranosyl)-2,4,6-tri-*O*-benzoyl-α-D-mannopyranoside (13). Calcined molecular sieves 4 Å were added to a solution of glycoside **12** (0.360 g, 0.602 mmol) and 2,3,4,6-tetra-*O*-benzoyl-α-D-mannopyranosyl bromide (prepared from 0.96 mmol of D-mannose pentabenzoate) in CH_2Cl_2 (5 mL), the mixture was stirred for 1 h at 0 °C, a solution of AgOTf (0.247 g, 0.96 mmol) in toluene (2 mL) was added, and the mixture was stirred for additional 40 min. The reaction mixture was diluted with chloroform, the solution was filtered through a layer of Celite HyFlo and washed with an aqueous solution of $Na_2S_2O_3$, and the solvent was evaporated. Column chromatography gave the glycoside of disaccharide **13**, yield 0.490 g (69%), $[\alpha]_D$ −34.6 (*c* 0.13); lit.:[32] $[\alpha]_D$ −42.6 (*c* 1.0, $CHCl_3$).

3-*O*-(2,3,4,6-Tetra-*O*-benzoyl-α-D-mannopyranosyl)-2,4,6-tri-*O*-benzoyl-D-mannopyranose (14). A mixture of bioside **13** (0.48 g, 0.408 mmol) and $(NH_4)_2Ce(NO_3)_6$ (0.447 g, 0.816 mmol) in an acetonitrile—water mixture (4.5 : 0.5 mL) was stirred for 15 min at ~20 °C and diluted with ethyl acetate. The organic layer was washed with water and an aqueous solution of $Na_2S_2O_3$ and concentrated. Column chromatography of the residue gave disaccharide **14**, yield 0.185 g (42%).

1-*O*-Acetyl-3-O-(2,3,4,6-tetra-*O*-benzoyl-α-D-mannopyranosyl)-2,4,6-tri-*O*-benzoyl-D-mannopyranose (15). The obtained disaccharide **14** (0.15 g, 0.14 mmol) was dissolved in pyridine (2 mL), Ac_2O (0.1 mL) was added, and the mixture was left for 14 h at ~20 °C. Water (0.5 mL) was added dropwise, and the mixture was diluted with chloroform, washed with water, 1 *M* HCl, water, and an aqueous solution of $NaHCO_3$. The organic layer was concentrated *in vacuo*, and chromatography of the residue gave 140 mg (90%) of disaccharide **15,** $[\alpha]_D$ −44.6 (*c* 0.125).

2-Methoxycarbonylethyl (2,3,4,6-tetra-*O*-benzoyl-α-D-mannopyranosyl)-(1→3)-(2,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (17). 1-*O*-Acetate **15** (28 mg, 0.025 mmol) was dissolved in CH_2Cl_2 (0.5 mL), and AcOH (0.05 mL) and AcBr (0.02 mL) were added. On cooling with ice water, AcOH (0.05 mL) and water (0.01 mL) were added, and the mixture was kept for 2 h. The reaction mixture was diluted with chloroform and washed with ice water and a saturated aqueous solution of $NaHCO_3$ to give 2,4,6-tri-*O*-benzoyl-3-*O*-(2,3,4,6-tetra-*O*-benzoyl-α-D-mannopyranosyl)-α-D-mannopyranosyl bromide (**16**).

Calcined molecular sieves 4 Å were added to a solution of 2-methoxycarbonylethyl (3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzoyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzoyl-1-thio-α-D-mannopyranoside (**10**) (41 mg, 0.027 mmol) and biosyl bromide **16** in CH_2Cl_2 (1 mL), and the mixture was stirred for 1 h at 0 °C. Then a solution of AgOTf (0.01 g) in toluene (0.5 mL) was added, and the mixture was stirred for additional 40 min. The reaction mixture was diluted with chloroform, filtered through a layer of Celite HyFlo, and washed with an aqueous solution of $Na_2S_2O_3$, and the solvent was evaporated. Gel permeation chromatography on a column (40S1.3 cm) with gel SX-1 in toluene gave pentasaccharide **17** (30 mg, 43%), $[\alpha]_D$ +48.3 (*c* 1).

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