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Syntheses of Three Interglycosidic Isomers of *N*-Acetyl-*β*-D-mannosaminyl-L-rhamnoses Associated with O-Antigens of Several Gram-Negative Opportunistic Pathogens

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We achieved practical, highly stereoselective syntheses of three interglycosidic isomers of *N*-acetyl-*β*-D-mannosaminyl-L-rhamnoses, among which a *β*(1→4)-isomer corresponds to the repeating unit of the O-antigen of lipopolysaccharide (LPS) from the opportunistic pathogens *Pseudomonas cepacia* O5 and *Pseudomonas aeruginosa* X (Meitert). The other isomers are a *β*(1→2)-disaccharide, a constituent of LPS from *Escherichia coli* O1A, and an artificial *β*(1→3)-isomer. The disaccharides were obtained by simple three-step reaction sequences from 2-(benzoyloxyimino)-2-deoxyglycosyl halides (mannosamine progenitor). *β*-Selective glycosylations of appropriately protected L-rhamnosyl acceptors were performed. Subsequent reduction of the 2-acyloxyimino function to an amino group, *N*-acetylation, and removal of the protecting groups provided the target disaccharides. ^{13}C-NMR and nuclear Overhauser effect spectra proved to be useful for structural determination of the positional isomers of the disaccharides.

Key words *β*-D-mannosaminyl-L-rhamnose; 2-ulose oxime; O-antigen; lipopolysaccharide; gram-negative bacteria; opportunistic infection

N-Acetyl-*β*-D-mannosaminyl-L-rhamnoses are of particular biological importance, since these disaccharide units constitute various O-antigens of lipopolysaccharide (LPS) of several gram-negative bacteria known to be responsible for opportunistic infections. For example, *β*-D-ManNAc-(1→4)-L-Rha represents a common, core repeating unit of the O-antigen from the opportunistic pathogens *Pseudomonas cepacia* O5[1] and *Pseudomonas aeruginosa* X[2] (Meitert), as well as from *Aeromonas salmonicida*,[3] a lethal aquatic bacterium which causes the disease furunculosis in salmonid fish. Another isomeric disaccharide *β*-D-ManNAc-(1→2)-L-Rha constitutes the O-antigen of *Escherichia coli* O1A[4] (Fig. 1).

Investigations directed towards the development of a synthetic vaccine based on the immunogenic specificity of these bacterial O-antigens require a facile, practical synthetic procedure for acquisition of the disaccharide epitopes, *β*-D-ManNAc-(1→2/4)-L-Rha.

Aside from the biomedical utility, another objective of this work is to provide appropriate reference substances along with standard NMR data for structural analyses of natural oligosaccharides from bacterial polysaccharide antigens.[4] We present here practical, stereoselective syntheses and NMR analyses of the three interglycosidic isomers of *N*-acetyl-*β*-D-mannosaminyl-L-rhamnoses, **9**, **14**, and **19**.

Results and Discussion

Synthesis of *β*-D-ManNAc-(1→4)-L-Rha (9), a Repeating Unit of the O-Antigens from *Pseudomonas cepacia* O5, *Pseudomonas aeruginosa* X (Meitert), and *Aeromonas salmonicida* A trisaccharide sequence, α-D-Glc-(1→3)-[*β*-D-ManNAc-(1→4)]-L-Rha, representing the repeating unit of the O-specific chain of the LPS of *Aeromonas salmonicida* has been synthesized[5] by elaboration of the mannosamine portion from the 3,4,6-tri-*O*-acetyl-2-azido-

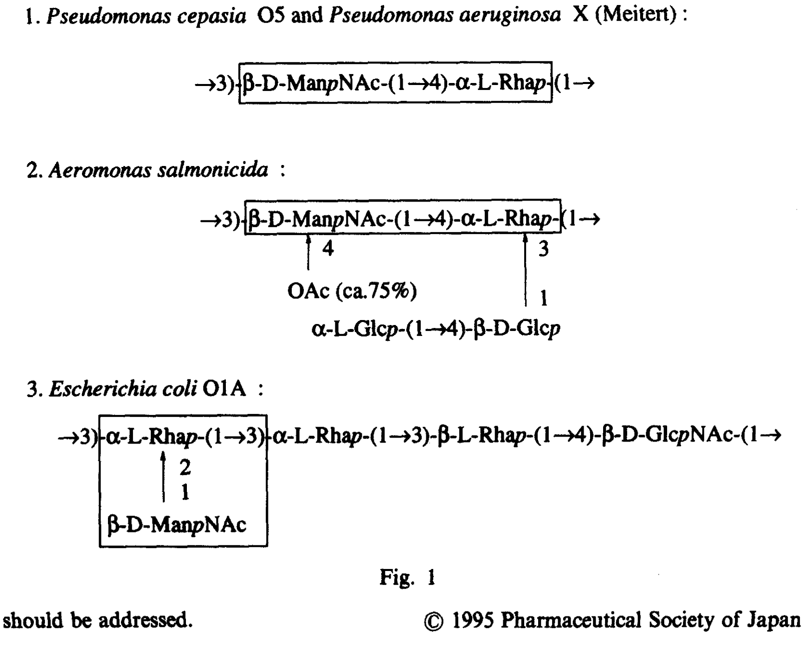

Fig. 1

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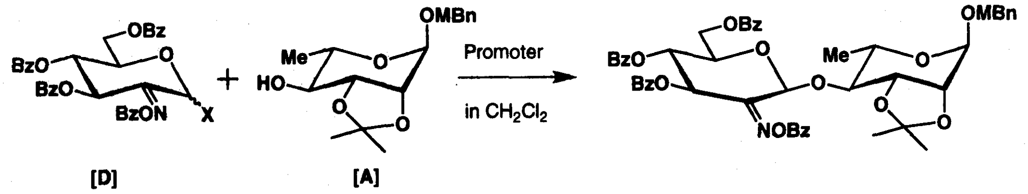
2-deoxy-α-D-mannopyranosyl bromide.[6] The method has several disadvantages. 1) The preparation of the 2-azido-2-deoxysugar unit entails 6 steps from D-glucose, affording only 30% overall yield with laborious manipulation. 2) The β-selectivity is poor in the glycosylation of a partially protected L-rhamnose acceptor having a free 4-OH group. 3) The yield of the β-glycoside is only 27%, while the undesired α-anomer was formed simultaneously in 55% yield.

In consequence, another more practical method should be developed for the straightforward assembly of the β-D-ManNAc-(1→4)-L-Rha unit. On the basis of ample evidence[7,8] that 2-(benzoyloxyimino)-2-deoxyglycosyl halides are useful glycosyl donors for the construction of *N*-acetyl-β-D-mannosamine-containing oligosaccharides, we evaluated the donor capacity of various 2-(benzoyloxyimino)-2-deoxyglycosyl derivatives, such as the bromide[9] (**1**), iodide[10] (**2**), and diethyl dithiocarbamate (**3**), in the β-selective glycosylation of 4-OH of a rhamnosyl acceptor, namely 4-methoxybenzyl 2,3-*O*-isopropylidene-α-L-rhamnopyranoside[11] (**4**).

The results of glycosylation of **4** with these donors in the presence of several promoters are summarized in Table 1. When the bromide **1**, readily accessible from D-glucose in a high-yield (59%), 6-step sequence,[9] was employed for glycosylation (Ag_2CO_3–I_2/CH_2Cl_2) of **4**, good β-selectivities in the 20 : 1 range were obtained, providing the expected β-glycosylated disaccharide **5** in yields of 24—30% (entries 1—3, in Table 1). The use of a highly active silver zeolite catalyst (silver aluminosilicate)[12] proved to be more propitious, affording good β-selectivity and higher yields of more than 50% (entries 5 and 6). Under these conditions, the reaction time required could be reduced from 48 h to only 3 h. The effects of leaving groups are not particularly marked: the iodide **2** was not superior to the bromide (entries 7—9). Although *N*,*N*-dialkyl dithiocarbamates have been suggested as good leaving groups for glycosylation,[13] the *N*,*N*-diethyl dithiocarbamate **3** resulted in only partial predominance of the β-glycoside with a very low yield of around 10% (entries 10 and 11). These results imply that the 2-(benzoyloxyimino)-2-deoxyglycosyl bromide **1** was selectively glycosidated with the alcohol component **4** in preference to the β-anomer under the insoluble, silver-salt-promoted conditions, as previously observed.[8,14] The active silver zeolite proved to be useful for *S*N2 mode glycosidation of the glycosyl bromide **1** having no participating group at the C-2 position, as rationalized by van Boeckel *et al.*[12]

The β-configuration of the uloside portion of **5** was unequivocally assigned on the basis of its ^{1}H-NMR spectra. The respective $J_{3',4'}$ and $J_{4',5'}$ values of 3.5 and 6.5 Hz reflect the conformational distortion of the pyran ring towards the twist-boat form, originating from the steric congestion between the 2-benzoyloxyimino group and the aglycon. This steric propensity has been observed exceptionally for the β-anomers of compounds of this type.[7,8]

The β(1→4) disaccharide **5** was then subjected to hydroboration with a twelve-fold molar excess of borane–tetrahydrofuran ($BH_3 \cdot THF$) complex in tetrahydrofuran (THF) to afford, on *N*-acetylation, the expected *N*-acetyl-β-D-mannosaminyl-(1→4)-L-rhamnoside **6** in 61% yield. The epimeric β-D-glucosaminyl isomer was not isolated from the reaction mixture so that the oxime reduction was almost stereospecific. Such high *manno*-selectivity may be anticipated from the stereochemical demand that BH_3 attacks from the α-side of **5**, entailing the formation of



[D]

1 : X = α-Br
2 : X = α-I
3 : X = β-SCNEt$_2$ $\beta\text{-S}\underset{\underset{\text{S}}{\|}}{\text{C}}\text{NEt}_2$

[A]

4

5

Table 1. Glycosidation of β-D-Mannosaminyl Donors (1—3) with 4-Methoxybenzyl 2,3-*O*-Isopropylidene-α-L-rhamnopyranoside (4)

Entry	Donor	Equiv. (D : A)	Promoter	Conditions	Yield (%) 5	α : β[a]
1	**1**	1.0 : 1.2	Ag_2CO_3/I_2	r.t., 2 d	24	1 : 20
2	**1**	1.0 : 1.5	Ag_2CO_3/I_2	r.t., 2 d	28	1 : 20
3	**1**	1.5 : 1.0	Ag_2CO_3/I_2	r.t., 2 d	30	1 : 20
4	**1**	1.3 : 1.0	Ag^+/zeolite	r.t., 3 h	33	1 : 20
5	**1**	1.5 : 1.0	Ag^+/zeolite	r.t., 3 h	50	1 : 20
6	**1**	2.0 : 1.0	Ag^+/zeolite	r.t., 3 h	52	1 : 20
7	**2**	1.0 : 1.2	Ag_2CO_3	r.t., 2 d	23	1 : 20
8	**2**	1.0 : 1.5	Ag_2CO_3	r.t., 2 d	28	1 : 20
9	**2**	1.5 : 1.0	Ag_2CO_3	r.t., 2 d	30	1 : 20
10	**3**	1.2 : 1.0	AgOTf/DTBP[b]	r.t., 2 h	10	1 : 5
11	**3**	1.0 : 1.2	AgOTf/DTBP[b]	r.t., 2 h	12	1 : 5

a) Anomeric ratios were estimated by ^{1}H-NMR integration of the respective anomeric protons. *b*) DTBP = 2,6-di-*tert*-butylpyridine. r.t. = room temperature.

1,2-*cis*-amino sugars with *β*-D-*manno* configuration, since *β*-side attack is hindered by the *β*-oriented bulky aglycon.[7)]

The configuration of the amino sugar moiety in **6** was deduced to be *β*-D-*manno* from the respective couplings $J_{1',2'}$, $J_{2',3'}$, $J_{3',4'}$, and $J_{4',5'}$ of 1.5, 4, 10, and 10 Hz. These data reflect a–e–a–a–a orientations for the ring protons H-1′, 2′, 3′, 4′, and 5′, corresponding to *β*-D-mannnopyranoside with $^4C_1$ conformation.

The subsequent de-*O*-benzoylation of **6** was smoothly effected with 0.05 M sodium methoxide in methanol to furnish **7** (33%) along with the 2,3-de-*O*-isopropylidenated product **8** (49%) generated by further deblocking of **7**. The mixture of **7** and **8** was hydrolyzed with 95% trifluoroacetic acid, providing the target disaccharide **9** in 82% yield. The structure of **9** was confirmed by the ^{1}H- and ^{13}C-NMR spectra as described in the last section. The anomeric ratio of the reducing end of **9** in D_2O solution was estimated to be $\alpha:\beta=2:1$ (^{1}H-NMR).

Synthesis of *β*-D-ManNAc-(1→3)-L-Rha (14) and *β*-D-

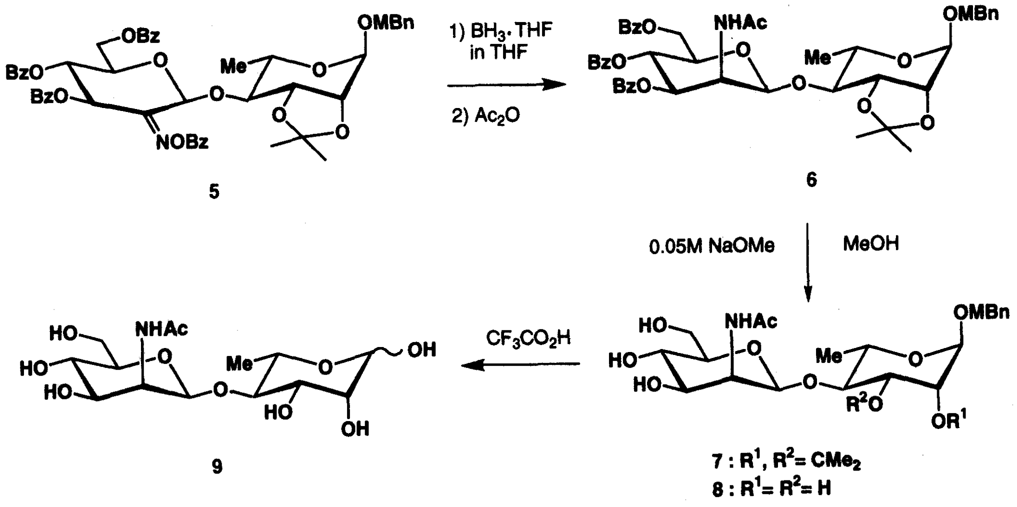


Chart 1

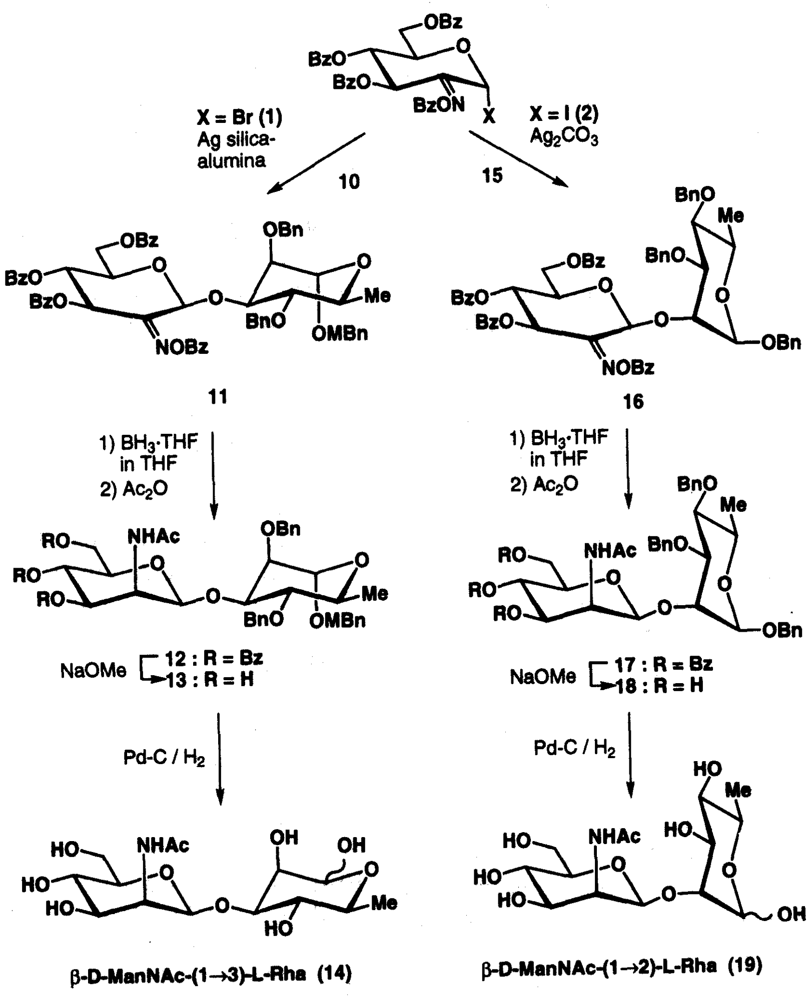


Chart 2

ManNAc-(1→2)-L-Rha (19), a Constituent of LPS from *Escherichia coli* O1A Replacing the glycosyl acceptor in the above glycosidation 1→5 with a suitably protected L-rhamnoside possessing a free 3-OH group similarly gave the desired disaccharide in preparatively useful fashion. Thus, 4-methoxybenzyl 2,4-di-*O*-benzyl-α-L-rhamnopyranoside[11] (**10**) was glycosylated with the bromide **1** in the presence of silver zeolite in dichloromethane to give the β(1→3) disaccharide **11** in a yield of 72% with high β-selectivity ($\beta:\alpha=20:1$, ^{1}H-NMR). Use of the iodide **2** as a glycosyl donor for glycosylation of **10** gave **11** in a low yield of 24% by promotion with silver carbonate in dichloromethane. The disaccharide **11** was then subjected to hydroboration followed by *N*-acetylation as described for **6**, affording **12** in 59% yield; the β-D-*gluco* epimer was not detected. The β-D-*manno* structure of the amino sugar portion of **12** was determined by ^{1}H-NMR spectroscopy, in the same manner as described for **6**. De-*O*-benzoylation of **12** with 0.05 M sodium methoxide gave **13** in 96% yield, and deblocking of the *O*-benzyl groups by catalytic hydrogenolysis provided β-D-ManNAc-(1→3)-L-Rha (**14**) in 89% yield. The anomeric composition of the reducing end of **14** in D_2O solution was estimated to be $\alpha:\beta=3:1$ by ^{1}H-NMR spectroscopy.

Assembly of another disaccharide, β-D-ManNAc-(1→2)-L-Rha (**19**), was commenced by glycosylation of benzyl 3,4-di-*O*-benzyl-α-L-rhamnopyranoside (**15**), a suitably protected L-rhamnosyl acceptor possessing a free 2-OH group, with the glycosyl donor **1** or **2**. In this case the β(1→2) disaccharide **16** could be secured in 55% yield by the use of the glycosyl iodide **2** as a glycosyl donor, while the bromide **1** also gave **16** in 54% yield by glycosylation of **15** in dichloromethane in the presence of an active silver zeolite catalyst.[12] Subsequent hydroboration was carried out as described for **11**→**12** to provide the fully protected β-D-mannosamine-containing disaccharide **17** in 70% yield, in an essentially stereospecific manner. Sodium methoxide-catalyzed de-*O*-benzoylation of **17** was smoothly effected to give **18** in 75% yield. The concluding de-*O*-benzylation of **18** was done by hydrogenolysis with palladium on carbon to afford the desired disaccharide, β-D-ManNAc-(1→2)-L-Rha (**19**) in a quantitative yield. The anomeric ratio of the reducing end of **19** was estimated to be $\alpha:\beta=3:1$ by ^{1}H-NMR in D_2O solution.

Structural Analyses of *N*-Acetyl-β-D-mannosaminyl-L-rhamnoses by NMR Spectroscopy The structures of the three isomeric disaccharides **9**, **14**, and **19** were elucidated on the basis of their ^{1}H- and ^{13}C-NMR spectra. In particular, their nuclear Overhauser and exchange spectroscopy (NOESY) spectra were useful to identify the interglycosidic linking modes between the constituent sugar units. As evidenced by the NOESY data in Fig. 2, distinct cross peaks for two dimensional (2D)-NOESY were observed between H-1′ and H-4 for **9α**,[15] H-1′ and H-3 for **14α**,[15] and H-1′ and H-2 for **19α**,[15] which are consistent with the expected glycosylating link-up. The β-configuration of the ManNAc portion was supported by the above data as well as 1,3-diaxial interactions between protons 1′–3′, 1′–5′, and 3′–5′, as shown in Fig. 2. In contrast, only adjacent protons in 1,2-*cis*-relationships exhibited the respective cross peaks between protons 1–2 and 2–3.

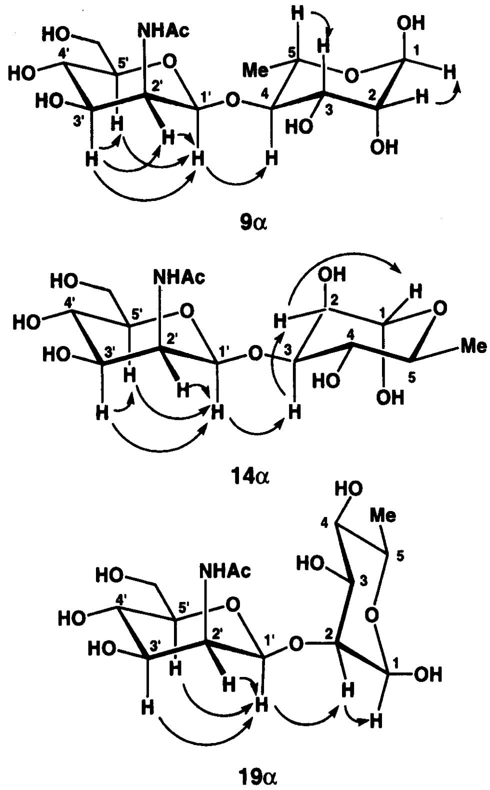


Fig. 2. NOESY Data for the Disaccharides **9α**, **14α**, and **19α**

^{13}C-NMR spectra of **9**, **14**, and **19** provided decisive information on the glycosylation sites as well as the anomeric configurations of the L-rhamnose portion; the following spectral features are worthy of note. 1) The chemical shifts of the glycosylation sites were observed at $\delta=80$—83 ppm, *i.e.*, *ca.* 10 ppm lower than those of non-glycosylating sites, and agree well with those of the corresponding natural products (Table 2, in italic). 2) In the α-anomers of the L-rhamnose moieties, the chemical shifts of C-3 and C-5 appeared at higher magnetic field than those of the corresponding β-anomers. A calculation of differences of ^{13}C-chemical shifts of C-3 and C-5 ($\Delta\delta$) by $\delta\alpha-\delta\beta$ amounts to 2.3—4.0 ppm, conceivably due to the stereochemical effect[16] of the axially oriented hydroxyl group at C-1 in the α-anomers. The respective $\Delta\delta$ values are underlined in the table. These findings were helpful in the structural elucidation of the disaccharide composed of *N*-acetyl-β-D-mannosaminyl-L-rhamnose units.

Conclusion

The concise, practical routes reported here appear to be the most straightforward methodology currently available for the chemical syntheses of *N*-acetyl-β-D-mannosaminyl-L-rhamnoses. The utility of this method was amply demonstrated: the three positional isomers with respect to the intersaccharide linkages were accessible by simple 10-step reaction sequences from D-glucose, in 13% overall yield for β-D-ManNAc-(1→4)-L-Rha (**9**), 23% overall yield for β-D-ManNAc-(1→3)-L-Rha (**14**), and 17% overall yield for β-D-ManNAc-(1→2)-L-Rha (**19**). This method should also be applicable to the synthesis of oligosaccha-

Table 2. ^{13}C-NMR Data for Synthetic β(1→4) Disaccharide **9**, β(1→3) **14**, and β(1→2) **19** of *N*-Acetyl-β-D-mannosaminyl-L-rhamnoses

Compd.	α/β-L-Rha						β-D-ManNAc						
	1	2	3	4	5	6	1′	2′	3′	4′	5′	6′	NAc
9α	94.73	71.86	70.57	*80.77*	67.76	17.79	100.8	54.33	72.93	67.49	77.02	61.14	22.80
9β	94.30	72.34	73.37	*80.23*	71.46	17.79	100.7	54.33	72.93	67.49	77.02	61.44	22.80
$\Delta\delta$ ($\alpha-\beta$)	+0.43	−0.48	$\underline{-2.80}$	+0.54	$\underline{-3.70}$	0.00	+0.1	0.00	0.00	0.00	0.00	0.00	0.00
14α	94.60	71.26	*80.60*	71.79	69.09	17.69	101.5	54.22	73.08	67.46	77.11	61.19	22.93
14β	94.12	71.75	*82.93*	72.55	71.46	17.66	101.4	54.22	73.08	67.46	77.11	61.19	22.93
$\Delta\delta$ ($\alpha-\beta$)	+0.48	−0.49	$\underline{-2.33}$	−0.76	$\underline{-2.37}$	+0.03	+0.1	0.00	0.00	0.00	0.00	0.00	0.00
19α	93.91	*80.43*	70.43	73.21	69.10	17.74	101.5	54.10	72.46	67.45	76.94	61.16	22.84
19β	93.28	*81.89*	73.26	72.71	73.05	17.66	100.8	53.97	72.46	67.33	77.22	61.04	22.84
$\Delta\delta$ ($\alpha-\beta$)	+0.63	−1.46	$\underline{-2.83}$	+0.50	$\underline{-3.95}$	+0.08	+0.7	+0.13	0.00	+0.12	−0.28	+0.12	0.00
Natural β(1→2)[a]	102.05	*77.81*	*79.94*	72.13	70.02	17.49	100.67	53.92	72.92	67.78	77.02	61.43	22.89
Natural β(1→4)[b]	96.63	70.52	70.14	*79.59*	67.36	16.85	99.62	49.67	75.97	65.00	76.09	60.32	21.83
Natural β(1→4)[c]	97.8	71.8	71.3	*80.9*	68.5	18.0	100.7	50.9	77.2	66.4	77.3	61.7	—

a) *E. coli* O1A polysaccharide.[4] *b*) *Ps. cepacia* O5 polysaccharide.[1] *c*) *Ps. aeruginosa* X (Meitert) polysaccharide.[2]

ride repeating units of O-antigens from other opportunistic pathogens involving methycillin-resistant *Staphylococcus aureus* (MRSA).[17]

Experimental

Melting points were measured on a Yamato MP-1 apparatus and a Yanagimoto micro melting point apparatus, and are uncorrected. Spectral data were recorded on the following instruments; IR, Jasco IR 810 spectrophotometer; $[\alpha]_D$, Jasco DIP-150 digital polarimeter; MS, JMS DX300 mass spectrometer; ^{1}H- and ^{13}C-NMR, Varian VXR-300 and XL-400 spectrometers. TLC was done on Merck Silica gel 60 F_{254} with the same solvent systems as used for column chromatography. The spots were visualized under UV light (254 nm) or by charring with 10% aqueous H_2SO_4. Column chromatography was achieved on Merck Silica gel 60 (70—230 mesh) and Kanto Kagaku silica gel (up to 100 mesh).

3,4,6-Tri-*O*-benzoyl-2-(benzoyloxyimino)-2-deoxy-*β*-D-*arabino*-hexopyranosyl *N*,*N*-Diethyldithiocarbamate (3) A mixture of sodium *N*,*N*-diethyldithiocarbamate (446 mg, 1.98 mmol) and molecular sieves (3 Å, 1.0 g) in dry acetone (2.0 ml) was stirred at room temperature for 1 h. 2-(Benzoyloxyimino)glycosyl bromide[9] (1.33 g, 2.0 mmol) was then added, and the whole was further stirred for 0.5 h, filtered through a pad of Celite, and concentrated to dryness. The residue was diluted with CH_2Cl_2 (30 ml) and washed with H_2O (3 × 10 ml). Drying and concentration gave a syrup, which was eluted from a silica gel column with MeC_6H_5–EtOAc (10 : 1). The major fraction was concentrated and crystallized from Et_2O–pentane to afford 1.27 g (86%) of **3** as colorless crystals, mp 78—79 °C, $[\alpha]_D^{20}$ +83.3° (c=0.5, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.15, 1.30 (3H each, t, $CH_2C\underline{H}_3$), 3.59, 3.67 (1H each, q, $C\underline{H}_2CH_3$), 3.99, 4.10 (1H, q, $C\underline{H}_2CH_3$), 4.24 (1H, dd, H-5), 4.63 (1H, dd, H-6a), 4.71 (1H, dd, H-6b), 5.74 (1H, dd, H-4), 6.23 (1H, d, H-3); $J_{3,4}=2$, $J_{4,5}=8$, $J_{5,6a}=6$, $J_{5,6b}=4$, $J_{6a,6b}=12$ Hz. ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 11.42, 12.57 (2 × $CH_2\underline{C}H_3$), 47.14, 50.81 (2 × $\underline{C}H_2CH_3$), 64.18 (C-6), 70.95 (C-3), 71.04 (C-4), 76.00 (C-5), 81.64 (C-1), 158.82 (C-2), 189.98 (C=S). MS (FAB) m/z: 741 $[M+1]^+$, 763 $[M+Na]^+$.

4-Methoxybenzyl 2,3-*O*-Isopropylidene-4-*O*-[3,4,6-tri-*O*-benzoyl-2-(benzoyloxyimino)-2-deoxy-*β*-D-*arabino*-hexopyranosyl]-*α*-L-rhamnopyranoside (5) Promotion by Ag^+/Zeolite: A mixture of 4-methoxybenzyl-2,3-*O*-isopropylidene-α-L-rhamnopyranoside[11] (**4**) (64.6 mg, 0.2 mmol), molecular sieves (4 Å, 400 mg), and silver aluminosilicate catalyst[12] (125 mg, 0.4 mmol) in dry CH_2Cl_2 (4 ml) was stirred in the dark under an N_2 atmosphere at room temperature for 15 min. 2-(Benzoyloxyimino)glycosyl bromide[9] (**1**) (202 mg, 0.30 mmol) was then added, and the whole was further stirred at ambient temperature for 3 h. After dilution with CH_2Cl_2 (20 ml) the mixture was filtered through a pad of Celite, and the filtrate was washed with H_2O (2 × 20 ml), dried (Na_2SO_4), and evaporated to dryness. The residue was purified by elution from a silica gel column with MeC_6H_5–EtOAc (10 : 1). The major fraction was concentrated to provide 90 mg (50%) of **5** as a colorless syrup, which was crystallized from Et_2O–pentane, mp 72—74 °C, $[\alpha]_D^{25}$ −19.2° (c=0.2, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.32 (3H, d, H-6), 1.36, 1.49 (3H each, s, CMe_2), 3.76 (1H, m, H-5), 3.78 (3H, s, OMe), 3.95 (1H, dd, H-4), 4.05 (1H, d, H-2), 4.24 (1H, ddd, H-5′), 4.35 (1H, dd, H-3), 4.40, 4.58 (1H each, d, $PhC\underline{H}_2$), 4.69 (1H, dd, H-6′a), 4.82 (1H, dd, H-6′b), 5.02 (1H, s, H-1), 5.84 (1H, dd, H-4′), 6.14 (1H, d, H-3′), 6.78 (1H, s, H-1′); $J_{1,2}<1$, $J_{2,3}=6$, $J_{3,4}=7$, $J_{4,5}=9.5$, $J_{5,6}=6.5$, $J_{3',4'}=3.5$, $J_{4',5'}=6.5$, $J_{5',6'a}=7$, $J_{5',6'b}=5$, $J_{6'a,6'b}=11.5$ Hz. ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 17.59 (C-6), 26.55, 27.89 ($C\underline{Me}_2$), 55.26 (OMe), 63.94 (C-5), 64.39 (C-6′), 68.77 ($Ph\underline{C}H_2$), 70.10 (C-3′), 70.19 (C-4′), 72.26 (C-5′), 76.27 (C-2), 78.04 (C-3), 91.15 (C-1′), 95.55 (C-1), 109.5 ($\underline{C}Me_2$). MS (FAB) m/z: 916 $[M+1]^+$, 938 $[M+Na]^+$. *Anal.* Calcd for $C_{51}H_{49}NO_{15}$: C, 66.88; H, 5.39; N, 1.53. Found: C, 66.86; H, 5.29; N, 1.51.

Promotion by AgOTf–DTBP: To a stirred solution of the carbamate **3** (74.1 mg, 0.10 mmol) and the rhamnoside **4** (39.2 mg, 0.12 mmol) in dry CH_2Cl_2 (1.0 ml) with molecular sieves (3 Å, 100 mg) were added AgOTf (116 mg, 0.45 mmol) and 2,6-di-*tert*-butylpyridine (DTBP) (0.02 ml, 0.10 mmol). The reaction mixture was stirred in the dark at room temperature for 2 h, then triethylamine (0.02 ml) was added, and the whole was filtered through a pad of Celite. The filtrate was evaporated to dryness and the residue was eluted from a silica gel column with MeC_6H_5–AcOEt (10 : 1) to give 11.2 mg (12%) of **5** as a colorless syrup contaminated with the corresponding α-anomer. The anomeric ratio was estimated to be $\alpha:\beta=ca.$ 1 : 5 by ^{1}H-NMR. ^{1}H-NMR (300 MHz, $CDCl_3$) β-anomer: described above for **5**; α-anomer δ: 5.06 (1H, s, H-1), 6.08 (1H, dd, H-4′), 6.31 (1H, s, H-1′), 6.39 (1H, d, H-3′); $J_{3',4'}=10$, $J_{4',5'}=7.5$ Hz. Other protons were difficult to assign owing to overlapping of the signals with those of the major β-anomer protons.

4-Methoxybenzyl 2,3-*O*-Isopropylidene-4-*O*-(2-acetamido-3,4,6-tri-*O*-benzoyl-2-deoxy-*β*-D-mannopyranosyl)-*α*-L-rhamnopyranoside (6) A 1 M solution of $BH_3 \cdot THF$ complex in THF (7.8 ml) was added dropwise to a solution of the disaccharide **5** (595 mg, 0.65 mmol) in THF (8.0 ml) at −10 °C under an atmosphere of N_2. The mixture was stirred at this temperature for 0.5 h and then allowed to warm up to room temperature. After further stirring for 2 h, excess reductant was quenched with MeOH (5 ml) followed by *N*-acetylation through stirring with Ac_2O (3 ml) for another 1 h at ambient temperature. The resulting mixture was passed through a basic resin (Amberlite IR-45), and washed with MeOH. The eluate was concentrated *in vacuo* and the residue was purified by elution from a silica gel column with $CHCl_3$–EtOAc (1 : 1). The major fraction was concentrated and the residue was crystallized from Et_2O–pentane, providing 335 mg (61%) of **6** as a colorless powder, mp 99—102 °C, $[\alpha]_D^{25}$ −55.1° (c=0.2, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.24 (3H, d, H-6), 1.33, 1.45 (3H each, s, CMe_2), 1.99 (3H, s, NAc), 3.65 (1H, dd, H-4), 3.72 (1H, dq, H-5), 3.80 (3H, s, OMe), 4.03 (1H, ddd, H-5′), 4.11 (1H, d, H-2), 4.20 (1H, dd, H-3), 4.22, 4.61 (1H each, d, $PhC\underline{H}_2$), 4.50 (1H, dd, H-6′a), 4.64 (1H, dd, H-6′b), 4.96 (1H, ddd, H-2′), 5.01 (1H, s, H-1), 5.43 (1H, d, H-1′), 5.49 (1H, dd, H-3′), 5.63 (1H, dd, H-4′), 5.80 (1H, d, NH); $J_{1,2}<1$, $J_{2,3}=6$, $J_{3,4}=6$, $J_{4,5}=10.5$, $J_{5,6}=6$, $J_{1',2'}=1.5$, $J_{2',3'}=4$, $J_{3',4'}=J_{4',5'}=10$, $J_{5',6'a}=6$, $J_{5',6'b}=3.5$, $J_{6'a,6'b}=12$ Hz. ^{13}C-NMR (75 MHz, CDCl) δ: 17.47 (C-6), 23.22 (NAc), 26.27, 27.93 ($C\underline{Me}_2$), 51.09 (C-2′), 55.27 (OMe), 63.31 (C-6′), 63.80 (C-5), 67.61 (C-4′), 68.64 ($Ph\underline{C}H_2$), 72.35 (C-3′), 72.70 (C-5′), 76.19 (C-2), 77.94 (C-3), 78.47 (C-4), 95.59 (C-1), 97.00 (C-1′). MS (FAB) m/z: 840 $[M+1]^+$, 862 $[M+Na]^+$. *Anal.* Calcd for $C_{46}H_{49}NO_{14}$: C, 65.78; H, 5.88; N, 1.67. Found: C, 65.50; H, 5.71; N, 1.50.

4-Methoxybenzyl 2,3-*O*-Isopropylidene-4-*O*-(2-acetamido-2-deoxy-*β*-D-mannopyranosyl)-*α*-L-rhamnopyranoside (7) and 4-Methoxybenzyl 4-*O*-(2-Acetamido-2-deoxy-*β*-D-mannopyranosyl)-*α*-L-rhamnopyranoside (8) A solution of **6** (210 mg, 0.25 mmol) in 0.05 M NaOMe in MeOH (5.0 ml) was stirred at room temperature for 1 h. Subsequent neutralization with an acidic resin (Dowex 50 W X2, H^+ type), filtration, and evaporation *in vacuo* gave a residue, which was eluted from a silica gel column with $CHCl_3$–MeOH (6:1) to afford, after concentration, 44 mg (33%) of **7** as a colorless syrup. Further elution from the column with MeOH, evaporation of the eluate, and washing of the residue with Et_2O gave 60 mg (49%) of **8** as a hygroscopic colorless powder.

7: $[\alpha]_D^{23}$ −78.4° (c=0.2, $CHCl_3$). ^{1}H-NMR (300 MHz, D_2O) δ: 1.15 (3H, d, H-6), 1.21, 1.42 (3H each, s, CMe_2), 1.96 (3H, s, NAc), 3.32 (1H, m, H-5′), 3.46 (1H, dd, H-4′), 3.60 (1H, dq, H-5), 3.60 (3H, s, OMe), 3.64 (1H, m, H-4), 3.70 (1H, dd, H-3′), 3.78 (2H, br m, H-6′a, 6′b), 3.99 (1H, d, H-2), 4.06 (1H, dd, H-3), 4.28, 4.44 (1H each, d, $PhC\underline{H}_2$), 4.39 (1H, dd, H-2′), 4.91 (1H, s, H-1), 4.94 (1H, d, H-1′); $J_{1,2}=0$, $J_{2,3}=5.5$, $J_{3,4}=7$, $J_{5,6}=7$, $J_{1',2'}<1$, $J_{2',3'}=4.5$, $J_{3',4'}=J_{4',5'}=9.5$ Hz. ^{13}C-NMR (75 MHz, D_2O) δ: 20.57 (C-6), 25.83 (NAc), 29.52, 30.95 (CMe_2), 57.36 (C-2′), 59.01 (OMe), 64.03 (C-6′), 68.43 (C-5), 70.53 (C-4′), 72.85 ($Ph\underline{C}H_2$), 76.27 (C-3′), 79.62 (C-2), 80.20 (C-5′), 81.10 (C-4), 81.35 (C-3), 99.36 (C-1), 101.12 (C-1′). MS (FAB) *m/z*: 528 $[M+1]^+$, 550 $[M+Na]^+$.

8: mp 109—114 °C, $[\alpha]_D^{24}$ −66.0° (c=1.1, MeOH). ^{1}H-NMR (300 MHz, D_2O) δ: 1.22 (3H, d, H-6), 1.97 (3H, s, NAc), 3.29 (1H, ddd, H-5′), 3.46 (1H, dd, H-4′), 3.60 (1H, dd, H-4), 3.64 (1H, m, H-5), 3.73 (1H, dd, H-3′), 3.73 (1H, dd, H-3), 3.74 (3H, s, OMe), 3.81 (1H, dd, H-6′a), 3.83 (1H, d, H-2), 3.85 (1H, dd, H-6′b), 4.41, 4.53 (1H each, d, $PhC\underline{H}_2$), 4.46 (1H, dd, H-2′), 4.78 (1H, s, H-1), 4.90 (1H, d, H-1′); $J_{1,2}=1.5$, $J_{2,3}=3$, $J_{3,4}=J_{4,5}=9$, $J_{5,6}=5.5$, $J_{1',2'}=1$, $J_{2',3'}=4$, $J_{3',4'}=J_{4',5'}=9$, $J_{5',6'a}=4.5$, $J_{5',6'b}=2.5$ Hz. ^{13}C-NMR (75 MHz, D_2O) δ: 20.65 (C-6), 25.86 (NAc), 57.36 (C-2′), 59.25 (OMe), 64.21 (C-6′), 70.54 (C-4′), 71.23 (C-5), 73.18 ($Ph\underline{C}H_2$), 74.06 (C-3), 74.31 (C-2), 76.03 (C-3′), 80.06 (C-5′), 83.53 (C-4), 103.17 (C-1), 103.75 (C-1′). MS (FAB) *m/z*: 488 $[M+1]^+$, 510 $[M+Na]^+$, 532 $[M+2Na-2]^+$.

4-*O*-(2-Acetamido-2-deoxy-*β*-D-mannopyranosyl)-*α*-L-rhamnopyranose (9) A solution of a mixture of **7** (42 mg, 0.08 mmol) and **8** (49 mg, 0.10 mmol) in 95% aq. CF_3CO_2H (2.0 ml) was stirred at ambient temperature for 20 min. Evaporation of the mixture was followed by coevaporation with MeOH to give a residue, which was purified by elution from a silica gel column with $CHCl_3$–MeOH–H_2O (5:4:1). The major fraction was concentrated to dryness, and the residue was lyophilized to furnish 54 mg (82%) of **9** as a colorless powder. The α/β-anomeric ratio of the reducing end was estimated as 2:1 by ^{1}H-NMR in D_2O, mp 144—146 °C, $[\alpha]_D^{21}$ −56.3° (c=0.25, MeOH). α-Anomer: ^{1}H-NMR (300 MHz, D_2O) δ: 1.23 (3H, d, H-6), 2.00 (3H, s, NAc), 3.31 (1H, ddd, H-5′), 3.46 (1H, dd, H-4′), 3.60 (1H, dd, H-4), 3.75 (1H, dd, H-3′), 3.80 (1H, dd, H-6′a), 3.81 (1H, dd, H-6′b), 3.84 (1H, dd, H-2), 4.47 (1H, dd, H-2′), 4.92 (1H, d, H-1′), 5.01 (1H, d, H-1); $J_{1,2}=1.5$, $J_{2,3}=4$, $J_{3,4}=J_{4,5}=9.5$, $J_{5,6}=6$, $J_{1',2'}=1.5$, $J_{2',3'}=4$, $J_{3',4'}=9.5$, $J_{4',5'}=10$, $J_{5',6'a}=4$, $J_{5',6'b}=2$, $J_{6'a,6'b}=12$ Hz. ^{13}C-NMR (75 MHz, D_2O) δ: see Table 2. β-Anomer: ^{1}H-NMR (300 MHz, D_2O) δ: 1.25 (3H, d, H-6), 1.99 (3H, s, NAc), 3.36 (1H, ddd, H-5′), 3.54 (1H, dd, H-4), 3.62 (1H, dd, H-3), 3.84 (1H, dd, H-2), 3.85 (1H, dd, H-3′), 3.80 (1H, dd, H-6′a), 3.81 (1H, dd, H-6′b), 3.84 (1H, dd, H-2), 3.85 (1H, dd, H-6′b), 4.47 (1H, dd, H-2′), 4.76 (1H, d, H-1), 4.92 (1H, d, H-1′); $J_{1,2}=1$, $J_{2,3}=4$, $J_{3,4}=J_{4,5}=9.5$, $J_{5,6}=6$, $J_{1',2'}=1.5$, $J_{2',3'}=4$, $J_{5',6'b}=2$, $J_{6'a,6'b}=12$ Hz. ^{13}C-NMR (75 MHz, D_2O) δ: see Table 2. MS (FAB) *m/z*: 368 $[M+1]^+$, 390 $[M+Na]^+$. *Anal.* Calcd for $C_{14}H_{25}NO_{10} \cdot 3H_2O$: C, 39.90; H, 7.36; N, 3.33. Found: C, 39.83; H, 6.95; N, 3.15.

4-Methoxybenzyl 2,4-Di-*O*-benzyl-3-*O*-[3,4,6-tri-*O*-benzoyl-2-(benzoyloxyimino)-2-deoxy-*β*-D-*arabino*-hexopyranosyl]-*α*-L-rhamnopyranoside (11) Use of Glycosyl Bromide **1**: A suspension of 4-methoxybenzyl 2,4-di-*O*-benzyl-α-L-rhamnopyranoside[11)] (**10**) (46.4 mg, 0.1 mmol), molecular sieves (4 Å, 200 mg), and silver zeolite[12)] (62.5 mg, 0.2 mmol), in dry CH_2Cl_2 (2.0 ml) was stirred in the dark under an atmosphere of N_2 at room temperature for 15 min. The glycosyl bromide **1**[9)] (100 mg, 0.15 mmol) was then added, and the whole was further stirred at ambient temperature for 2.5 h. Dilution of the mixture with CH_2Cl_2, filtration through a pad of Celite, consecutive washing with 5% aqueous Na_2CO_3 and H_2O, drying (Na_2SO_4), and evaporation of the solvent gave a colorless syrup, which was purified by elution from a silica gel column with MeC_6H_5–EtOAc (5:1). Concentration of the major fraction and crystallization from Et_2O–pentane provided 76 mg (72%) of **11** as a colorless powder, mp 55—57 °C, $[\alpha]_D^{26}$ −39.9° (c=1.4, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.25 (3H, d, H-6), 3.61 (1H, dd, H-4), 3.71 (1H, m, H-5), 3.80 (3H, s, OMe), 4.05 (1H, d, H-2), 4.15 (1H, m, H-5′), 4.33, 4.57 (1H each, d, $PhC\underline{H}_2$), 4.35, 4.59 (1H each, d, $PhC\underline{H}_2$), 4.37 (1H, dd, H-3), 4.62, 4.83 (1H each, d, $PhC\underline{H}_2$), 4.67 (1H, dd, H-6′a), 4.80 (1H, s, H-1), 4.84 (1H, dd, H-6′b), 5.91 (1H, dd, H-4′), 6.20 (1H, d, H-3′), 6.24 (1H, s, H-1′); $J_{1,2}=2$, $J_{2,3}=3.5$, $J_{3,4}=J_{4,5}=9$, $J_{5,6}=6$, $J_{3',4'}=3$, $J_{4',5'}=7.5$, $J_{5',6'a}=4$, $J_{5',6'b}=5.5$, $J_{6'a,6'b}=12$ Hz. ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 18.03 (C-6), 55.25 (OMe), 63.96 (C-6′), 68.48 (C-5), 68.74, 72.97, 74.94 (3 × $Ph\underline{C}H_2$), 70.69 (C-4′), 71.78 (C-5′), 78.10 (C-2), 78.77 (C-4), 84.31 (C-3), 95.77 (C-1′), 96.75 (C-1), 157.2 (C-2′). MS (FAB) *m/z*: 1056 $[M+1]^+$, 1078 $[M+Na]^+$. *Anal.* Calcd for $C_{62}H_{57}NO_{15}$: C, 70.51; H, 5.44; N, 1.33. Found: C, 70.20; H, 5.18; N, 1.30.

Use of Glycosyl Iodide **2**: The rhamnoside **10** (93 mg, 0.2 mmol) was glycosylated with glycosyl iodide **2**[10)] (216 mg, 0.3 mmol) in dry CH_2Cl_2 (4.0 ml) in the presence of Ag_2CO_3 (275 mg, 1.0 mmol) by stirring at room temperature for 4 h. After aqueous work-up as described above, the product was purified by elution from a silica gel column with MeC_6H_5–EtOAC (10:1) to furnish 51 mg (24%) of **11**.

4-Methoxybenzyl 2,4-Di-*O*-benzyl-3-*O*-(2-acetamido-3,4,6-tri-*O*-benzoyl-2-deoxy-*β*-D-mannopyranosyl)-*α*-L-rhamnopyranoside (12) A solution of the disaccharide **11** (633 mg, 0.6 mmol) in dry THF (7.2 ml) was treated with a 1 M solution of $BH_3 \cdot$THF complex in THF (7.2 ml) as described for **5**→**6**. Termination with MeOH (6 ml) and subsequent *N*-acetylation with Ac_2O (3 ml) followed by processing of the mixture as described for **6** gave a syrup, which was eluted from a silica gel column with $CHCl_3$–EtOAc (5:1), and crystallized from Et_2O–pentane to provide 346 mg (59%) of **12** as colorless crystals, mp 67—69 °C, $[\alpha]_D^{22}$ −27.4° (c=0.10, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.33 (3H, d, H-6), 1.85 (3H, s, NAc), 3.60 (1H, dd, H-4), 3.72 (1H, dq, H-5), 3.81 (3H, s, OMe), 3.89 (1H, d, H-2), 4.03 (1H, ddd, H-5′), 4.12 (1H, dd, H-3), 4.33, 4.52 (1H each, d, $PhC\underline{H}_2$), 4.41 (1H, dd, H-6′a), 4.56, 4.74 (1H each, d, $PhC\underline{H}_2$), 4.63, 4.75 (1H each, d, $PhC\underline{H}_2$), 4.67 (1H, dd, H-6′b), 4.73 (1H, s, H-1), 5.06 (1H, ddd, H-2′), 5.12 (1H, s, H-1′), 5.37 (1H, d, H-3′), 5.65 (1H, d, H-4′), 5.80 (1H, d, NH); $J_{1,2}=1.5$, $J_{2,3}=3.5$, $J_{3,4}=J_{4,5}=9$, $J_{5,6}=6$, $J_{1',2'}=1.5$, $J_{2',3'}=4$, $J_{3',4'}=J_{4',5'}=10$, $J_{5',6'a}=5.5$, $J_{5',6'b}=3$, $J_{5'a,6'b}=12$, $J_{2',NH}=8.5$ Hz. ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 18.01 (C-6), 23.12 (NAc), 51.37 (C-2′), 55.27 (OMe), 63.07 (C-6′), 67.11 (C-4′), 68.12 (C-5), 68.53, 73.44, 75.80 (3 × $Ph\underline{C}H_2$), 72.29 (C-3′), 72.48 (C-5′), 78.71 (C-2), 80.14 (C-4), 82.00 (C-3), 97.17 (C-1), 100.96 (C-1′). MS (FAB) *m/z*: 980 $[M+1]^+$, 1002 $[M+Na]^+$. *Anal.* Calcd for $C_{57}H_{57}NO_{14}$: C, 69.85; H, 5.86; N, 1.43. Found: C, 69.40; H, 5.73; N, 1.45.

4-Methoxybenzyl 2,4-Di-*O*-benzyl-3-*O*-(2-acetamido-2-deoxy-*β*-D-mannopyranosyl)-*α*-L-rhamnopyranoside (13) The disaccharide **12** (245 mg, 0.25 mmol) was de-*O*-benzoylated with 0.05 M NaOMe in dry MeOH (5.0 ml) as described for **6**→**7**. The crude product was purified by elution from a silica gel column with $CHCl_3$–MeOH (6:1) to afford 160 mg (96%) of **13** as a colorless syrup, $[\alpha]_D^{23}$ −79.4° (c=1.0, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.32 (3H, d, H-6), 1.85 (3H, s, NAc), 3.06 (1H, m, H-5′), 3.46 (1H, d, H-3′), 3.56 (1H, dd, H-4), 3.56 (1H, d, H-4′), 3.66 (1H, dd, H-6′a), 3.70 (1H, dq, H-5), 3.79 (3H, s, OMe), 3.80 (1H, dd, H-6′b), 3.82 (1H, dd, H-2), 4.02 (1H, dd, H-3), 4.36 (1H, ddd, H-2′), 4.37, 4.65 (1H each, d, $PhC\underline{H}_2$), 4.58, 4.69 (1H each, d, $PhC\underline{H}_2$), 4.60, 4.75 (1H each, d, $PhC\underline{H}_2$), 4.74 (1H, s, H-1′), 4.77 (1H, s, H-1), 6.76 (1H, d, NH); $J_{1,2}=2$, $J_{2,3}=3.5$, $J_{3,4}=9.5$, $J_{4,5}=9$, $J_{5,6}=6$, $J_{1',2'}<1$, $J_{2',3'}=3$, $J_{3',4'}=10$, $J_{4',5'}=9$, $J_{5',6'a}=3$, $J_{5',6'b}=4.5$, $J_{6'a,6'b}=12$, $J_{2',NH}=7$ Hz. ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 17.99 (C-6), 22.90 (NAc), 54.38 (C-2′), 55.26 (OMe), 61.45 (C-6′), 67.14 (C-4′), 68.16 (C-5), 68.68, 73.29, 75.45 (3 × $Ph\underline{C}H_2$), 70.10 (C-3′), 76.08 (C-5′), 78.75 (C-2), 80.50 (C-4), 82.67 (C-3), 97.03 (C-1), 100.51 (C-1′). MS (FAB) *m/z*: 668 $[M+1]^+$, 690 $[M+Na]^+$.

3-*O*-(2-Acetamido-2-deoxy-*β*-D-mannopyranosyl)-*α*-L-rhamnopyranose (14) A solution of **13** (128 mg, 0.19 mmol) in MeOH–H_2O (4:1, 50 ml) containing AcOH (2.5 ml) was hydrogenolyzed in the presence of 10% Pd–C (250 mg) under an atmosphere of H_2 (310 kPa) for 24 h. The resulting mixture was filtered through a pad of Celite and the filtrate was concentrated *in vacuo* to give a syrup, which was purified by elution from a column of silica gel with $CHCl_3$–MeOH–H_2O (5:4:1). The major fraction was concentrated and the residue was lyophilized to give 63 mg (89%) of **14** as a colorless powder ($\alpha:\beta=3:1$ by ^{1}H-NMR in D_2O), mp 142—143 °C, $[\alpha]_D^{21}$ −35.1° (c=0.25, MeOH). α-Anomer: ^{1}H-NMR (300 MHz, D_2O) δ: 1.20 (3H, d, H-6), 2.01 (3H, s, NAc), 3.33

(1H, ddd, H-5′), 3.43 (1H, dd, H-4), 3.46 (1H, dd, H-4′), 3.74 (1H, dd, H-3′), 3.81 (1H, dq, H-5), 3.83 (1H, dd, H-3), 4.06 (1H, dd, H-2), 4.49 (1H, dd, H-2′), 4.90 (1H, d, H-1′), 5.02 (1H, d, H-1); $J_{1,2}=1.5$, $J_{2,3}=3$, $J_{3,4}=J_{4,5}=9.5$, $J_{5,6}=6$, $J_{1',2'}=1$, $J_{2',3'}=4$, $J_{3',4'}=J_{4',5'}=9$, $J_{5',6'a}=2.5$, $J_{5',6'b}=4.5$ Hz. ^{13}C-NMR (75 MHz, D_2O) δ: see Table 2. β-Anomer: ^{1}H-NMR (300 MHz, D_2O) δ: 1.21 (3H, d, H-6), 2.01 (3H, s, NAc), 3.35 (1H, ddd, H-5′), 3.66 (1H, dd, H-3′), 4.07 (1H, dd, H-2), 4.49 (1H, dd, H-2′), 4.78 (1H, d, H-1), 4.90 (1H, d, H-1′); $J_{1,2}=1$, $J_{2,3}=3$, $J_{5,6}=6$, $J_{1',2'}=1$, $J_{2',3'}=4$, $J_{3',4'}=J_{4',5'}=9$, $J_{5',6'a}=2$, $J_{5',6'b}=4$ Hz. ^{13}C-NMR (75 MHz, D_2O) δ: see Table 2. MS (FAB) *m*/*z*: 368 $[M+1]^+$, 390 $[M+Na]^+$. *Anal.* Calcd for $C_{14}H_{25}NO_{10}\cdot 2H_2O$: C, 41.69; H, 7.23; N, 3.47. Found: C, 41.43; H, 6.95; N, 3.28.

Benzyl 3,4-Di-*O*-benzyl-2-*O*-[3,4,6-tri-*O*-benzoyl-2-(benzoyloxyimino)-2-deoxy-β-D-*arabino*-hexopyranosyl]-α-L-rhamnopyranoside (16) Use of Glycosyl Iodide **2**: A mixture of benzyl 3,4-di-*O*-benzyl α-L-rhamnopyranoside (**15**)[18] (130 mg, 0.3 mmol), molecular sieves (3 Å, 300 mg), and Ag_2CO_3 (414 mg, 1.5 mmol) in dry CH_2Cl_2 (6.0 ml) was stirred in the dark at room temperature for 1 h. 2-(Benzoyloxyimino)glycosyl iodide **2**[10] (216 mg, 0.3 mmol) was added, and the whole was further stirred for 2 h. After dilution with CH_2Cl_2 (20 ml) the mixture was filtered through a pad of Celite, and the filtrate was washed consecutively with 1 M aqueous $Na_2S_2O_3$ (20 ml), 5% aqueous $NaHCO_3$ (20 ml), and H_2O (3 × 20 ml). Drying (Na_2SO_4), evaporation to dryness, elution from a silica gel column with hexane–EtOAc (2 : 1), and concentration of the major fraction furnished a colorless syrup, which was crystallized from Et_2O–pentane, providing 168 mg (55%) of **16** as a colorless powder, mp 56—58 °C, $[\alpha]_D^{24}$ −4.8° (*c*=1.0, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.26 (3H, d, H-6), 3.48 (1H, dd, H-4), 3.70 (1H, dq, H-5), 4.00 (1H, dd, H-3), 4.47 (1H, m, H-5′), 4.49 (1H, dd, H-6′a), 4.50 (1H, m, H-2), 4.54 (1H, dd, H-6′b), 5.07 (1H, d, H-1), 5.86 (1H, dd, H-4′), 6.14 (1H, d, H-3′), 6.76 (1H, s, H-1′); $J_{1,2}=1.5$, $J_{2,3}=2.5$, $J_{3,4}=J_{4,5}=9$, $J_{5,6}=6$, $J_{3',4'}=J_{4',5'}=3.5$, $J_{5',6'a}=4$, $J_{5',6'b}=6$, $J_{6'a,6'b}=12$ Hz. ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 17.84 (C-6), 64.34 (C-6′), 68.46 (C-5), 68.93 (C-3′), 69.03, 72.65, 75.18 (3 × $Ph\underline{C}H_2$), 69.44 (C-4′), 74.16 (C-2), 77.19 (C-5′), 79.60 (C-3), 80.60 (C-4), 91.75 (C-1′), 98.03 (C-1). MS (FAB) *m*/*z*: 1024 $[M+1]^+$, 1048 $[M+Na]^+$. *Anal.* Calcd for $C_{61}H_{55}NO_{14}$: C, 68.36; H, 6.59; N, 1.37. Found: C, 68.58; H, 6.50; N, 1.46.

Use of Glycosyl Bromide **1**: The rhamnoside **15** (43.4 mg, 0.10 mmol) was glycosylated with 2-(benzoyloxyimino)glycosyl bromide **1** (101 mg, 0.15 mmol) in dry CH_2Cl_2 (2.0 ml) in the presence of silver zeolite as described for **5**. After aqueous work-up, purification by elution from a silica gel column with MeC_6H_5–EtOAc (10 : 1) gave 58 mg (54%) of **16**.

Benzyl 3,4-Di-*O*-benzyl-2-*O*-(2-acetamido-3,4,6-tri-*O*-benzoyl-2-deoxy-β-D-mannopyranosyl)-α-L-rhamnopyranoside (17) A solution of the disaccharide **16** (654 mg, 0.64 mmol) in dry THF (7.8 ml) was treated with 1 M $BH_3\cdot THF$ complex (7.8 ml) as described for **12**. After general work-up, purification by silica gel column chromatography ($CHCl_3$–EtOAc, 4 : 1), and crystallization from Et_2O–pentane gave 426 mg (70%) of **17** as a colorless powder, mp 56—59 °C, $[\alpha]_D^{20}$ −29.3° (*c*=1.0, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.31 (3H, d, H-6), 1.72 (3H, s, NAc), 3.40 (1H, dd, H-4), 3.69 (1H, dq, H-5), 3.89 (1H, dd, H-3), 3.92 (1H, d, H-2), 4.16 (1H, m, H-5′), 4.19, 4.44 (1H each, d, $PhC\underline{H}_2$), 4.35, 4.63 (1H each, d, $PhC\underline{H}_2$), 4.60, 4.76 (1H each, d, $PhC\underline{H}_2$), 4.68 (1H, dd, H-6′a), 4.74 (1H, dd, H-6′b), 4.97 (1H, ddd, H-2′), 4.98 (1H, d, H-1′), 5.02 (1H, d, H-1), 5.57 (1H, dd, H-3′), 5.61 (1H, dd, H-4′), 6.29 (1H, d, NH); $J_{1,2}=1.5$, $J_{2,3}=3$, $J_{3,4}=9$, $J_{4,5}=9.5$, $J_{5,6}=6$, $J_{1',2'}=J_{2',3'}=2$, $J_{3',4'}=J_{4',5'}=7$, $J_{5',6'a}=4$, $J_{5',6'b}=6$, $J_{6'a,6'b}=12$, $J_{2',NH}=8.5$ Hz. ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 17.76 (C-6), 22.74 (NAc), 48.78 (C-2′), 64.14 (C-6′), 67.84 (C-4′), 68.18 (C-5), 68.90, 73.42, 75.34 (3 × $Ph\underline{C}H_2$), 69.63 (C-3′), 72.44 (C-5′), 78.73 (C-2), 79.87 (C-3), 80.74 (C-4), 98.18 (C-1), 100.05 (C-1′). MS (FAB) *m*/*z*: 950 $[M+1]^+$, 972 $[M+Na]^+$. *Anal.* Calcd for $C_{56}H_{55}NO_{13}$: C, 70.80; H, 5.83; N, 1.47. Found: C, 70.85; H, 5.86; N, 1.37.

Benzyl 3,4-Di-*O*-benzyl-2-*O*-(2-acetamido-2-deoxy-β-D-mannopyranosyl)-α-L-rhamnopyranoside (18) A solution of **17** (354 mg, 0.37 mmol) in 0.05 M NaOMe in dry MeOH (5.0 ml) was processed as described for **7**. After general work-up, purification by silica gel column chromatography ($CHCl_3$–MeOH, 6 : 1) gave 178 mg (75%) of **18** as a colorless syrup, $[\alpha]_D^{20}$ −23.9° (*c*=0.8, $CHCl_3$). ^{1}H-NMR (300 MHz, $CDCl_3$) δ: 1.27 (3H, d, H-6), 2.01 (3H, s, NAc), 3.14 (1H, ddd, H-5′), 3.43 (1H, dd, H-4), 3.54 (1H, ddd, H-3′), 3.65 (1H, dd, H-4′), 3.66 (1H, dd, H-6′a), 3.74 (1H, dq, H-5), 3.77 (1H, dd, H-6′b), 3.91 (1H, dd, H-3), 3.92 (1H, dd, H-2), 4.43, 4.65 (1H each, d, $PhC\underline{H}_2$), 4.47 (1H, ddd, H-2′), 4.58, 4.76 (1H each, d, $PhC\underline{H}_2$), 4.65 (1H, d, H-1′), 4.63, 4.99 (1H each, d, $PhC\underline{H}_2$), 4.94 (1H, d, H-1), 5.16 (1H, d, 3′-OH), 6.81 (1H, d, NH); $J_{1,2}=1$, $J_{2,3}=3$, $J_{3,4}=J_{4,5}=10$, $J_{5,6}=6$, $J_{1',2'}=2$, $J_{2',3'}=3.5$, $J_{3',4'}=J_{4',5'}=9$, $J_{5',6'a}=J_{5',6'b}=3$, $J_{6'a,6'b}=12$, $J_{2',NH}=6.5$, $J_{3',OH}=4.5$ Hz. ^{13}C-NMR (75 MHz, $CDCl_3$) δ: 17.97 (C-6), 22.91 (NAc), 53.97 (C-2′), 61.57 (C-6′), 67.75 (C-4′), 68.30 (C-5), 69.06, 72.88, 75.48 (3 × $Ph\underline{C}H_2$), 73.98 (C-3′), 76.31 (C-5′), 76.58 (C-2), 79.71 (C-3), 80.15 (C-4), 98.12 (C-1), 99.79 (C-1′). MS (FAB) *m*/*z*: 638 $[M+1]^+$, 660 $[M+Na]^+$.

2-*O*-(2-Acetamido-2-deoxy-β-D-mannopyranosyl)-α-L-rhamnopyranose (19) The disaccharide **18** (154 mg, 0.24 mmol) was hydrogenolyzed as described for **14**. After general work-up, purification of the product by elution from a silica gel column with $CHCl_3$–MeOH–H_2O (5 : 4 : 1), and lyophilization gave 89 mg (quantitative yield) of **19** as a colorless powder (α : β = 3 : 1 by ^{1}H-NMR in D_2O), mp 139—142 °C, $[\alpha]_D^{21}$ −23.0° (*c*=1.0, MeOH). α-Anomer: ^{1}H-NMR (300 MHz, D_2O) δ: 1.16 (3H, d, H-6), 2.01 (3H, s, NAc), 3.23 (1H, dd, H-4), 3.29 (1H, ddd, H-5′), 3.46 (1H, dd, H-4′), 3.72 (1H, dd, H-6′a), 3.74 (1H, dq, H-5), 3.75 (1H, dd, H-3′), 3.78 (1H, dd, H-3), 3.82 (1H, dd, H-6′b), 3.90 (1H, dd, H-2), 4.49 (1H, dd, H-2′), 4.81 (1H, d, H-1′), 5.22 (1H, d, H-1); $J_{1,2}=2$, $J_{2,3}=3$, $J_{3,4}=J_{4,5}=9.5$, $J_{5,6}=6$, $J_{1',2'}=2$, $J_{2',3'}=4.5$, $J_{3',4'}=J_{4',5'}=9.5$, $J_{5',6'a}=5$, $J_{5',6'b}=2.5$, $J_{6'a,6'b}=12$ Hz. ^{13}C-NMR (75 MHz, D_2O) δ: see Table 2. β-Anomer: ^{1}H-NMR (300 MHz, D_2O) δ: 1.19 (3H, d, H-6), 2.02 (3H, s, NAc), 3.17 (1H, dd, H-4), 3.32 (1H, dq, H-5), 3.39 (1H, ddd, H-5′), 3.49 (1H, dd, H-4′), 3.58 (1H, dd, H-3), 3.79 (1H, dd, H-3′), 3.89 (1H, dd, H-6′b), 4.04 (1H, dd, H-2), 4.58 (1H, dd, H-2′), 4.73 (1H, d, H-1), 4.83 (1H, d, H-1′); $J_{1,2}<1$, $J_{2,3}=3$, $J_{3,4}=J_{4,5}=9.5$, $J_{5,6}=6$, $J_{1',2'}=2$, $J_{2',3'}=4.5$, $J_{3',4'}=J_{4',5'}=9.5$, $J_{5',6'a}=5$, $J_{5',6'b}=2.5$, $J_{6'a,6'b}=12$ Hz. ^{13}C-NMR (75 MHz, D_2O) δ: see Table 2. MS (FAB) *m*/*z*: 368 $[M+1]^+$, 390 $[M+Na]^+$. *Anal.* Calcd for $C_{14}H_{25}NO_{10}\cdot 3H_2O$: C, 39.90; H, 7.41; N, 3.32. Found: C, 39.51; H, 7.07; N, 3.03.

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