Synthesis of Branched-Chain Oligosaccharides in Sarsasaponins by Dehydrative Glycosylation

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The branched-chain oligosaccharides, 6-*O*-(β-D-glucopyranosyl)-4-*O*-(α-L-rhamnopyranosyl)-D-glucopyranose, and 2,6-di-*O*-(β-D-glucopyranosyl)-4-*O*-(α-L-rhamnopyranosyl)-D-glucopyranose, which compose sarsasaponins, as well as the structurally related 2-*O*-(β-D-glucopyranosyl)-4-*O*-(α-L-rhamnopyranosyl)-D-glucopyranose were synthesized stepwise via dehydrative glycosylation by a ternary mixture of *p*-nitrobenzenesulfonyl chloride, silver triflate, and triethylamine.

The dehydrative condensation of a protected monosaccharide, in which a reducing hydroxyl group and one of the nonreducing hydroxyl groups are unprotected, proceeds slowly, even under forced conditions, and its selectivity is generally poor.[2] The starting material used in such glycosylation is an anomeric mixture which may undergo self-condensation to give a nonreducing disaccharide. Because of these deficiencies, oligosaccharides with a fine structure have never been attempted using dehydrative glycosylation. Glycosylation of this kind, however, has an attractive feature in that it uses glycosyl donors with much longer shelf-lives compared to those of such hydrolyzable donors[3] as glycosyl halides and their equivalents. Studies of dehydrative glycosylation[4] have indicated that a ternary mixture of *p*-nitrobenzenesulfonyl chloride (NsCl), silver triflate (AgOTf), and triethylamine (Et_3N) (NST mixture) performs cross-condensation between 2,3,4,6-tetra-*O*-benzyl-D-glucopyranose (**1**) and various alcohols.[5] The reaction proceeds with moderate efficiencies and its selectivity depends on the type of donors,[6-9] reactivity of acceptors,[5,10] as well as the nature of any additives.[11] This report deals with the synthesis of bifurcated *O*-β-D-glucopyranosyl-(1→2)-*O*-[α-L-rhamnopyranosyl-(1→4)]-D-glucopyranose (**2**) and *O*-β-D-glucopyranosyl-(1→6)-*O*-[α-L-rhamnopyranosyl-(1→4)]-D-glucopyranose (**3**) as well as of trifurcated *O*-β-D-glucopyranosyl-(1→2)-*O*-[β-D-glucopyranosyl-(1→6)]-O-[α-L-rhamnopyranosyl-(1→4)]-D-glucopyranose (**4**),[12] while showing a practical limitation of glycosylation with an NST mixture.[5] The tetrasaccharide **4** composes the antibiotic saponins, parillin and sarsaparilloside from *Radix sarsaparillae*,[13] whereas the trisaccharide **2** might possibly constitute avenacoside A from the leaves and seeds of *Avena sativa*,[14] and another trisaccharide **3** is contained in a harb saponin, saikosaponin-*c* from the root of *Bupleurum falcatum* L.[15]

α-L-Rhap-(1→4)-D-Glcp
2
↑
β-D-Glcp

2

β-D-Glcp
1
↓
6
α-L-Rhap-(1→4)-D-Glcp

3

β-D-Glcp
1
↓
6
α-L-Rhap-(1→4)-D-Glcp
2
↑
β-D-Glcp

4

Synthesis of the Trisaccharide 2. The acceptor **5** for the synthesis of **2** was prepared from a known acetal **6**.[16] A controlled allylation of **6** with allyl bromide and sodium hydride gave 2-*O*-allyl ether **7** (54%) and an isomer **8** (11%). The structure of **7** was confirmed by measuring the ^1H NMR of its 3-acetate. Benzylation of **7** and a subsequent hydrolysis gave the diol **9**, which was subjected to controlled benzylation with benzyl chloride and sodium hydride to afford the desired **5** (55%) and the isomer **10** (11%).

Condensation of 2,3,4-tri-*O*-benzyl-L-rhamnopyranose[17] (**11**) and methyl 2,3,6-tri-*O*-benzyl-β-D-glucopyranoside[11] (**12**) using the NST mixture was first examined. The use of a 1.5 molar amount of the donor **11** produced a cross-condensate **13** (72% from **12**) and a self-condensate **14** (36% from **11**). The configuration of the interglycoside linkage was confirmed by measuring a $^1J_{CH}$[18] (170 Hz) for the signal (δ 98.4) of the anomeric carbon of the rhamnosyl residue in **13** and that in the corresponding debenzylated compound **15** (δ 102.3, 170 Hz). Rhamnosylation of **16**[16] with **11** was similarly carried out in order to furnish the disaccharide derivative **17** (68% from **16**) and **14** (36% from **11**). The anomeric carbon of the α-rhamnosyl residue of **17** appeared at δ 98.2 again with a $^1J_{CH}$ of 170 Hz (Table 1), whereas the corresponding proton gave a characteristic doublet (δ 5.07) with a small splitting (1.8 Hz). Thus, rhamnosylation with **11** of the 4-OH group was stereoselective but was apt to let the self-condensation of the donor undergo, differing from the case of glucosylation with **1**.[11] The acceptor **5** was then similarly condensed with **11** to give the

condensate **18** (81%). The anomeric carbon of the α-rhamnosyl moiety resonated at δ 98.2 with a $^1J_{CH}$ of 169 Hz. Deallylation of **18** with a rhodium complex and a subsequent hydrolysis[9] afforded the disaccharide acceptor **19**.

The 2-OH group of the simple acceptor **20**, which was readily prepared from **9**, was glucosylated with a 1.3 molar amount of **1** and the NST mixture to give the sophorose derivative **22** (38%) and a kojibiose derivative **21** (29%). The chemical shift of the anomeric proton (δ 5.20) and the anomeric carbon (δ 98.9) of the reducing end of **22** showed characteristic downfield shifts caused by a substitution by the tetra-*O*-benzylglucosyl residue at the 2-OH group in **20** (Table 1). Thus, glucosylation with **1** of the 2-OH group was marginally selective for the β-anomer.[10] Then, a similar glucosylation was applied to **19** to afford the desired trisaccharide derivative **24** (41%) and

Table 1. ^1H[a] and ^{13}C[b] NMR Data (δ) for the Anomeric Centers of the Fully Benzylated Glycosides

Compd. confgn.	H-1 α-D-Glc	H-1′→2 β-D-Glc	H-1″→4 α-L-Rha	H-1‴→6 β-D-Glc	C-1 α-D-Glc	C-1′→2 β-D-Glc	C-1″→4 α-L-Rha	C-1‴→6 β-D-Glc
22	5.20(3.5)	4.83(7.8)			98.9	103.4		
17	4.85(3.5)		5.07(1.8)		95.1(167)		98.2(170)	
30	4.88(4.0)			4.42(8.0)	95.2			103.8
24	5.11(3.0)	4.76(7.6)	5.08(2.0)		98.6(168)	103.2(162)	98.8(171)	
32	4.80(4.0)		5.10(2.0)	4.38(8.0)	95.0(168)		97.8(168)	104.0(159)
45	5.12(3.5)	4.72(7.5)	5.11(2>)	4.41(8.0)	97.7(167)	103.2(159)	98.5(173)	103.8(157)

a) The values in parentheses are those for $^3J_{HH}$(Hz) of the anomeric protons. b) The values in parentheses are those for $^1J_{CH}$(Hz) of the anomeric carbons.

Table 2. ^{13}C NMR Data (δ)[a] for the Glycosides in D_2O

	C-atom	MR[b]	S[c]	MS[d]	**15**	G[e]	**2**	**3**	**4**
	1α		92.4			92.5	92.5(172)	93.3(172)	93.1(173)
	1β		95.1	102.4	104.5(161)	96.4	95.5(164)	97.4(164)	96.2(162)
	2α		81.4			72.1	81.7	72.9	82.1
	2β		82.1	82.1	74.8	74.7	82.3	75.2	81.8
	3α		72.5			73.7	72.8	73.1	73.3
	3β		76.5	77.0	76.4	76.3	75.4	75.8	75.9
D-Glc	4α		70.4			70.3	78.2	78.7	78.5
	4β		70.4	70.1	78.8	70.3	78.2	78.7	78.5
	5α		71.8			71.0	71.3	70.6	70.4
	5β		76.5	77.0	75.9	75.3	75.9	75.8	75.2
	6α		61.7			69.4	61.0	69.3	69.3
	6β		61.7	61.4	61.6	69.4	61.0	69.3	69.3
	1′α		104.4				104.8(159)		105.4(162)
	1′β		103.2	104.6			103.5(159)		103.8(160)
	2′		74.2	75.0			74.2		74.7
β-D-Glc-(1′→2)	3′		76.5	77.0			76.6		77.1
	4′		70.4	70.4			70.3		71.0
	5′		76.5	77.3			76.4		77.1
	6′		61.7	61.4			61.5		62.1
	1″	101.9			102.3(170)		101.8(169)	102.2(171)	102.2(168)
	2″	71.0			71.5		71.0	71.6	71.6
	3″	71.3			71.7		71.3	71.8	71.8
α-L-Rha-(1″→4)	4″	73.1			73.3		72.8	73.3	73.3
	5″	69.4			70.5		69.9	70.5	70.4
	6″	17.7			17.8		17.8	17.8	17.8
	1‴					103.0		103.8(159)	103.8(160)
	2‴					73.3		74.3	74.3
β-D-Glc-(1‴→6)	3‴					76.3		77.3	77.1
	4‴					70.3		71.0	71.0
	5‴					76.3		77.1	77.1
	6‴					61.7		62.1	62.1

a) The values in parentheses are those for $^1J_{CH}$(Hz). b) MR=methyl α-L-rhamunopyranoside (Ref. 22). c) S=sophorose (Ref. 20). d) MS=methyl β-sophoroside: the values are those in C_5D_5N (Ref. 21) subtracted by 1.0 arbitrarily. e) G=gentiobiose (Ref. 20).

the α-isomer **23** (29%). The new anomeric carbon resonated at δ 103.2 with a $^1J_{CH}$ of 162 Hz, indicating the β-configuration. The chemical shifts of the anomeric protons and carbons of **24** correspond well with those of the relevant disaccharide derivatives, **17** and **22** (Table 1).

A hydrogenolytic debenzylation of **24** furnished the trisaccharide **2**, the ^{13}C NMR spectrum of which was consistent with the proposed structure (Table 2); the assignment was tentatively carried out based on the spectra of sophorose,[20] methyl sophoroside,[21] methyl α-L-rhamnopyranoside,[22] and **15**.

Synthesis of the Trisaccharide 3. The synthesis was started from the known acceptor **25**.[16] The first glycosylation of **25** with **1** in the presence of the NST mixture afforded the gentiobiose derivative **27** (64%) and the isomaltose derivative **26** (21%). The new anomeric carbon of **27** appeared at δ 103.8, indicating the β-configuration. The glucosylation of the acceptor **28**[23] with **1** also gave the gentiobiose derivative **30**[24,25] (75%) and the α-isomer **29** (22%). Deallylation of **27** gave **31**, which was then subjected to the α-rhamnosylation with **11**. In this case, however, the 4-OH group of **31** was so unreactive to the activated **11**, due to the presence of the tetra-*O*-benzylglucosyloxyl group at the C-6 position, that a significant amount (18%) of the *p*-nitrobenzenesulfonate of **31** was formed expectedly,[26] indicating a practical limitation of the rhamnosylation with **11** and the NST mixture. Nevertheless, the desired trisaccharide derivative **32** was produced in a 36% yield with complete selectivity. The anomeric carbon of the α-rhamnosyl moiety in **32** appeared at δ 97.8 with a $^1J_{CH}$ of 168 Hz; the chemical shifts of the anomeric protons and carbons nicely correspond with those of the relevant disaccharide derivatives, **17** and **30** (Table 1).

Hydrogenolysis of **32** afforded the trisaccharide **3**, the ^{13}C NMR spectrum of which was tentatively assigned based on the spectra of gentiobiose[20] and **15** and was consistent with the proposed structure (Table 2).

Synthesis of the Tetrasaccharide 4. The key

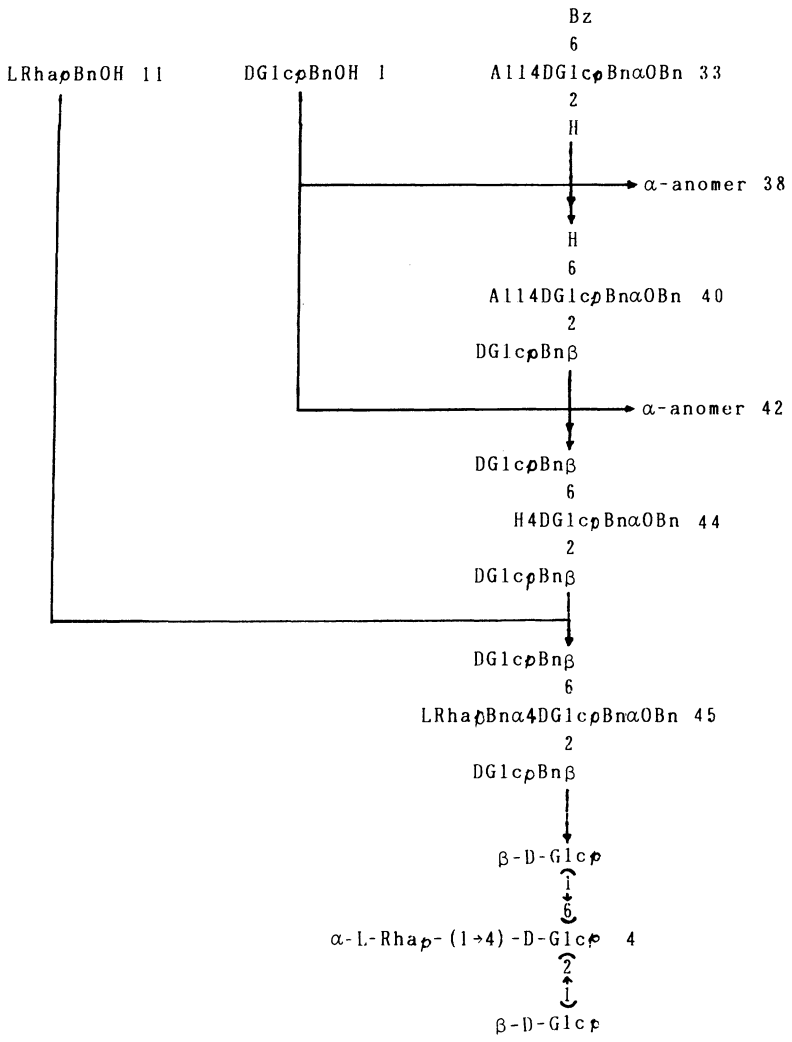
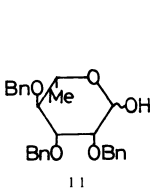


Fig. 1. Synthetic diagram[24] for the tetrasaccharide **4** (All=$-CH_2CH{=}CH_2$, Bn=CH_2Ph, Bz=$-COPh$).

acceptor **33** was prepared from the dityrityl ether **34**.[27] Brief heating of **34** in allyl bromide in the presence of a limited amount of sodium hydride, followed by forced benzylation by hot benzyl chloride and excess potassium hydroxide, and a subsequent detritylation with trifluoroacetic acid in methanolic chloroform gave the 4-*O*-allyl derivative **35** (79%) and the isomer **36** (9%). A bulky trityloxyl group at the C-2 position in **34** well diminished the reactivity of the neighboring 3-OH group. The structure of **35** was confirmed by converting it into the known **16**.[16] A mild benzoylation of **35** with benzoyl chloride in pyridine gave the desired acceptor **33** (52%) and the isomer **37** (12%). The H-2 of the 6-benzoate **33** resonates at δ 3.53, whereas that of the 2-benzoate **37** was so deshielded that it gave a signal at δ 4.90.

The first glucosylation of **33** with **1** and the NST mixture gave the desired product **39** (45%) and the α-isomer **38** (39%). As described above, a significant formation of the α-glucosides was also observed in glucosylation with **1** for the 2-OH group of **19** and **20**. The anomeric carbon of the nonreducing β-glucosyl residue of **39** appeared at δ 103.6. Debenzoylation of **39** gave the acceptor **40**. This was successively benzylated and deallylated to give another acceptor **41**. Rhamnosylation of **41** with **11** and the NST mixture provided the trisaccharide derivative **24** described above. Thus, the structure of **33** was strictly confirmed.

The second glucosylation of the 6-OH group of **40**



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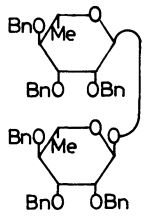

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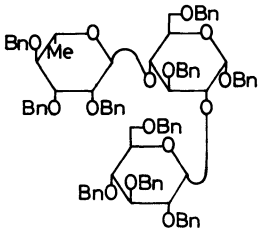

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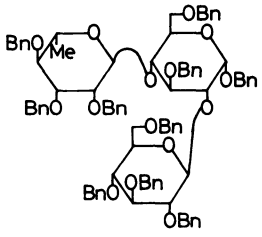

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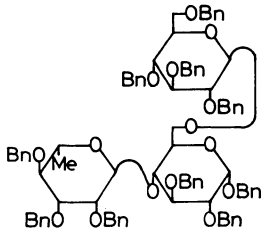

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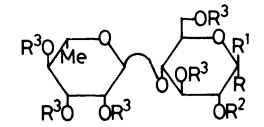
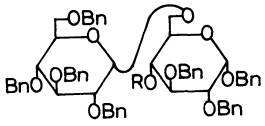
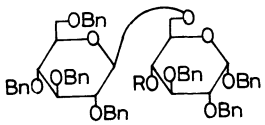


	R	R¹	R²	R³	R⁴	R⁵
1	OH, H		Bn	Bn	Bn	Bn
5	OBn	H	All	Bn	H	Bn
6	OBn	H	H	H		Bd
7	OBn	H	All	H		Bd
8	OBn	H	H	All		Bd
9	OBn	H	All	Bn	H	H
10	OBn	H	All	Bn	Bn	H
12	H	OMe	Bn	Bn	H	Bn
16	OBn	H	Bn	Bn	H	Bn
20	OBn	H	H	Bn	Bn	Bn
25	OBn	H	Bn	Bn	All	H
28	OBn	H	Bn	Bn	Bn	H
33	OBn	H	H	Bn	All	Bz
34	OBn	H	Tr	H	H	Tr
35	OBn	H	H	Bn	All	H
36	OBn	H	H	All	Bn	H
37	OBn	H	Bz	Bn	All	H

All = $-CH_2-CH=CH_2$
Bd = $>CH(Ph)$
Bn = $-CH_2Ph$
Bz = $-COPh$
Tr = $-CPh_3$

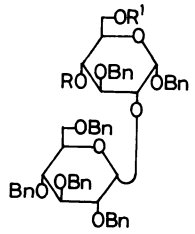


26 R = All
29 R = Bn

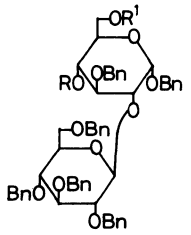


27 R = All
30 R = Bn
31 R = H

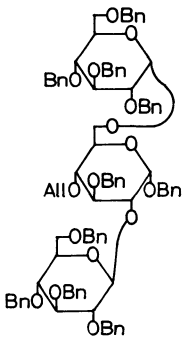
	R	R¹	R²	R³
13	H	OMe	Bn	Bn
15	H	OMe	H	H
17	OBn	H	Bn	Bn
18	OBn	H	All	Bn
19	OBn	H	H	Bn



21 R = R¹ = Bn
38 R = All, R¹ = Bz



22 R = R¹ = Bn
39 R = All, R¹ = Bz
40 R = All, R¹ = H
41 R = H , R¹ = Bn



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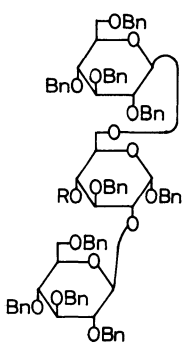
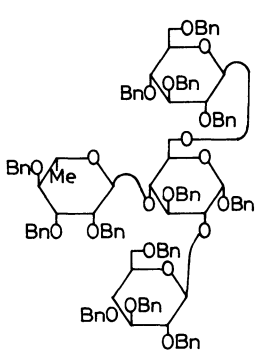


43 R = All
44 R = H



45

with **1** and the NST mixture furnished the desired **43** (68%) and the α-anomer **42** (31%). The anomeric carbon of the newly introduced β-glucosyl moiety of **43** appeared at δ 104.0. Deallylation of **43** smoothly gave the trisaccharide acceptor **44**.

The final rhamnosylation of **44** with **11** and the NST mixture afforded the fully benzylated tetrasaccharide **45** in a 37% yield, as the sole cross-condensate. The anomeric carbon of the α-rhamnosyl moiety appeared at δ 98.5 with a $^1J_{CH}$ of 173 Hz. All the anomeric carbons and protons of **45** are well correlated with those of the component trisaccharide derivative **24** and **32** (Table 1).

A catalytic hydrogenolysis of **45** gave the trifurcated tetrasaccharide **4**, the ^{13}C NMR spectrum of which was consistent with the proposed structure (Table 2). The assignment was tentatively carried out based on the spectra of sophorose,[20] gentiobiose,[20] **15**, **2**, and **3**.

Thus, the work described may illustrate the scope and limitations for the synthesis of complex oligosaccharides using the dehydrative glycosylation with an NST mixture.[5]

Experimental

The solvent systems for chromatography on a silica-gel column (gradient elution) and TLC were toluene–2-butanone (TB), hexane–ethyl acetate (HE), hexane–acetone (HA), IPE†–ethyl acetate (IE), and chloroform–methanol (CM) systems. The glycosylation with the NST mixture and the accompanying processing were performed as described earlier.[5,6,10] Sodium hydride in an oil suspension (60% of NaH by wt) was used without pre-washing. Hydrogenolytic debenzylation was carried out using a Parr-3911 hydrogenation apparatus under 340 kPa of H_2 at room temp. A concentration of the solution was carried out under reduced pressure. The NMR spectra were recorded with a Varian XL-400 spectrometer at 400 MHz for ^1H and at 100.6 MHz for ^{13}C or with a Varian VXR-300 spectrometer at 300 MHz for ^1H and at 75.5 MHz for ^{13}C; the chemical shifts of ^1H NMR are relative to the satelite peak of $CDCl_3$ at δ 7.26 in $CDCl_3$ and the peak of DOH at δ 4.70 in D_2O and those for ^{13}C NMR are to the central peak of $CDCl_3$ at δ 77.0 in $CDCl_3$ and the peak of 1,4-dioxane at δ 67.4 in D_2O. A routine measurement of the NMR spectra was carried out with a Varian EM-390 spectrometer at 90 MHz for ^1H and with a JEOL-PS-100 spectrometer linked to a JEOL-EC-100 computer at 25.2 MHz for ^{13}C; the chemical shifts are relative to the peak of internal TMS at δ 0.0 in $CDCl_3$ and that of external TMS at δ 0.0 in D_2O. For other items, refer to previous reports,[5,10,11] unless otherwise described.

Benzyl 2-*O*- and 3-*O*-Allyl-4,6-*O*-benzylidene-α-D-glucopyranosides (7 and 8). A mixture of **6**[16] (1.00 g), NaH in an oil suspension (144 mg) and allyl bromide (12 ml) was stirred for 3 h at 80 °C. The mixture was diluted with toluene and washed with cold H_2O. The organic layer was concentrated and chromatographed (IE system) to give the diallyl ether (0.11 g, 9%), **7** (0.60 g, 54%), mp 153—154 °C (from IPE), $[\alpha]_D^{20}$ +138° (*c* 0.7, $CHCl_3$), ^1H NMR ($CDCl_3$, 90 MHz) δ=3.42 (1H, dd, $J_{1,2}$=3.6 Hz, $J_{2,3}$=9.3 Hz, H-2), 5.01 (1H, d, H-1), 5.53 (1H, s, benzylidene), 5.7—6.2 (1H, m, allyl), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=62.4 (C-5), 69.0 (C-6), 79.4 (C-2), 81.3 (C-4), 95.8 (C-1), 102.0 (benzylidene), 118.0, 134.4 (allyl), and **8** (0.12 g, 11%), mp 95—97 °C (from hexane), $[\alpha]_D^{20}$ +83° (*c* 2.8, $CHCl_3$), ^1H NMR ($CDCl_3$, 90 MHz) δ=5.01 (1H, d, $J_{1,2}$=3.0 Hz, H-1), 5.51 (1H, s, benzylidene), 5.7—6.2 (1H, m, allyl), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=62.9 (C-5), 68.9 (C-6), 78.6 (C-4), 81.9 (C-3), 98.3 (C-1), 101.2 (benzylidene), 117.2, 135.0 (allyl).

Found: **7**, C, 68.91; H, 6.55%. **8**, C, 68.89; H, 6.51%. Calcd for $C_{23}H_{26}O_6$: C, 69.33; H, 6.58%.

A sample of **7** was acetylated with acetic anhydride and pyridine, followed by chromatography (HA system) to give the homogeneous acetate, ^1H NMR (CCl_4, 90 MHz) δ=2.02 (3H, s, Ac), 3.42 (1H, dd, $J_{1,2}$=3.6 Hz, $J_{2,3}$=9.6 Hz, H-2), 3.43 (1H, dd, $J_{3,4}$=9.6 Hz, $J_{4,5}$=9.0 Hz, H-4), 4.88 (1H, d, H-1), 5.36 (1H, s, benzylidene), 5.47 (1H, t, H-3) indicating that Ac is at the O-3 of **7**.

Benzyl 2-*O*-Allyl-3-*O*-benzyl-α-D-glucopyranoside (9). A mixture of **7** (0.55 g), crushed KOH (0.3 g), and $PhCH_2Cl$ (2.8 ml) was stirred for 1 h at 125 °C. The mixture was diluted with toluene and washed with cold H_2O. The organic layer was concentrated at 95 °C and then heated in aq AcOH (80%, 16 ml) for 1 h at 95 °C. The mixture was concentrated and chromatographed (TB system) to give **9** (0.52 g, 94%), mp 78—80 °C (from IPE), $[\alpha]_D^{20}$ +94° (*c* 2.1, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=62.3 (C-6), 79.7 (C-2), 81.2 (C-3), 95.5 (C-1), 117.5, 134.6 (allyl).

Found: C, 68.71; H, 6.93%. Calcd for $C_{23}H_{28}O_6$: C, 68.98; H, 7.05%.

Benzyl 2-*O*-Allyl-3,6- and -3,4-di-*O*-benzyl-α-D-glucopyranosides (5 and 10). A mixture of **9** (294 mg), NaH in an oil suspension (40 mg) and $PhCH_2Cl$ (2.9 ml) was stirred for 2 h at 110 °C. The mixture was processed and chromatographed (TB system) to give a fully benzylated product (49 mg, 11%), **5** (198 mg, 55%), $[\alpha]_D^{20}$ +79° (*c* 2.7, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=79.5 (C-2), 81.4 (C-3), 95.4 (C-1), 117.4, 134.6 (allyl), and **10** (38 mg, 11%), mp 55—56 °C, $[\alpha]_D^{20}$ +86° (*c* 5.8, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=61.7 (C-6), 77.4 (C-4), 79.9 (C-2), 81.8 (C-3), 95.5 (C-1), 117.4, 134.7 (allyl).

Found: **5**, C, 73.07; H, 6.93%. **10**, C, 73.77; H, 6.92%. Calcd for $C_{30}H_{34}O_6$: C, 73.45; H, 6.99%.

A sample of **5** was acetylated with acetic anhydride and pyridine, followed by chromatography (HA system) to afford the homogeneous acetate, ^1H NMR (CCl_4, 90 MHz) δ=1.71 (3H, s, Ac), 3.38 (1H, dd, $J_{1,2}$=3.6 Hz, $J_{2,3}$=9.3 Hz, H-2), 3.83 (1H, t, $J_{3,4}$=9.3 Hz), 4.83 (1H, d, H-1), 4.87 (1H, dd, $J_{4,5}$=9.6 Hz) indicating the presence of Ac at the O-4 or **5**.

Methyl *O*-(2,3,4-Tri-*O*-benzyl-α-L-rhamnopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-β-D-glucopyranoside (13) and *O*-(2,3,4-Tri-*O*-benzyl-α-L-rhamnopyranosyl)-(1→1)-2,3,4-tri-*O*-benzyl-α-L-rhamnopyranoside (14). The acceptor **12**[11] (30.0 mg) was condensed with **11**[17] (42.1 mg) in the presence of NsCl (43.0 mg), AgOTf (Aldrich, 49.8 mg), and Et_3N (27.1 μl) in CH_2Cl_2 (0.4 ml), followed by chromatography (TB system) to give **14** (15.2 mg, 36% from **11**), $[\alpha]_D^{20}$ −74° (*c* 0.9, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=18.0 (C-6), 68.8 (C-5), 93.7 (C-1), and **13** (41.2 mg, 72% from **12**), $[\alpha]_D^{20}$ −23° (*c* 2, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=17.8 (C-6′), 56.8 (MeO), 98.4 ($^1J_{CH}$=170 Hz, C-1′), 104.9 ($^1J_{CH}$=156 Hz, C-1).

13, Found: C, 74.94; H, 6.73%. Calcd for $C_{55}H_{60}O_{10}$: C, 74.98; H, 6.86%.

† IPE=diisopropyl ether.

14, Found: C, 76.00; H, 6.88%. Calcd for $C_{54}H_{58}O_9$: C, 76.21; H, 6.87%.

Methyl *O*-α-L-Rhamnopyranosyl-(1→4)-β-D-glucopyranoside (15). Hydrogenolysis of **13** (76.5 mg) over Pd on C (10%, 50 mg) in AcOH (6 ml) containing H_2O (50 μl) overnight, followed by chromatography (CM system), gave a hygroscopic foam of **15** (17.3 mg, 59%), $[\alpha]_D^{20}$ −58° (*c* 1.2, H_2O), ^1H NMR (D_2O, 90 MHz) δ=1.28 (3H, d, $J_{5',6'}$=6.0 Hz, H-6'), 3.57 (3H, s, MeO), 4.39 (1H, d, $J_{1,2}$=7.8 Hz, H-1), 4.87 (1H, d, $J_{1',2'}$=1.8 Hz, H-1').

Found: C, 45.64; H, 7.16%. Calcd for $C_{13}H_{24}O_{10}$: C, 45.88; H, 7.11%.

Benzyl *O*-(2,3,4-Tri-*O*-benzyl-α-L-rhamnopyranosyl)-(1→4)-2,3,6-tri-*O*-benzyl-α-D-glucopyranoside (17). Rhamnosylation of **16**[16] (45.8 mg) with **11** (55.2 mg), NsCl (54.6 mg), AgOTf (65.4 mg), and Et_3N (35.5 μl) in CH_2Cl_2 (0.3 ml), followed by chromatography (TB system), furnished **14** (19.7 mg, 36% from **11**) and then **17** (55.4 mg, 68% from **16**), $[\alpha]_D^{20}$ +16° (*c* 1.9, $CHCl_3$).

Found: C, 76.28; H, 6.55%. Calcd for $C_{61}H_{64}O_{10}$: C, 76.54; H, 6.74%.

Benzyl *O*-(2,3,4-Tri-*O*-benzyl-α-L-rhamnopyranosyl)-(1→4)-2-*O*-allyl-3,6-di-*O*-benzyl-α-D-glucopyranoside (18). The acceptor **5** (260.7 mg) was treated with **11** (346.4 mg) in the presence of NsCl (353.5 mg), AgOTf (410.2 mg), and Et_3N (224.0 μl) in CH_2Cl_2 (2 ml). Chromatography (TB system) gave **14** (55.7 mg, 16% from **11**) and then **18** (388.8 mg, 81% from **5**), $[\alpha]_D^{20}$ +32° (*c* 1.3, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 100 MHz) δ=18.0 (C-6'), 95.1 ($^1J_{CH}$=168 Hz, C-1), 98.2 ($^1J_{CH}$=169 Hz, C-1'), 117.6, 134.7 (allyl).

Found: C, 75.29; H, 6.93%. Calcd for $C_{57}H_{64}O_{11}$: C, 75.47; H, 6.89%.

Benzyl *O*-(2,3,4-Tri-*O*-benzyl-α-L-rhamnopyranosyl)-(1→4)-3,6-di-*O*-benzyl-α-D-glucopyranoside (19). A mixture of **18** (346.1 mg), TRC†† (Aldrich, 30 mg) and EBW†† (7.7 ml) was refluxed overnight. The mixture was concentrated and then heated in acetone (6 ml) containing aq HCl (3.5%, 60 μl) for 1 h at 45 °C. Chromatography (HE system) gave **19** (277.9 mg, 85%), $[\alpha]_D^{20}$ +32° (*c* 1.7, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 100 MHz) δ=17.8 (C-6'), 97.6 ($^1J_{CH}$=168 Hz, C-1), 98.2 ($^1J_{CH}$=170 Hz, C-1').

Found: C, 74.85; H, 6.63%. Calcd for $C_{54}H_{58}O_{10}$: C, 74.80; H, 6.74%.

Benzyl 3,4,6-Tri-*O*-benzyl-α-D-glucopyranoside (20). A mixture of **9** (0.44 g), crushed KOH (0.74 g), and $PhCH_2Cl$ (5.3 ml) was stirred for 2 h at 125 °C. After processing, chromatography (HE system) gave the product, which was then refluxed in EBW (4 ml) in the presence of TRC (20 mg) overnight. After concentration, the residue was heated in acetone (4 ml) containing aq HCl (3.5%, 40 μl) for 1 h at 45 °C. Chromatography (HE system) furnished **20** (0.27 g, 45%), $[\alpha]_D^{20}$ +105° (*c* 1.8, $CHCl_3$) ^{13}C NMR ($CDCl_3$, 75 MHz) δ=68.4 (C-6), 69.8 (C-5), 70.7 (C-2), 73.1, 73.5, 75.0, 75.4 (benzyl), 77.4 (C-4), 83.5 (C-3), 97.9 (C-1).

Found: C, 75.60; H, 6.66%. Calcd for $C_{34}H_{36}O_6$: C, 75.53; H, 6.71%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-α- and β-D-glucopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-glucopyranosides (21 and 22). The acceptor **20** (53.5 mg) was glucosylated with **1** (Pfanstiehl, 69.5 mg), NsCl (37.3 mg), AgOTf (43.3 mg), and Et_3N (23.5 μl) in CH_2Cl_2 (0.5 ml), followed by chromatography (TB system), gave **22** (40.1 mg, 38%), $[\alpha]_D^{20}$ +48° (*c* 0.9, $CHCl_3$), and then **21** (30.5 mg, 29%), $[\alpha]_D^{20}$ +79° (*c* 1.9, $CHCl_3$), ^1H NMR ($CDCl_3$, 400 MHz) δ=5.09 (1H, d, $J_{1',2'}$=3.6 Hz, H-1'), 5.24 (1H, d, $J_{1,2}$=3.5 Hz, H-1), ^{13}C NMR ($CDCl_3$, 100 MHz) δ=94.0 (C-1'), 95.0 (C-1).

Found: **21**, C, 76.76; H, 6.73%. **22**, C, 76.53; H, 6.62%. Calcd for $C_{68}H_{70}O_{11}$: C, 76.81; H, 6.64%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-α- and β-D-glucopyranosyl)-(1→2)-*O*-[(2,3,4-tri-*O*-benzyl-α-L-rhamnopyranosyl)-(1→4)]-3,6-di-*O*-benzyl-α-D-glucopyranosides (23 and 24).
(i) The acceptor **19** (48.4 mg) was glucosylated with **1** (39.2 mg) in the presence of NsCl (24.8 mg), AgOTf (28.8 mg), and Et_3N (15.6 mg) in CH_2Cl_2 (0.4 ml), followed by chromatography (TB system), gave **24** (32.1 mg, 41%), $[\alpha]_D^{20}$ +20° (*c* 1.2, $CHCl_3$), and **23** (22.6 mg, 29%), $[\alpha]_D^{20}$ +48° (*c* 0.7, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 100 MHz) δ=94.1 (C-1'), 94.9 (C-1), 98.3 (C-1'').

Found: **23**, C, 76.19; H, 6.64%. **24**, C, 76.27; H, 6.82%. Calcd for $C_{88}H_{92}O_{15}$: C, 76.06; H, 6.67%.

(ii) Rhamnosylation of **41** (see below, 38.9 mg) with **11** (26.0 mg), NsCl (26.6 mg), AgOTf (30.9 mg), and Et_3N (14.7 μl) in CH_2Cl_2 (0.4 ml), followed by chromatography (TB system), gave **14** (5.8 mg, 15%) and **24** (21.1 mg, 38%), the ^{13}C NMR spectrum of which was identical with that of **24** described above.

***O*-β-D-Glucopyranosyl-(1→2)-*O*-[α-L-rhamnopyranosyl-(1→4)]-D-glucopyranose (2).** Hydrogenolysis of **24** (58.8 mg) over Pd on C (10%, 36 mg) in AcOH (6 ml) containing H_2O (50 μl) overnight, followed by chromatography (CM system), afforded a hygroscopic foam of **2** (17.0 mg, 82%), $[\alpha]_D^{20}$ +1.4° (*c* 1.2, H_2O), ^1H NMR (D_2O, 300 MHz) δ=4.53 (0.7H, d, $J_{1',2'}$=7.5 Hz, H-1'α), 4.60 (0.3H, d, $J_{1,2}$=7.6 Hz, H-1β), 4.75 (1H, d, $J_{1'',2''}$=1.5 Hz, H-1''), 5.32 (0.7H, d, $J_{1,2}$=4.0 Hz, H-1α).

Found: C, 44.54; H, 6.98%. Calcd for $C_{18}H_{32}O_{15}$: C, 44.26; H, 6.60%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-α- and β-D-glucopyranosyl)-(1→6)-4-*O*-allyl-2,3-di-*O*-benzyl-α-D-glucopyranosides (26 and 27). The acceptor **25**[16] (50.0 mg) was condensed with **1** (60.0 mg) in the presence of NsCl (34.0 mg), AgOTf (39.5 mg), and Et_3N (21.4 μl) in CH_2Cl_2 (0.6 ml), followed by chromatography (TB system), gave **26** (22.2 mg, 21%), $[\alpha]_D^{20}$ +76° (*c* 1.3, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=94.5 (C-1), 97.3 (C-1'), 116.8, 135.0 (allyl), and **27** (65.8 mg, 64%), $[\alpha]_D^{20}$ +51° (*c* 1.1, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=95.2 (C-1), 103.8 (C-1'), 116.6, 134.8 (allyl).

Found: **26**, C, 76.12; H, 6.89%. **27**, C, 75.97; H, 6.83%. Calcd for $C_{64}H_{68}O_{11}$: C, 75.87; H, 6.76%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-α- and β-D-glucopyranosyl)-(1→6)-2,3,4-tri-*O*-benzyl-α-D-glucopyranosides (29 and 30). Condensation of **28**[23] (54.0 mg) with **1** (70.2 mg) in the presence of NsCl (37.7 mg), AgOTf (43.7 mg), and Et_3N (23.7 μl) in CH_2Cl_2 (0.54 ml), followed by chromatography (TB system), gave **29** (23.3 mg, 22%), mp 106—107 °C, $[\alpha]_D^{20}$ +79° (*c* 1.7, $CHCl_3$) [lit,[24] mp 102—105 °C, $[\alpha]_D^{20}$ +64° (*c* 0.6, $CHCl_3$)], ^{13}C NMR ($CDCl_3$, 75 MHz) δ=94.6 (C-1), 97.3 (C-1'), and **30** (79.2 mg, 75%), mp 132—134 °C, $[\alpha]_D^{20}$ +41° (*c* 0.7, $CHCl_3$) [lit, mp 128—130 °C,[24] 133—134 °C,[25] $[\alpha]_D^{20}$ +39° (*c* 0.4, $CHCl_3$),[24] +17.1° (*c* 1, $CHCl_3$)[25]].

Found: **29**, C, 76.53; H, 6.63%. **30**, C, 76.53; H, 6.54%.

†† TRC=tris(triphenylphosphine)rhodium(I) chloride and EBW is the mixture of EtOH, benzene, and H_2O (7:3:1, v/v) (Ref. 19).

Calcd for $C_{68}H_{70}O_{11}$: C, 76.81; H, 6.64%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→6)-2,3-di-*O*-benzyl-α-D-glucopyranoside (31). A mixture of **27** (73.5 mg), TRC (20 mg), and EBW (4 ml) was refluxed overnight. After concentration, the residue was heated in acetone (2 ml) containing aq HCl (3.5%, 50 μl) for 1 h at 45 °C. Chromatography (HE system) gave **31** (43.6 mg, 62%), mp 128—129 °C, $[\alpha]_D^{20}$ +35° (*c* 0.7, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=95.6 (C-1), 103.9 (C-1′).

Found: C, 75.18; H, 6.67%. Calcd for $C_{61}H_{64}O_{11}$: C, 75.29; H, 6.63%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→6)-*O*-[(2,3,4-tri-*O*-benzyl-α-L-rhamnopyranosyl)-(1→4)]-2,3-di-*O*-benzyl-α-D-glucopyranoside (32). Rhamnosylation of **31** (54.4 mg) with **11** (36.5 mg) in the presence of NsCl (27.3 mg), AgOTf (43.2 mg), and Et_3N (23.5 μl) in CH_2Cl_2 (0.4 ml), followed by chromatography (TB system), gave **14** (16.0 mg, 45% from **11**), the *p*-nitrobenzenesulfonate of **31** (12.0 mg, 18% from **31**), $[\alpha]_D^{20}$ +31° (*c* 1.3, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=94.5 (C-1), 103.7 (C-1′), 123.8, 125.8, 142.3, 149.9 (*p*-nitrobenzenesulfonyl) [Found: C, 69.64; H, 5.81; N, 1.28%. Calcd for $C_{67}H_{67}NO_{15}S$: C, 69.47; H, 5.83; N, 1.21%], and then **32** (27.7 mg, 36% from **31**), $[\alpha]_D^{20}$ +17 (*c* 1.7, $CHCl_3$).

Found: C, 75.64; H, 6.54%. Calcd for $C_{88}H_{92}O_{15}$: C, 76.06; H, 6.67%.

***O*-β-D-Glucopyranosyl-(1→6)-*O*-[α-L-rhamnopyranosyl-(1→4)]-D-glucopyranose (3).** Hydrogenolysis of **32** (77.6 mg) over Pd on C (10%, 50 mg) in AcOH (6 ml) containing H_2O (50 μl) for 2 d, followed by chromatography (CM system), gave a hygroscopic glass of **3** (15.4 mg, 56%), $[\alpha]_D^{20}$ −5.1° (*c* 1.1, H_2O), ^1H NMR (D_2O, 300 MHz) δ=4.35 (0.4H, d, $J_{1'',2''}$=8.0 Hz, H-1″α), 4.37 (0.6H, $J_{1'',2''}$=8.0 Hz, H-1″β), 4.54 (0.6H, $J_{1,2}$=8.0 Hz, H-1β), 4.80 (1H, s, H-1′), 5.11 (0.4H, $J_{1,2}$=4.0 Hz, H-1α).

Found: C, 43.98; H, 6.98%. Calcd for $C_{18}H_{32}O_{15}$: C, 44.26; H, 6.60%.

Benzyl 4-*O*-Allyl-3-*O*-benzyl- and 3-*O*-Allyl-4-*O*-benzyl-α-D-glucopyranosides (35 and 36). A mixture of **34**[27] (6.09 g), NaH in an oil suspension (0.49 g) and allyl bromide (30.7 ml) was stirred for 4 h at 60 °C. After removing some insoluble matter by filtration, the solution was evaporated to dryness. The residue was vigorously stirred in $PhCH_2Cl$ (160 ml) containing crushed KOH (60 g) for 6 h at 120 °C. After filtration and evaporation at 95 °C, the residue was refluxed in a mixture of MeOH (20 ml), $CHCl_3$ (30 ml), and trifluoroacetic acid (Tokyo Kasei, 5 ml) for 1.5 h. After Et_3N (11 ml) being added, evaporation and chromatography (TB system) gave **35** (2.56 g, 79%), mp 81—82 °C (from hexane containing IPE), $[\alpha]_D^{20}$ +131° (*c* 1.0, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 75 MHz) δ=61.7 (C-6), 69.9 (C-5), 71.3 (C-2), 77.2 (C-4), 83.0 (C-3), 97.8 (C-1), 117.3, 134.5 (allyl), 136.8, 138.6 (benzyl), and **36** (0.28 g, 9%), mp 94.5—95.5 °C (from IPE), $[\alpha]_D^{20}$ +105° (*c* 0.3, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 75 MHz) 61.7 (C-6), 69.9 (C-5), 71.3 (C-2), 77.2 (C-4), 82.8 (C-3), 97.8 (C-1), 116.8, 135.1 (allyl), 136.8, 137.8 (benzyl).

Found: **35**, C, 68.84; H, 7.01%. **36**, C, 68.75; H, 7.03%. Calcd for $C_{23}H_{28}O_6$: C; 68.98, H; 7.05%.

A sample (28.2 mg) of **35** was treated in DMF (0.6 ml) with NaH in an oil suspension (17 mg) and $PhCH_2Br$ (52 μl) at room temp for 1 h. Processing followed by chromatography (HE system) gave a product which was refluxed overnight in EBW (4 ml) containing TRC (8 ml). After concentration, the residue was heated in acetone (4 ml) containing aq HCl (3.5%, 40 μl) for 1 h at 45 °C. Chromatography (HE system) gave **16** (19.4 mg, 51%), which was identified with a sample prepared following the known method.[16]

Benzyl 4-*O*-Allyl-6- and -2-*O*-benzoyl-3-*O*-benzyl-α-D-glucopyranosides (33 and 37). To a solution of **35** (2.71 g) in pyridine (13.5 ml) was added PhCOCl (0.79 ml) portionwise at −10 °C. The mixture was then stirred overnight at 0 °C. Processing and chromatography (TB system) gave the dibenzoate (0.77 g, 19%), **33** (1.79 g, 52%), $[\alpha]_D^{20}$ +105° (*c* 1.0, $CHCl_3$), ^1H NMR (CCl_4, 90 MHz) δ=3.53 (1H, dd, $J_{1,2}$=4 Hz, $J_{2,3}$=10 Hz, H-2), 4.82 (1H, d, H-1), and **37** (0.40 g, 12%), $[\alpha]_D^{20}$ +174° (*c* 3.1, $CHCl_3$) ^1H NMR (CCl_4, 90 MHz) 4.06 (1H, dd, $J_{2,3}$=10 Hz, $J_{3,4}$=9 Hz, H-3), 4.90 (1H, dd, $J_{1,2}$=4 Hz, H-2), 5.12 (1H, d, H-1).

Found: **33**, C, 71.11; H, 6.32%. **37**, C, 71.01; H, 6.32%. Calcd for $C_{30}H_{32}O_7$: C, 71.41; H, 6.39%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-α- and β-D-glucopyranosyl)-(1→2)-4-*O*-allyl-6-*O*-benzoyl-3-*O*-benzyl-α-D-glucopyranosides (38 and 39). The acceptor **33** (1.749 g) was glucosylated with **1** (2.44 g) in the presence of NsCl (1.31 g), AgOTf (1.52 g), and Et_3N (0.82 ml) in CH_2Cl_2 (18 ml), followed by chromatography (TB system), gave **39** (1.6 g, 45%), $[\alpha]_D^{20}$ +56° (*c* 5.4, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=98.9 (C-1), 103.6 (C-1′), 117.6, 134.6 (allyl), 166.0 (C=O), and **38** (1.37 g, 39%), $[\alpha]_D^{20}$ +93° (*c* 2.3, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=94.5 (C-1′), 95.2 (C-1), 117.6, 133.3 (allyl), 166.6 (C=O).

Found: **38**, C, 74.79; H, 6.67%. **39**, C, 74.57; H, 6.54%. Calcd for $C_{64}H_{66}O_{12}$: C, 74.83; H, 6.48%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→2)-4-*O*-allyl-3-*O*-benzyl-α-D-glucopyranoside (40). A mixture of **39** (1.53 g), MeOH (20 ml), and 1,4-dioxane (7.5 ml) was treated with dil methanolic NaOMe (7.5%, 7.5 ml) for 6.5 h at room temp. After AcOH was added, evaporation and chromatography (TB system) gave **40** (1.19 g, 87%), $[\alpha]_D^{20}$ +67° (*c* 0.6, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=99.1 (C-1), 103.6 (C-1′), 117.3, 134.9 (allyl).

Found: C, 74.13; H, 6.91%. Calcd for $C_{57}H_{62}O_{11}$: C, 74.17; H, 6.77%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→2)-3,6-di-*O*-benzyl-α-D-glucopyranoside (41). A mixture of **40** (199.5 mg), NaH in oil suspension (41 mg), and DMF (1.5 ml) was stirred for 0.5 h at −5 °C. After $PhCH_2Br$ (0.13 ml) was added, the mixture was stirred for 1 h at room temp. Quenching with MeOH, processing, and subsequent chromatography (HE system) gave the product, which was then refluxed in EBW (4 ml) containing TRC (30 mg). After evaporation, the residue was heated in acetone (2 ml) containing aq HCl (3.5%, 30 μl) for 1 h at 45 °C. Chromatography (HE system) afforded **41** (80.1 mg, 40%), $[\alpha]_D^{20}$ +45° (*c* 1.3, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 100 MHz) δ=99.0 (C-1), 103.5 (C-1′).

Found: C, 75.02; H, 6.72%. Calcd for $C_{61}H_{64}O_{11}$: C, 75.29; H, 6.63%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→2)-*O*-[(2,3,4,6-tetra-*O*-benzyl-α- and -β-D-glucopyranosyl)-(1→6)]-4-*O*-allyl-3-*O*-benzyl-α-D-glucopyranosides (42 and 43). The acceptor **40** (1.19 g) was glucosylated with **1** (0.91 g), NsCl (0.49 g), AgOTf (0.57 g), and Et_3N (0.31 ml) in CH_2Cl_2 (7.0 ml), followed by chromatography (TB system) to afford

42 (0.58 g, 31%), $[\alpha]_D^{20}$ +69° (*c* 1.7, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=97.5 (C-1″), 98.6 (C-1), 103.6 (C-1′), 117.0, 135.2 (allyl), and **43** (1.26 g, 68%), $[\alpha]_D^{20}$ +43° (*c* 2.6, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=98.9 (C-1), 103.6 (C-1′), 104.0 (C-1″), 116.7, 135.0 (allyl).

Found: **42**, C, 75.34; H, 6.50%. **43**, C, 75.52; H, 6.52%. Calcd for $C_{91}H_{96}O_{16}$: C, 75.60; H, 6.69%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→2)-*O*-[(2,3,4,6-tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→6)]-3-*O*-benzyl-α-D-glucopyranoside (44). A mixture of **43** (1.04 g), TRC (0.20 g), and EBW (33 ml) was refluxed for 3 h. After evaporation, the residue was refluxed in acetone (50 ml) containing aq HCl (3.5%, 2 ml) for 0.5 h. Chromatography (TB system) furnished **44** (0.82 g, 81%), $[\alpha]_D^{20}$ +34° (*c* 1.1, $CHCl_3$), ^{13}C NMR ($CDCl_3$, 25 MHz) δ=99.2 (C-1), 103.8 (2C, C-1′ and C-1″).

Found: C, 75.28; H, 6.55%. Calcd for $C_{88}H_{92}O_{16}$: C, 75.19; H, 6.60%.

Benzyl *O*-(2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→2)-*O*-[(2,3,4,6-tetra-*O*-benzyl-β-D-glucopyranosyl)-(1→6)]-*O*-[(2,3,4-tri-*O*-benzyl-α-L-rhamnopyranosyl)-(1→4)]-3-*O*-benzyl-α-D-glucopyranoside (45). Rhamnosylation of **44** (735 mg) with **11** (431 mg) in the presence of NsCl (348 mg), AgOTf (404 mg), and Et_3N (219 μl) in CH_2Cl_2 (2.8 ml) and subsequent chromatography (TB system) gave, after the elution of **14** and the *p*-nitrobenzenesulfonate of **44**, ^{13}C NMR ($CDCl_3$, 25 MHz) δ=98.4 (C-1), 103.3 (C-1′), 104.0 (C-1″), 124.2, 126.3, 142.6, 150.2 (*p*-nitrobenzenesulfonyl), the sole cross-condensate **45** (352 mg, 37%), $[\alpha]_D^{20}$ +19° (*c* 1.3, $CHCl_3$).

Found: C, 75.63; H, 6.68%. Calcd for $C_{115}H_{120}O_{20}$: C, 75.80; H, 6.64%.

***O*-β-D-Glucopyranosyl-(1→2)-*O*-[β-D-glucopyranosyl-(1→6)]-*O*-[α-L-rhamnopyranosyl-(1→4)]-D-glucopyranose (4).** Hydrogenolysis of **45** (75 mg) over Pd on C (10%, 75 mg) in AcOH (6 ml) containing H_2O (50 μl) for 3 d, followed by chromatography (CM system), afforded **4** (11.5 mg, 43%), mp 179—180 °C (decomp), $[\alpha]_D^{20}$ −16° (*c* 0.3, H_2O), ^1H NMR (D_2O, 300 MHz) δ=4.35 (0.7H, d, $J_{1''',2'''}$=8.0 Hz, H-1‴α), 4.37 (0.3H, d, $J_{1''',2'''}$=8.0 Hz, H-1‴β), 4.52 (0.7H, d, $J_{1',2'}$=8.0 Hz, H-1′α), 4.60 (0.3H, d, $J_{1,2}$=8.0 Hz, H-1β), 4.80 (1H, d, $J_{1'',2''}$= 1.5 Hz, H-1″), 5.31 (0.7H, d, $J_{1,2}$=4.0 Hz, H-1α).

Found: C, 44.04; H, 6.65%. Calcd for $C_{24}H_{42}O_{20}$: C, 44.31; H, 6.51%.

References

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2) K. Matsuzaki and T. Uryu, *Seibutsu Butsuri*, **20**, 1 (1980).

3) H. Paulsen, *Chem. Soc. Rev.*, **13**, 15 (1984); R. R. Schmidt, *Angew. Chem., Int. Ed. Engl.*, **25**, 212 (1986); H. Kunz, *ibid.*, **26**, 294 (1987).

4) S. Koto, N. Morishima, T. Irisawa, Y. Hashimoto, M. Yamazaki, and S. Zen, *Nippon Kagaku Kaishi*, **1982**, 1651.

5) S. Koto, T. Sato, N. Morishima, and S. Zen, *Bull. Chem. Soc. Jpn.*, **53**, 1761 (1980).

6) S. Koto, N. Morishima, Y. Kihara, H. Suzuki, S. Kosugi, and S. Zen, *Bull. Chem. Soc. Jpn.*, **56**, 188 (1983).

7) S. Koto, N. Morishima, H. Sato, Y. Sato, and S. Zen, *Bull. Chem. Soc. Jpn.*, **58**, 120 (1985).

8) N. Morishima, S. Koto, T. Irisawa, Y. Hashimoto, M. Yamazaki, T. Higuchi, and S. Zen, *Chem. Lett.*, **1982**, 1383.

9) S. Koto, N. Morishima, K. Takenaka, C. Uchida, and S. Zen, *Bull. Chem. Soc. Jpn.*, **58**, 1464 (1985).

10) S. Koto, S. Inada, T. Yoshida, M. Toyama, and S. Zen, *Can. J. Chem.*, **59**, 255 (1981).

11) S. Koto, N. Morishima, M. Owa, and S. Zen, *Carbohydr. Res.*, **130**, 73 (1984).

12) N. Morishima, S. Koto, M. Uchino, and S. Zen, *Chem. Lett.*, **1982**, 1183.

13) R. Tschesche, R. Kottler, and G. Wulff, *Justus Liebigs Ann. Chem.*, **699**, 212 (1966); R. Tschesche, G. Luedke, and G. Wulff, *Chem. Ber.*, **102**, 1253 (1969).

14) R. Tschesche, M. Tauscher, H.-W. Fehlhaber, and G. Wulff, *Chem. Ber.*, **102**, 2072 (1969).

15) T. Kubota and H. Hinoh, *Tetrahedron Lett.*, **1968**, 303.

16) A. Lubineau, A. Thieffry, and A. Veyrières, *Carbohydr. Res.*, **46**, 143 (1976).

17) J. M. J. Fréchet and H. H. Baer, *Carbohydr. Res.*, **42**, 369 (1975).

18) K. Bock and C. Pedersen, *J. Chem. Soc., Perkin Trans. 2*, **1974**, 293.

19) P. A. Gent and R. Gigg, *Carbohydr. Res.*, **49**, 325 (1976).

20) T. Usui, N. Yamaoka, K. Matsuda, K. Tuzimura, H. Sugiyama, and S. Seto, *J. Chem. Soc., Perkin Trans. 1*, **1973**, 2425.

21) K. Mizutani, H. Kajita, K. Tashima, and O. Tanaka, *Nippon Kagaku Kaishi*, **1982**, 1595.

22) K. Bock and C. Pedersen, *Adv. Carbohydr. Chem. Biochem.*, **41**, 27 (1983).

23) S. David, A. Lubineau, and A. Thieffry, *Tetrahedron*, **34**, 299 (1978).

24) S. Koto, N. Morishima, C. Kusuhara, S. Sekido, T. Yoshida, and S. Zen, *Bull. Chem. Soc. Jpn.*, **55**, 2995 (1982).

25) R. R. Schmidt, M. Reichrath, and U. Moering, *J. Carbohydr. Chem.*, **3**, 67 (1984).

26) S. Koto, Y. Hamada, and S. Zen, *Chem. Lett.*, **1975**, 587.

27) S. Koto, N. Morishima, T. Yoshida, M. Uchino, and S. Zen, *Bull. Chem. Soc. Jpn.*, **56**, 1171 (1983).