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SYNTHESIS AND CONFORMATIONAL ANALYSIS OF METHYL 3-*O*-[α-L(AND D)-RHAMNOPYRANOSYL]MALTOSIDE DERIVATIVES: A BRANCHED TRISACCHARIDE WITH THE CENTRAL GLUCOPYRANOSE RESIDUE IN THE $^1C_4$ CONFORMATION*

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ABSTRACT

The branched trisaccharide 4-*O*-α-D-glucopyranosyl-3-*O*-α-L-rhamnopyranosyl-β-D-glucopyranose is a model for a part of the lipopolysaccharide from *Shigella flexneri* serotype I,1a, which has[1] the structure →2)-α-L-Rha-(1→3)-α-L-tives, using silver triflate-promoted glycosylation reactions. Similarly, the model disaccharide glucosides methyl 3-*O*-α-L(and D)-rhamnopyranosyl-α(and β)-D-glucopyranosides have been synthesised. The acetylated derivatives of the trisaccharides have been converted into their glycosyl bromides (**22** and **23**) and glycosyl fluorides (**24** and **25**), and the latter transformed into the 1,6-anhydro derivatives by treatment with strong base. The conformations of the acetylated derivatives have been analysed by ^{1}H- and ^{13}C-n.m.r. spectroscopy. In most of the branched trisaccharide derivatives, the conformation of the central glucopyranose residue is predominantly $^1C_4$. X-Ray analysis showed that, in the solid state for the glycosyl fluoride **24**, the conformation of the central glucopyranose residue is $^1C_4$.

INTRODUCTION

The branched trisaccharide 4-*O*-α-D-glucopyranosyl-3-*O*-α-L-rhamnopyranosyl-β-D-glucopyranose is a model for a part of the lipopolysaccharide from *Shigella flexneri* serotype I,1a, which has[1] the structure →2)-α-L-Rha-(1→3)-α-L-Rha-(1→3)-[α-D-Glc-(1→4)]-β-D-GlcNAc-(1→2)-α-L-Rha-(1→. Simple empirical computer calculation (HSEA) has shown[2] that the minimum energy conformation calculated is not in good agreement with the requirements of the *exo*-anomeric

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effect. Therefore, we have synthesised the trisaccharides 3-*O*-[α-L(and D)-rhamnopyranosyl]maltose and related model compounds in order to investigate their conformations in solution using ^{1}H- and ^{13}C-n.m.r. spectroscopy.

RESULTS AND DISCUSSION

The synthesis of methyl 3-*O*-α-L-rhamnopyranosyl-α-D-glucopyranoside (**6**) was accomplished by silver triflate-promoted glycosylation of methyl 2-*O*-benzoyl-4,6-*O*-benzylidene-α-D-glucopyranoside[3,4] (**1**) with 2,3,4-tri-*O*-acetyl-α-L-rhamnopyranosyl bromide (**2**), to give the crystalline protected disaccharide **4** (75%). *O*-Deacylation of **4** with methanolic sodium methoxide followed by treatment with aqueous 90% trifluoroacetic acid gave the glycoside **6** (93%), which was characterised by its ^{1}H- and ^{13}C-n.m.r. data (Tables I and II).

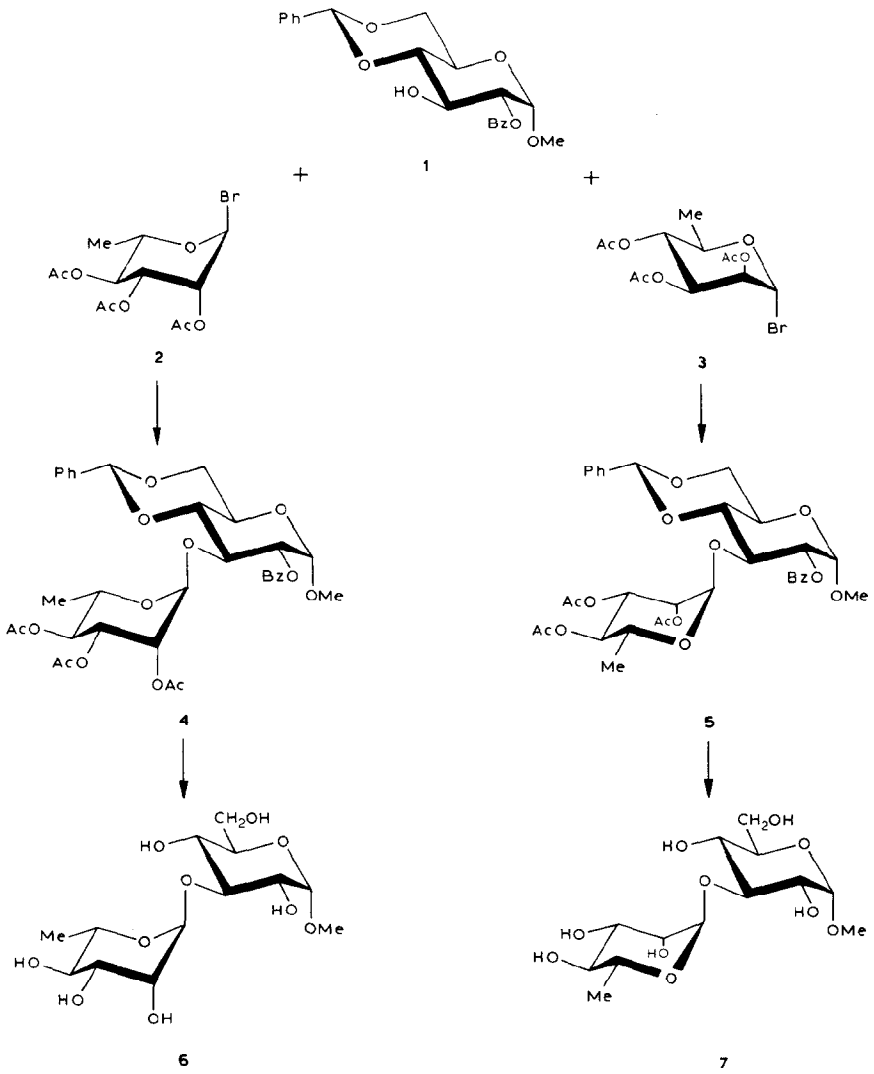
Likewise, methyl 3-*O*-α-D-rhamnopyranosyl-α-D-glucopyranoside (**7**, 72%) was prepared using 2,3,4-tri-*O*-acetyl-α-D-rhamnopyranosyl bromide (**3**) and **1**. The derivative **5** was deprotected as described above, to give the glycoside **7** (85%) which was characterised on the basis of its ^{1}H- and ^{13}C-n.m.r. parameters (Tables I and II).

As model compounds with anomeric configurations similar to those of the trisaccharide described below, the corresponding methyl β-glucosides **11** and **12** were also prepared, using analogous methods but starting with the β-D-glucoside derivature[3,4] **8**. The yields of **9–12** were similar to those reported above.

Silver triflate-promoted glycosylation of methyl 2,6,2′,3′,4′,6′-hexa-*O*-acetyl-β-maltoside[5] (**15**) with the rhamnosyl bromides **2** and **3** gave the trisaccharide derivatives **16** (61%) and **17** (57%), respectively. Treatment of **16** and **17** with methanolic sodium methoxide gave the trisaccharide glycosides **18** (98%) and **19** (96%), respectively, which were characterised on the basis of their ^{1}H- and ^{13}C-n.m.r. parameters (Tables I and II).

The 1-*O*-acetyl derivatives of the branched trisaccharides were also synthesised in order to be able to prepare the corresponding glycosyl bromides and fluorides. Thus, 1,2,6,2′,3′,4′,6′-hepta-*O*-acetyl-β-maltose[5] (**13**) was glycosylated, as described above, with **2** or **3** to give the trisaccharide derivatives **20** (69%) and **21** (53%), respectively. Treatment of these compounds with $TiBr_4$ in chloroform gave almost quantitative yields of the corresponding glycosyl bromide **22** and **23**, which were unstable but could be characterised on the basis of their n.m.r. data (Tables III and IV). The bromides were converted into the corresponding crystalline β-glycosyl fluorides **24** (72%) and **25** (80%) by treatment with silver fluoride in acetonitrile and characterised on the basis of their ^{1}H- and ^{13}C-n.m.r. data (Tables III and IV). Formed in addition to **24** was 5% of the 1-hydroxy compound **32**, which was characterised on the basis of its ^{1}H- and ^{13}C-n.m.r. parameters (Tables III and IV).

Attempts to prepare the deblocked glycosyl fluorides corresponding to **24** and **25** were not successful. When the *O*-deacetylation of **24** with a catalytic amount



of sodium methoxide in methanol-d_4 was monitored by ^{1}H-n.m.r. spectroscopy at 500 MHz until **24** had disappeared, analysis by n.m.r. spectroscopy showed the product to be a mixture of the 1-hydroxy compound **30**, the glycosyl fluoride **33**, the methyl glycoside **18**, and the 1,6-anhydro compound **28** in the ratios 10:3:3:1. If **24** and **25** were treated with strong base (potassium hydroxide in ethanol), the crystalline 1,6-anhydro derivatives **26** (68%) and **27** (50%), respectively, could be isolated after re-acetylation. Deblocking of **26** and **27** gave the trisaccharides **28** and **29**, respectively, which were characterised on the basis of their ^{1}H- and ^{13}C-n.m.r. data (Tables I and II).

Attempts to *O*-deacetylate the L-trisaccharide deca-acetate **20** with

TABLE I

^{1}H-N.M.R. DATA FOR UNPROTECTED COMPOUNDS[a]

Compound/unit	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-6'*	*OMe*
6 α-L-Rha	5.08	4.06	3.79	3.45	4.02	1.26		
	1.8	3.4	9.8	9.7	6.3			
→3)-α-D-GlcOMe	4.79	3.66	3.75	3.46	3.66	3.88	3.76	3.43
	3.7	9.6	9.0	10.1	2.3	12.2		
					5.5			
7 α-D-Rha	5.18	4.06	3.81	3.47	4.03	1.29		
	1.8	3.3	9.8	9.8	6.2			
→3)-α-D-GlcOMe	4.83	3.62	3.79	3.54	3.68	3.88	3.77	3.44
	3.7	9.7	9.0	10.1	2.3	12.0		
					5.4			
11 α-L-Rha	5.13	4.06	3.79	3.46	4.02	1.26		
	1.7	3.5	9.8	9.7	6.3			
→3)-β-D-GlcOMe[b]	4.40	3.38	3.61	3.45	3.48	3.94	3.73	3.58
	8.1	9.2	8.5	9.8	2.0	12.3		
					5.5			
12 α-D-Rha	5.13	4.05	3.79	3.45	4.02	1.26		
	1.8	3.4	9.8	9.7	6.3			
→3)-β-D-GlcOMe[b]	4.38	3.31	3.60	3.51	3.47	3.92	3.72	3.57
	7.9	9.3	8.5	9.8	2.1	12.2		
					5.6			
18 α-L-Rha	5.24	4.13	3.81	3.46	3.85	1.29		
	1.9	3.3	9.6	9.6	6.1			
α-D-Glc	5.53	3.57	3.65	3.43	3.64	3.85	3.77	
	4.0	9.8	9.1	10.0	2.4	12.2		
					4.3			
→3,4)-β-D-GlcOMe[b]	4.39	3.46	3.95	3.87	3.61	3.93	3.78	3.57
	7.9	8.8	8.2	9.1	2.4	12.0		
					5.2			
19 α-D-Rha	5.07	4.13	3.78	3.48	3.95	1.26		
	1.8	3.4	9.6	9.6	6.2			
α-D-Glc	5.35	3.57	3.63	3.43	3.68	3.84	3.77	
	4.0	9.8	9.1	10.1	2.3	12.4		
					4.9			
→3,4)-β-D-GlcOMe[b]	4.40	3.40	3.82	3.81	3.59	3.94	3.80	3.57
	7.9	8.7		9.1	2.1	12.3		
					5.1			
28 α-L-Rha	4.96	3.97	3.75	3.48	3.68	1.32		
	1.9	3.3	9.7	9.6	6.1			
α-D-Glc	5.10	3.58	3.82	3.47	3.75	3.85	3.80	
	3.8	9.9	9.1	10.0	2.2	12.0		
					4.9			
→3,4)-1,6-Anhydro-β-D-Glc[b]	5.51	3.67	3.84	3.84	4.80	4.15	3.82	
	2.0 H-2				1.0	8.0		
	1.4 H-3				6.0			
29 α-D-Rha	4.95	3.95	3.80	3.48	3.73	1.32		
	1.9	3.3	9.7	9.7	6.3			
α-D-Glc	5.11	3.58	3.83	3.46	3.80	3.87	3.78	
	3.8	9.8	9.2	10.0				
→3,4)-1,6-Anhydro-β-D-Glc[b]	5.51	3.70	3.82	3.84	4.82	4.14	3.81	
					1.1	8.0		
					6.0			

TABLE I *(continued)*

Compound/unit	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-6'*	*OMe*
30α α-L-Rha	5.25	4.17	3.84	3.48	3.86	1.30		
	1.8	3.3	9.7	9.7	5.8			
α-D-Glc	5.56	3.58	3.67	3.45	3.65	3.86	3.78	
	4.5	10.0	9.0	10.0	2.5	12.4		
					5.0			
→3,4)-α-D-Glc[b]	5.19	3.82	4.09		3.99	3.84	3.84	
	3.9	9.0	8.0					
30β α-L-Rha	5.28	4.16	3.84	3.48	3.86	1.29		
	1.8	3.3	9.7	9.7	6.0			
α-D-Glc	5.58	3.58	3.66	3.45	3.65	3.86	3.78	
	4.8	10.0	9.0	10.0	2.5	12.4		
					5.0			
→3,4)-β-D-Glc[b]	4.66	3.44	3.96	3.89	3.61	3.91	3.78	
	8.0	8.6	8.0	9.0	2.5	12.4		
					5.0			
31α α-D-Rha	5.08	4.16	3.80	3.50	3.99	1.29		
	1.8	3.3	9.6	9.8	6.0			
α-D-Glc	5.38	3.58	3.66	3.44	3.71	3.86	3.79	
	4.0	10.0	9.0	10.0	2.6	12.4		
					4.9			
→3,4)-α-D-Glc[b]	5.25	3.68	4.01	3.83	3.97	3.84	3.84	
	3.9	9.3	8.3					
31β α-D-Rha	5.09	4.14	3.80	3.50	3.98	1.29		
	1.8	3.3	9.6	9.8	6.0			
α-D-Glc	5.38	3.59	3.65	3.44	3.70	3.86	3.78	
	4.0	10.0	9.0	10.0	2.6	12.4		
					4.9			
→3,4)-β-D-Glc[b]	4.67	3.38	3.84	3.84	3.61	3.92	3.80	
	8.0	9.1		9.1	2.5	12.0		
					5.4			

[a]Measured at 500 MHz on solutions in D_2O at 27°, using acetone (2.22 p.p.m.) as internal reference: ^3J values given in Hz (±0.3 Hz) below the chemical shift values refer to coupling with the next higher-numbered proton. [b]Assignments based on COSY experiments.

methanolic sodium methoxide were also unsuccessful, even though a low temperature and short time of reaction were used. The product was contaminated with decomposition products, glucose, and rhamnose, but it was possible to characterise the product as α,β-**30** by using ^{1}H- and ^{13}C-n.m.r. spectroscopy (Tables I and II). *O*-Deacetylation of the D-trisaccharide deca-acetate **21** gave a reasonably good yield of the trisaccharide **31** but which was still contaminated with small amounts of glucose and rhamnose.

Analysis of the ^{1}H-n.m.r. coupling constants for solutions of the trisaccharide derivatives **16, 17, 20, 21, 24, 25, 32**α, and **32**β in $CDCl_3$, using limiting values calculated by the semi-empirical method proposed by Altona *et al.*[6] (Table V), indicated that the central glucopyranosyl residue was not in the usual $^4C_1$ conformation (Table VI). The same results were found for **16, 17, 20**, and **24** when C_6D_6 was the solvent (Table VII), but the proportion of the $^4C_1$ conformation in the

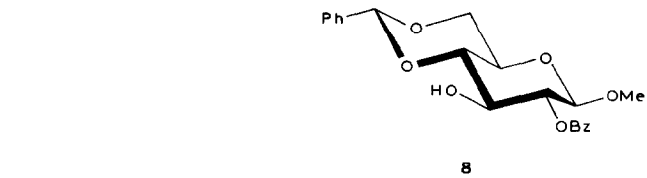
TABLE II

^{13}C-N.M.R. DATA FOR UNPROTECTED DERIVATIVES[a]

Compound/unit	*C-1*	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	*OMe*
6 α-L-Rha	102.6	71.8	71.7	73.4	70.2	17.9	
→3)-α-D-GlcOMe[b]	100.8	73.1	81.5	69.4	73.1	62.0	56.5
7 α-D-Rha	102.6	72.0	71.8	73.6	70.4	18.1	
→3)-α-D-GlcOMe[b]	101.1	71.5	81.3	71.7	73.0	62.0	56.5
11 α-L-Rha	102.3	71.6	71.5	73.2	70.1	17.7	
→3)-β-D-GlcOMe[c]	104.3	74.9	83.9	69.4	77.2	62.0	58.5
12 α-D-Rha	102.4	71.6	71.5	73.3	70.1	17.8	
→3)-β-D-GlcOMe	104.6	73.0	83.5	71.4	76.9	61.8	58.5
18 α-L-Rha	102.2	71.6	71.2	73.1	71.0	18.0	
α-D-Glc	98.5	72.5	73.9	70.4	73.8	61.5	
→3,4)-β-D-GlcOMe[b]	104.6	74.4	84.7	72.7	75.7	62.1	58.6
19 α-D-Rha	103.0	71.5	71.4	73.2	70.6	17.7	
α-D-Glc	100.2	72.4	74.2	70.4	74.0	61.6	
→3,4)-β-D-GlcOMe[c]	104.3	73.6	87.4	75.7	75.6	62.0	58.4
28 α-L-Rha	101.0	71.5	71.4	73.2	71.0	18.0	
α-D-Glc	98.5	72.7	74.2	70.8	73.7	61.7	
→3,4)-1,6-Anhydro-β-D-Glc[c]	102.0	67.9	74.5	74.7	76.4	66.1	
29 α-D-Rha	100.0	71.5	71.3	73.3	70.6	17.9	
α-D-Glc	95.9	72.6	74.1	70.8	73.7	61.7	
→3,4)-1,6-Anhydro-β-D-Glc[c]	101.9	69.4	74.7	73.0	76.4	66.2	
30α α-L-Rha	102.6	71.7[e]	71.3	73.2	71.6[e]	18.0	
α-D-Glc	98.6	72.5[d]	74.1	70.5	73.9	61.7	
→3,4)-α-D-Glc	93.0	72.6[d]	82.4	72.7[d]	71.6[e]	62.1	
30β α-L-Rha	102.2	71.7[e]	71.3	73.2	71.5[e]	18.0	
α-D-Glc	98.4	72.6[d]	74.1	70.5	73.9	61.7	
→3,4)-β-D-Glc	97.1	75.6	85.0	72.7[d]	75.8	61.9	
31α α-D-Rha	103.0	71.6	71.5	73.2	70.6	17.9	
α-D-Glc	100.2	72.6	74.2	70.5	74.1	61.7	
→3,4)-α-D-Glc[c]	93.0	71.9	85.0	75.6	71.2	62.0	
31β α-D-Rha	103.0	71.6	71.5	73.2	70.6	17.9	
α-D-Glc	100.3	72.5	74.2	70.5	74.1	61.7	
→3,4)-β-D-Glc[c]	97.0	74.8	87.5	75.7	75.6	62.1	

[a]Measured at 125.7 MHz on solutions in D_2O at 27°, using 1,4-dioxane (67.4 p.p.m.) as internal reference. [b]Assignments based on heteronuclear 2-D correlated experiments. [c]Assignments based on CHORTLE experiments. [d]Assignments may be reversed. [e]Assignments may be reversed.

equilibrium appeared to be larger (Table VI). The vicinal coupling constants indicated the presence of a substantial amount of the $^1C_4$ conformation in equilibrium with the $^4C_1$ conformation as indicated in Table VI. The proportion of $^4C_1$ conformation appeared to be dependent on the 1-substituent of the central glucose residue. In the glycosyl fluoride **24**, where the anomeric effect is the strongest, the central glucose residue was almost completely in the $^1C_4$ conformation. The proportion of the $^1C_4$ conformation calculated from the $J_{4,5}$ values was consistently smaller than that calculated using the other ^3J values. This might be explained, as also discussed by David[7], by considering participation in the equilibrium of the S_2^O skew-boat conformation. For the ideal skew form[8], the



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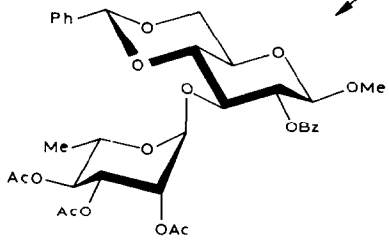

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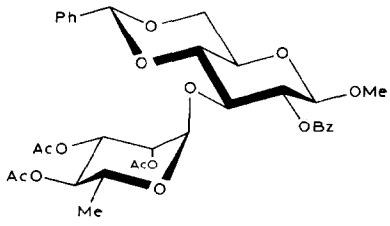

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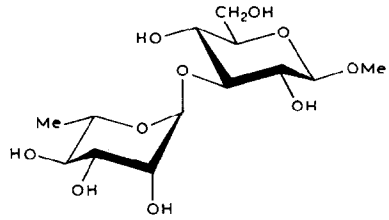

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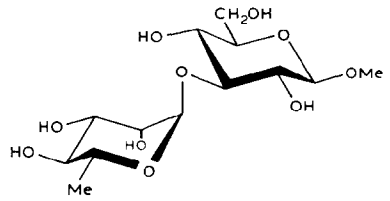

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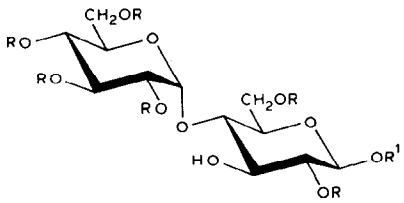


13 R = R^1 = Ac
14 R = H, R^1 = Me
15 R = Ac, R^1 = Me

dihedral angles for H-1/4 are 87°, 49°, 87°, and 153°, respectively, which correspond to ^3J values (without correction for electronegativity) of 0, 3.3, 0, and 7.3 Hz, respectively. In the glycosyl fluorides **24** and **25**, the proportion of the $^1C_4$ conformation deduced from the $J_{3,4}$ and $J_{4,5}$ values was smaller than that deduced from the $J_{1,2}$ and $J_{2,3}$ values, which might indicate a contribution of the skew form S^1_5 with the corresponding dihedral angles of 49°, 87°, 153°, and 169° and the ^3J values of

TABLE III

^{1}H-N.M.R. DATA FOR PROTECTED DERIVATIVES[a]

Compound/unit	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-6'*	*OMe*
1 α-D-GlcOMe	5.07	5.03	4.34	3.62	3.90	4.31	3.79	3.39
	3.6	9.5	9.5	9.5	4.8	10.0		
			2.6(H-3,OH)		10.2			
4 α-L-Rha	5.00	5.05	5.22	4.89	4.16	0.75		
	1.8	3.6	10.0	9.9	6.3			
→3)-α-D-GlcOMe	5.10	5.08	4.41	3.72	3.94	4.33	3.81	3.38
	3.6	9.4	9.4	9.4	4.6	10.2		
					10.4			
5 α-D-Rha	5.18	5.35	5.08	4.86	3.77	0.92		
	1.8	3.5	10.0	9.9	6.3			
→3)-α-D-GlcOMe[b]	5.02	5.18	4.40	3.80	3.89	4.33	3.80	3.41
	3.7	9.6	9.3	9.5	4.7	10.1		
					10.4			
8 β-D-GlcOMe	4.60	5.16	4.05	3.67	3.52	4.39	3.83	3.49
	8.1	9.5	9.5	9.5	4.8	10.0		
			3.5(H-3,OH)		10.2			
9 α-L-Rha	4.81	5.02	5.24	4.84	4.13	0.74		
	1.7	3.6	10.0	10.0	6.2			
→3)-β-D-GlcOMe[b]	4.58	5.31	4.12	3.79	3.58	4.42	3.86	3.49
	7.8	8.9	9.4	9.4	5.0	10.2		
					10.3			
10 α-D-Rha	5.16	5.38	5.10	4.83	3.61	0.70		
	2.0	3.5	10.0	10.0	6.3			
→3)-β-D-GlcOMe	4.61	5.32	4.14	3.87	3.52	4.42	3.85	3.50
	7.8	9.4	9.4	9.4	4.7	10.1		
					10.3			
13 α-D-Glc	5.34	5.00	5.43	5.07	4.13	4.26	4.09	
	3.6	10.5	9.5	10.0	4.5	12.2		
					2.0			
→4)-β-D-Glc	5.66	4.94	3.87	3.68	3.72	4.49	4.19	
	8.2	9.0	9.0	9.0	1.5	12.2		
					5.0			

TABLE III *(continued)*

Compound/unit	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-6'*	*OMe*
16 α-L-Rha	5.04	5.23	5.17	5.02	3.88	1.19		
	2.0	3.4	9.8	9.6	6.4			
α-D-Glc	5.43	5.02	5.36	5.08	4.09	4.25	4.10	
	4.0	10.2	9.0	10.2	5.0	12.6		
→3,4)-β-D-GlcOMe[b]	4.51	4.89	3.94	3.89	3.90	4.47	4.29	3.46
	5.5	6.0	6.5		3.5	11.8		
					5.0			
17 α-D-Rha	5.02	5.07	5.15	5.08	3.96	1.19		
	1.9	3.1	10.2	9.8	6.3			
α-D-Glc	5.55	5.11	5.29	5.11	4.05	4.25	4.08	
	4.0	10.2	9.2	10.2	4.6	12.2		
					2.5			
→3,4)-β-D-GlcOMe[b]	4.35	4.95	3.98	3.98	3.73	4.45	4.30	3.45
	6.7	8.1		8.8	3.2	12.2		
					4.5			
20 α-L-Rha	5.05	5.25	5.17	5.07	3.85	1.22		
	1.9	3.5	10.0	9.4	6.2			
α-D-Glc	5.32	4.93	5.38	5.07	4.15	4.23	4.12	
	3.8	9.8	9.6	9.6	4.8	12.0		
					2.3			
→3,4)-β-D-Glc	5.97	4.92	4.01	3.84	4.16	4.46	4.30	
	3.6	4.2	4.6	5.4	4.5	11.8		
					6.5			
21 α-D-Rha	5.01	5.10	5.17	5.10	3.96	1.20		
	2.0	3.1	10.2	9.7	6.2			
α-D-Glc	5.47	5.05	5.30	5.09	4.06	4.23	4.06	
	3.9	10.2	9.3	10.2	4.9	12.5		
					2.3			
→3,4)-β-D-Glc[b]	5.76	5.01	4.06	3.94	3.97	4.50	4.30	
	6.1	7.0	6.3	7.2	3.5	12.0		
					4.8			
22 α-L-Rha	4.96	5.38	5.15	5.11	3.94	1.18		
	2.0	3.4	10.0	9.8	6.2			
α-D-Glc	5.60	5.13	5.33	5.04	4.03	4.25	4.08	
	4.0	10.0	9.5	10.0	4.0	12.2		
					2.0			

TABLE III *(continued)*

Compound/unit	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-6'*	*OMe*
→3,4)-α-D-GlcBr[b]	6.67	4.70	4.18	3.99	4.05	4.49	4.26	
	4.0	9.0	7.7	10.0	2.2	12.2		
					4.0			
23 α-D-Rha	5.15	5.19	5.14	5.11	4.08	1.22		
	1.9	2.7	10.0	9.5	6.2			
α-D-Glc	5.51	5.06	5.27	5.09	4.08	4.25	4.08	
	3.9	10.5	9.0	9.5	4.6	12.2		
→3,4)-α-D-GlcBr[b]	6.53	4.72	4.38	3.97	4.18	4.58	4.38	
	4.0	9.4	8.6	9.8	2.2	12.4		
					3.6			
24 α-L-Rha	5.08	5.23	5.18	5.06	3.84	1.22		
	2.0	3.3	9.9	9.4	6.2			
α-D-Glc	5.32	4.90	5.39	5.04	4.16	4.22	4.12	
	3.9	10.2	9.4	9.9	4.9	11.8		
					2.2			
→3,4)-β-D-GlcF[b]	5.58	4.96	4.00	3.94	4.34	4.48	4.37	
	2.0	3.0	4.3	3.9	5.8	11.5		
	51.7(H-1,F)	6.5(H-2,F)			5.8	1.3(H-6,F)		
25 α-D-Rha	5.00	5.15	5.18	5.09	3.98	1.22		
	1.9	3.2	10.0	10.0	6.2			
α-D-Glc	5.39	4.98	5.35	5.07	4.12	4.22	4.12	
	3.9	10.2	9.5	10.0				
→3,4)-β-D-GlcF[b]	5.50	5.12	4.00	4.09	4.23	4.56	4.30	
	2.6	3.8	5.7	6.5	5.0	12.0		
	52.5(H-1,F)	5.8(H-2,F)			5.0	1.0(H-6,F)		
26 α-L-Rha	5.14	5.25	5.22	5.07	3.75	1.22		
	1.9	3.4	9.0	10.0	6.2			
α-D-Glc	5.26	4.85	5.51	5.08	4.45	4.24	4.18	
	3.8	10.3	9.5	10.3	4.8	12.3		
					3.3			
→3,4)-1,6-Anhydro-β-D-Glc[b]	5.47	4.49	3.82	3.56	4.77	4.12	3.80	
	2.1(H-2)		~1.3(H-2)		1.0	8.0		
	1.3(H-3)		~1.3(H-4)		6.0			
			~1.3(H-5)					

27 α-D-Rha	4.86	5.18	5.21	5.10	4.10	1.24	
	1.9	3.4	10.0	9.5	6.3		
α-D-Glc	5.24	4.88	5.47	5.07	4.49	4.23	4.18
	3.8	10.3	9.5	10.3	4.8	12.3	
					2.9		
→3,4)-1,6-Anhydro-β-D-Glc[b]	5.45	4.75	3.81	3.56	4.81	4.10	3.78
	1.9(H-2)		~1.3(H-2)		1.0		
	1.3(H-3)		~1.3(H-4)		6.0	7.8	
			~1.3(H-5)				
32α α-L-Rha	4.95	5.40	5.18	5.03	3.94	1.16	
	2.2	3.3	10.2	9.6	6.3		
α-D-Glc	5.59	5.13	5.34	5.12	4.07	4.27	4.07
	3.9	10.3	9.2	10.2			
→3,4)-α-D-Glc[b]	5.51	4.72	4.21	3.88	4.18	4.47	4.21
	3.6	9.0	7.2	9.0			
32β α-L-Rha	4.99	5.27	5.16	5.04		1.17	
	2.2	3.3	10.2	9.6			
α-D-Glc	5.50	5.13	5.32	5.12			
	3.9	10.3	9.2	10.2			
→3,4)-β-D-Glc[b]	4.74	4.84	3.98				
	6.4	7.8	6.4				
34 β-D-GlcF	5.36	5.11	5.21	5.21	3.91	4.27	4.22
	6.0				4.8		
	52.0(H-1,F)				2.5	12.5	

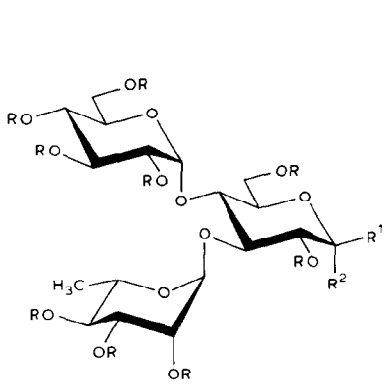
[a]Measured at 500 MHz on solutions in $CDCl_3$ at 27°: the ^3J values given in Hz (±0.3 Hz) below the chemical shifts refer to the next higher-numbered proton unless indicated otherwise in brackets. [b]Assignments based on COSY experiments.

TABLE IV

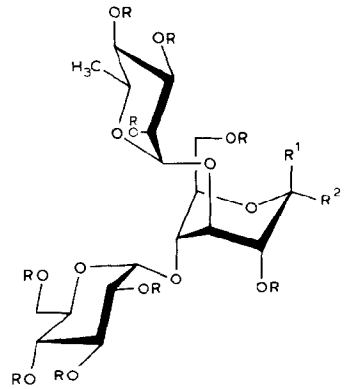
^{13}C-N.M.R. DATA FOR PROTECTED DERIVATIVES[a]

Compound/unit	*C-1*	*C-2*	*C-3*	*C-4*	*C-5*	*C-6*	*OMe*
1 α-D-GlcOMe	97.4	74.1	68.9	81.5	62.1	69.0	55.5
4 α-L-Rha	98.1	69.5	69.0	71.1	66.3	16.6	
→3)-α-D-GlcOMe	97.8	74.8	73.3	79.6	62.7	69.0	55.5
5 α-D-Rha	98.2	69.5	68.9[c]	70.9	66.5	17.4	
→3)-α-D-GlcOMe	97.9	71.9	73.5	82.2	62.1	69.1[c]	55.5
9 α-L-Rha	98.0	69.4	68.7	71.1	66.4	16.6	
→3)-β-D-GlcOMe[b]	102.4	74.4	76.3	78.9	66.7	68.8	57.1
10 α-D-Rha	98.2	69.4	68.6	70.6	66.6	17.0	
→3)-β-D-GlcOMe	102.7	72.3	77.3	81.4	66.1	69.0	57.2
16 α-L-Rha	98.1	69.6	68.6	70.7	67.9	17.3	
α-D-Glc	96.0	69.8	70.1	68.3	68.5	61.9	
→3,4)-β-D-GlcOMe[b]	100.9	71.1	78.8	75.6	72.8	63.7	56.5
17 α-D-Rha	98.2	69.8	68.7	70.5	67.7	17.0	
α-D-Glc	96.4	70.0	70.3	68.3	68.5	62.0	
→3,4)-β-D-GlcOMe[b]	101.3	72.2	81.0	74.8	72.5	63.2	56.5
20 α-L-Rha	97.6	69.4	68.7	70.5	68.0	17.3	
α-D-Glc	96.6	70.3	69.8	68.2	68.2	61.8	
→3,4)-β-D-Glc[b]	91.3	68.7	75.3	75.4	72.8	63.5	
21 α-D-Rha	97.8	69.7	68.6	70.4	67.8	17.1	
α-D-Glc	96.7	70.1	70.1	68.2	68.6	61.9	
→3,4)-β-D-Glc[b]	91.6	70.7	78.2	74.3	73.1	63.0	
22 α-L-Rha	100.4	69.2[d]	68.9	70.3[c]	68.2	17.4	
α-D-Glc	95.6	69.3[d]	70.2[c]	68.3	68.7	61.7	
→3,4)-α-D-GlcBr	86.8	72.1	81.3	73.4	72.6	62.3	
23 α-D-Rha	97.7	69.2	68.8	70.3	67.3	17.0	
α-D-Glc	96.5	70.0	69.8	68.1	68.6	61.8	
→3,4)-α-D-GlcBr[b]	87.3	71.5	76.2	75.4	72.9	61.9	
24 α-L-Rha	97.2	69.5	68.5	70.6	68.1	17.3	
α-D-Glc	97.0	70.4	69.8	68.3	68.4	61.8	
→3,4)-β-D-GlcF[b]	105.2	67.4	73.4	74.8	72.8	63.5	
	220.3(C-1,F)	41.1(C-2,F)					
25 α-D-Rha	98.4	69.7	68.7	70.5	67.8	17.2	
α-D-Glc	96.9	70.3	69.9	68.3	68.5	61.9	
→3,4)-β-D-GlcF[b]	105.3	69.6	77.0	73.6	72.6	63.1	
	221.3(C-1,F)	39.7(C-2,F)					
26 α-L-Rha	96.1	69.5	68.6	70.9	67.7	17.4	
α-D-Glc	97.1	70.9	69.8	68.4	67.7	62.0	
→3,4)-1,6-Anhydro-β-D-Glc[b]	99.4	68.2	72.7	78.4	74.0	64.7	
27 α-D-Rha	97.7	69.9[e]	69.0[d]	70.7[c]	67.7	17.2	
α-D-Glc	97.1	70.6[e]	70.0[e]	68.3	68.5	62.0	
→3,4)-1,6-Anhydro-β-D-Glc	99.4	69.1[d]	75.4	77.3	74.0	64.9	
32α α-L-Rha	100.2	69.3[e]	68.9	70.4[c]	68.2	17.3	
α-D-Glc	95.6	69.4[e]	70.3[c]	68.2	68.5	61.7	
→3,4)-α-D-Glc	89.2	72.3	80.7	74.6	68.2	63.2	

[a]Measured at 125.7 MHz on solutions in $CDCl_3$ at 27°. [b]Assignments based on CHORTLE experiments. [c]Assignments may have to be reversed. [d]Assignments may have to be reversed. [e]Assignments may have to be reversed.

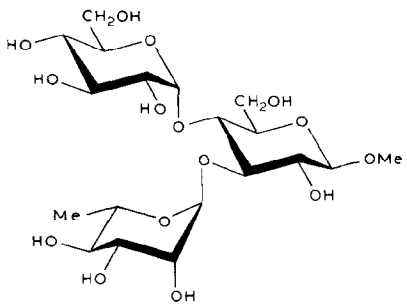


$^4C_1$



$^1C_4$

16 R = Ac, R^1 = OMe, R^2 = H
20 R = Ac, R^1 = OAc, R^2 = H
22 R = Ac, R^1 = H, R^2 = Br
24 R = Ac, R^1 = F, R^2 = H
32α R = Ac, R^1 = H, R^2 = OH
32β R = Ac, R^1 = OH, R^2 = H



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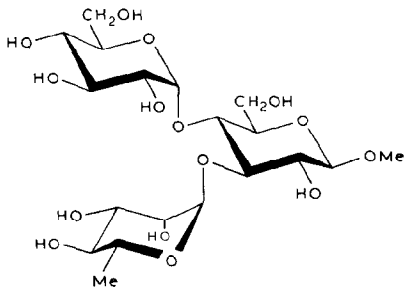

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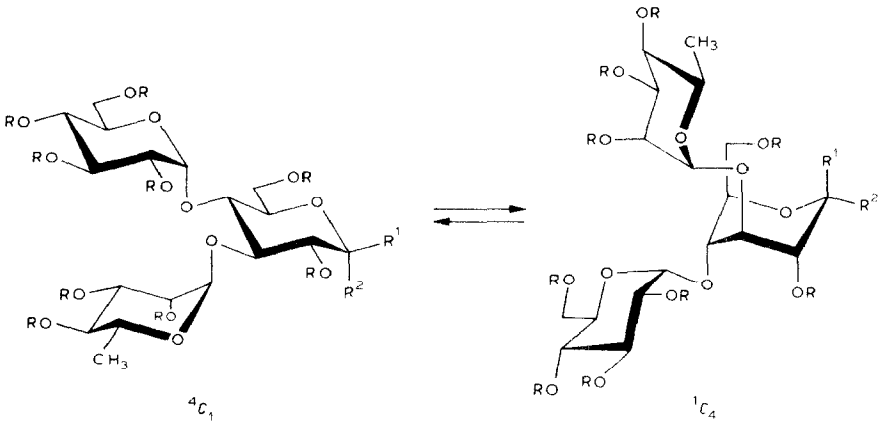
3.3, 0, 7.3, and 8.8 Hz. In this conformation and in the $^1C_4$ conformation, the fluorine is axial, whereas it is in an isoclinal position in the S^{O}_{2} conformation.

The α-glycosyl bromides **22** and **23** were completely in the $^4C_1$ conformation due to the strong anomeric effect of the bromine substituent, but for **22**, the $J_{3,4}$ value (7.7 Hz) might reflect a local flattening of the pyranose ring at C-3,4. The same behaviour is shown by the α anomer of the trisaccharide **32** where a $J_{3,4}$ value of 7.2 Hz is observed. This flattening should be considerable because a change of one degree in the torsion angles would be reflected[6] by a decrease in ^3J of only 0.03–0.07 Hz[6]. The higher proportion of the $^1C_4$ conformation for **32β** than for **32α** reflects how a β-anomeric substituent helps to invert the chair conformation, in spite of the consequent steric interaction with the axial substituents.



$^4C_1$ $^1C_4$

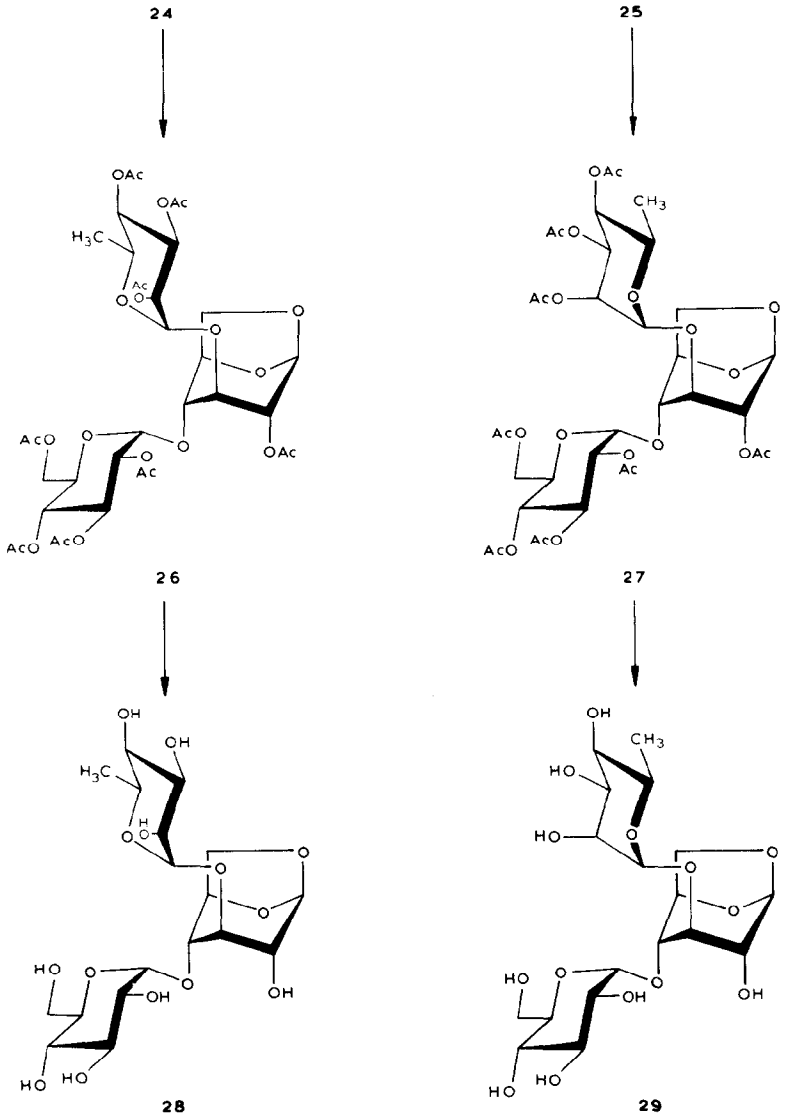
17 R = Ac, R^1 = OMe, R^2 = H
21 R = Ac, R^1 = OAc, R^2 = H
23 R = Ac, R^1 = H, R^2 = Br
25 R = Ac, R^1 = F, R^2 = H

The $^4C_1 \rightleftharpoons {}^1C_4$ equilibrium of the central glucose residue is shifted from $^4C_1$ in the glycosyl bromide **22** to $^1C_4$ in the 1,6-anhydride **26**. The proportion of the $^1C_4$ conformation of **32**β, **16, 20**, and **24** (33, 48, 74, 92%, respectively, in $CDCl_3$) increases with the increasing anomeric effect of the substituents on the anomeric carbon (OH<OMe<OAc<F).

Furthermore, the proportion of $^1C_4$ conformation in the equilibrium is reflected by the regular variation of the ^{13}C chemical shifts of the resonances of C-1a,1c,2b,3b,4b (Table VIII). C-1a,2b,3b are shielded and C-1c,4b are deshielded with increasing proportions of the $^1C_4$ conformation. These effects are most likely caused by changes in torsion angles around the glycosidic bonds as discussed recently by Bock *et al.*[9].

The differences between the results discussed above for the L compounds **16, 20**, and **24**, which appear to have a higher percentage of the $^1C_4$ conformation in the equilibrium compared to the D compounds **17, 21**, and **25**, is most likely caused by the *exo*-anomeric effect. For the L compounds, there will be non-bonded interaction of the rhamnose with the 4-linked α-D-glucopyranose residue as a result of the *exo*-anomeric effect, and the populations discussed in Table VI are a result of a compromise between the *exo*-anomeric effect for the L-rhamnose and D-glucose residues and the anomeric effect for the central glucopyranosyl residue. For the D compounds, the result of the *exo*-anomeric effect is opposite and the rhamnose residue will move away from the 4-linked α-D-glucose residue and, therefore, the proportion of the $^1C_4$ conformation will be smaller for this series of compounds.

These changes in conformational behaviour are reflected in the ^1H- and ^{13}C-n.m.r. parameters of the compounds investigated both for the vicinal coupling constants as discussed above, and the ^1H- and ^{13}C-n.m.r. chemical shifts (Tables

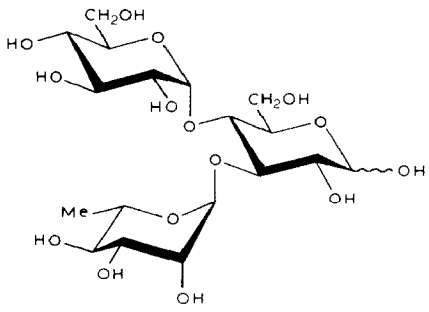


III, IV, and VII). This study shows that when a conformational analysis is carried out by comparison with model compounds, unusual interactions will be reflected in the n.m.r. parameters.

An X-ray analysis showed that, in the solid state for the glycosyl fluoride **24**, the conformation of the central glucosyl residue is exclusively $^1C_4$.

The experimental details* of the crystal structure determination are given in

*Fractional atomic co-ordinates, equivalent isotropic thermal parameters, and the observed and calculated structure factors have been deposited with, and can be obtained from, Elsevier Science Publishers B.V., BBA Data Deposition, P.O. Box 1527, Amsterdam, The Netherlands. Reference should be made to No. BBA/DD/398/*Carbohydr. Res.*, 179 (1988) 97–124.



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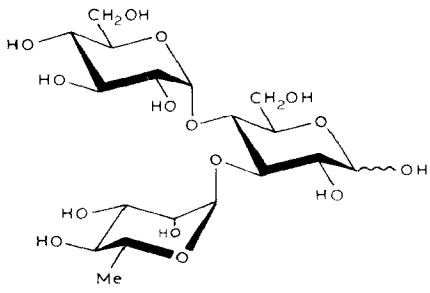

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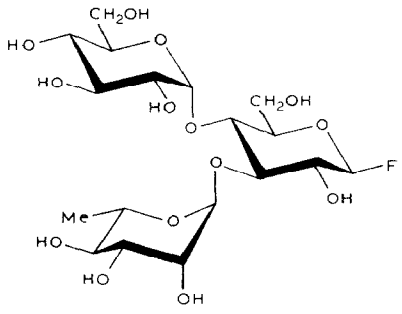

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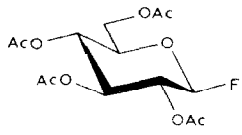

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Table IX. Table X (see Fig. 1) lists the fractional atomic co-ordinates of the non-hydrogen atoms. A stereoplot of the structure, where all the acetyl substituents have been omitted, is shown in Fig. 2. A calculation of puckering parameters (Cremer and Pople[10]) with standard deviations (Norrestam[11]) gives the ϕ_2 and B values: 9.8(6), 12(3); 5.5(2), −4(7); and −10.0(6), 13(4)° for the pyranose rings of the α-L-Rha, →3,4)-β-D-Glc, and α-D-Glc units. These values are rather close to those (0,0°) expected for ideal chair conformations. The total puckering amplitudes 0.591 (6), 0.475 (6), and 0.555 (6) Å for the three rings indicate that the F-substituted

TABLE V

CALCULATED COUPLING CONSTANTS[a] FOR α-D-GLUCOPYRANOSE (A), β-GLUCOPYRANOSE (B), AND α-GLUCOPYRANOSYL FLUORIDE (C)

Unit	*Conformation*	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$
A	$^4C_1$	3.6	9.8	9.3	9.7
A	$^1C_4$	1.8	3.6	3.6	1.3
B	$^4C_1$	7.8	9.3	9.3	9.7
B	$^1C_4$	1.8	3.6	3.6	1.3
C	$^4C_1$	7.3	9.3	9.3	9.7
C	$^1C_4$	2.0	3.6	3.6	1.3

[a]Using the method described by Altona *et al.*[6].

TABLE VI

CALCULATED PROPORTION OF $^1C_4$ CONFORMATION (%)

Compound	*H-1,H-2*	*H-2,H-3*	*H-3,H-4*	*H-4,H-5*	*Average values*
16[a]	(5.5)[c] 38	(6.0) 58	(6.5) 49		48
16[b]	(5.7) 35	(7.0) 40	(6.5) 49	(7.3) 39	38
17[a]	(6.7) 18	(8.1) 21		(8.8) 11	17
17[b]	(7.0) 13	(8.6) 12	(8.2) 19	(9.1) 7	13
20[a]	(3.6) 70	(4.2) 90	(4.6) 83	(5.4) 51	74
20[b]	(4.5) 79	(5.8) 62	(5.0) 76	(5.5) 50	67
21[a]	(6.1) 28	(7.0) 41	(6.3) 53	(7.2) 30	38
24[a]	(2.0) 100	(3.0) 110	(4.3) 82	(3.9) 70	92
24[b]	(2.6) 89	(4.6) 83	(5.0) 76	(4.8) 58	77
25[a]	(2.6) 89	(3.8) 96	(5.7) 64	(6.5) 49	72
32α[a]	(3.6) 0	(9.0) 13	(7.2) 37	(9.0) 9	15
32β[a]	(6.4) 23	(7.8) 26	(6.4) 51	—	33

[a]In $CDCl_3$. [b]In C_6D_6. [c]^3J values (Hz) in parentheses.

central glucose residue [→3,4)-β-D-Glc] is somewhat flattened. The amplitude calculated for an average glucopyranose ring is 0.57(2) Å (Norrestam *et al.*[12]). From the selected intramolecular bond distances in Table XI, it is evident that the largest discrepancies between the three pyranose rings of the molecule occur at C-1. Thus, the C-1–O-6 distance of 1.382 Å in the central ring is considerably shorter than those (1.412 and 1.408 Å) found in the two other rings. This compound represents, to our knowledge, the first example of an oligosaccharide in which a glucopyranosyl residue adopts the $^1C_4$(D) conformation caused by steric non-bonded interactions from substituents on the glucopyranosyl residue.

An analysis of the conformational behaviour of the unprotected oligosaccharides in aqueous solution will be discussed elsewhere.

EXPERIMENTAL

Melting points are uncorrected. Optical rotations were measured with a Perkin–Elmer 241 polarimeter. N.m.r. spectra were recorded with a Bruker AM-500 instrument on solutions in $CDCl_3$, C_6D_6, CCl_4 (protected compounds), and D_2O (unprotected compounds) relative to internal acetone (δ 2.22) for ^{1}H-n.m.r. spectra and 1,4-dioxane (67.4 p.p.m.) for ^{13}C-n.m.r. spectra. Microanalyses were performed by Novo Microanalytical Laboratory, Copenhagen (Denmark). T.l.c. was performed on Silica Gel F_{254} (Merck) with detection by charring with sulfuric acid.

Methyl 2-O-benzoyl-4,6-O-benzylidene-3-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-α-D-glucopyranoside (**4**). — To a stirred solution of **1** (0.50 g, 1.29 mmol) in dichloromethane (10 mL) containing molecular sieves (3 Å, 1 g), silver triflate (498 mg, 1.94 mmol), and 1,1,3,3-tetramethylurea (0.23 mL, 1.94 mmol)

TABLE VII

^{1}H-N.M.R. DATA

Compound/unit	*H-1*	*H-2*	*H-3*	*H-4*	*H-5*	*H-6*	*H-6'*	*OMe*
16[a] α-L-Rha	5.48	5.78	5.73	5.59	4.21	1.43		
	2.0	3.3	9.8	9.6	6.2			
α-D-Glc	5.76	5.47	5.93	5.52	4.47	4.56	4.47	
	3.8	10.1	8.9	10.1	4.5	12.0		
→3,4)-β-D-GlcOMe[a]	4.42	5.33	4.17	4.09	3.69	4.70	4.46	3.37
	5.7	7.0	6.5	7.3	3.8	12.0		
					5.1			
16[b] α-L-Rha	4.99	5.11	5.15	4.86	3.88	1.17		
	2.0	3.5	9.8	9.9	6.2			
α-D-Glc	5.33	4.89	5.20	4.93	4.05	4.17	4.00	
	4.0	10.2	9.0	10.2	4.8	12.0		
					2.2			
→3,4)-β-D-GlcOMe[b]	4.50	4.79	3.92	3.88	3.88	4.40	4.23	3.43
	5.3	6.2			3.3	11.6		
					4.8			
17[a] α-D-Rha	5.46	5.58	5.68	5.69	4.20	1.46		
	2.0	2.5			6.0			
α-D-Glc	6.07	5.68	5.93	5.55	4.41	4.56	4.44	
	3.9	10.0	9.2	9.8	4.3	12.0		
					2.5			
→3,4)-β-D-GlcOMe[a]	4.20	5.41	4.15	4.25	3.34	4.75	4.48	3.36
	7.0	8.6	8.2	9.1	3.0	12.0		
					4.0			
20[a] α-L-Rha	5.43	5.77	5.71	5.64	4.22	1.43		
	1.9	3.4	9.5	9.5	6.0			
α-D-Glc	5.62	5.31	5.88	5.48	4.47	4.47	4.47	
	3.8	10.0	9.0	9.5				
→3,4)-β-D-Glc[a]	6.21	5.24	4.22	4.02	4.04	4.69	4.46	
	4.5	5.8	5.0	5.5	3.8	11.5		
					5.5			
24[a] α-L-Rha	5.37	5.62	5.62	5.50	4.13	1.37		
	1.7			9.7	6.2			
α-D-Glc	5.43	5.08	5.70	5.25	4.30	4.30	4.25	
	3.9	10.2	9.2	10.0				
→3,4)-β-D-GlcF[a]	5.29	5.04	4.08	4.01	4.26	4.60	4.45	
	2.6	4.6	5.0	4.8	5.7	11.9		
	52.7(H-1,F)	7.8(H-2,F)			5.7	1.0(H-6,F)		
34[a] β-D-GlcF[a]	5.21	5.51	5.51	5.51	3.56	4.43	4.27	
	6.0				5.4	12.4		
	52.0(H-1,F)				2.4			

[a]In C_6D_6. [b]In CCl_4.

was added, at room temperature under nitrogen, a solution of **2** (685 mg, 1.94 mmol) in dichloromethane (1 mL). The mixture was stirred for 1 h at room temperature under nitrogen and then filtered, and the insoluble material was washed with dichloromethane (50 mL). The filtrate and washings were combined, washed with saturated aqueous sodium hydrogencarbonate (2 × 25 mL) and water

TABLE VIII

VARIATION OF THE ^{13}C CHEMICAL SHIFT WITH THE PROPORTION OF THE $^1C_4$ CONFORMATION IN $CDCl_3$

Configuration	*Compound*	$^1C_4$ (%)	*Carbon*[a]				
			C-1a	*C-1c*	*C-2b*	*C-3b*	*C-4b*
Rha is α-L	**22**	0	100.4	95.6	72.1	81.3	73.4
	32α	15	100.2	95.6	72.3	80.7	74.6
	16	48	98.1	96.0	71.1	78.8	75.6
	20	74	97.6	96.6	68.7	75.3	75.4
	24	92	97.2	97.0	67.4	73.4	74.8
	26	100	96.1	97.1	68.2	75.4	78.4
Rha is α-D	**23**	0	97.7	96.5	71.5	76.2	75.4
	17	17	98.2	96.4	72.2	81.0	74.8
	21	38	97.8	96.7	70.7	78.2	74.3
	25	72	98.4	97.1	69.6	77.0	73.6
	27	100	97.7	97.1	69.1	75.4	74.0

[a]a–c refer to the Rha, →3,4)-β-D-Glc, and α-D-Glc units, respectively.

(2 × 25 mL), dried ($MgSO_4$), and concentrated. Preparative t.l.c. (hexane–ethyl acetate, 1:1) of the residue gave **4** (638 mg, 97 mmol, 75%), m.p. 166–167° (from ethanol), $[\alpha]_D^{23}$ +50° (*c* 0.9, chloroform), R_F 0.37 (ethyl acetate–hexane, 1:2). See Tables III and IV for the ^1H- and ^{13}C-n.m.r. data.

Anal. Calc. for $C_{33}H_{38}O_{14}$: C, 60.18; H, 5.82. Found: C, 60.02; H, 5.77.

Methyl 2-O-benzoyl-4,6-O-benzylidene-3-O-(2,3,4-tri-O-acetyl-α-D-rhamnopyranosyl)-α-D-glucopyranoside (**5**). — Compound **1** (0.50 g, 1.29 mmol) was treated with **3** (685 mg, 1.94 mmol), as described for the preparation of **4**, to give **5** (610 mg, 0.93 mmol, 72%), m.p. 158–159° (from ethanol), $[\alpha]_D^{23}$ +139° (*c* 0.9, chloroform), R_F 0.39 (ethyl acetate–hexane, 1:2). See Tables III and IV for the ^1H- and ^{13}C-n.m.r. data.

Anal. Calc. for $C_{33}H_{38}O_{14}$: C, 60.18; H, 5.82. Found: C, 59.97; H, 5.84.

Methyl 2-O-benzoyl-4,6-O-benzylidene-3-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-β-D-glucopyranoside (**9**). — To a stirred solution of **8** (0.25 g, 0.65 mmol) in dichloromethane (5 mL) containing molecular sieves (3 Å, 1 g), silver triflate (332 mg, 1.29 mmol), and 1,1,3,3-tetramethylurea (0.15 mL, 1.29 mmol) was added, at room temperature under nitrogen, a solution of **2** (4.57 mg, 1.29 mmol) in dichloromethane (0.5 mL). The mixture was stirred for 1 h under nitrogen, then processed as described for the preparation of **4**. Preparative t.l.c. (dichloromethane–methanol, 40:1) of the product gave a syrup (395 mg), from which **9** (335 mg, 0.51 mmol, 78%) could be crystallised from ethanol; m.p. 258–259°, $[\alpha]_D^{23}$ −49° (*c* 1, chloroform), R_F 0.30 (ethyl acetate–hexane, 1:2). See Tables III and IV for the ^1H- and ^{13}C-n.m.r. data.

Anal. Calc. for $C_{33}H_{38}O_{14}$: C, 60.18; H, 5.82. Found: C, 60.19; H, 5.76.

Methyl 2-O-benzoyl-4,6-O-benzylidene-3-O-(2,3,4-tri-O-acetyl-α-D-rhamno-

TABLE IX

EXPERIMENTAL CONDITIONS FOR THE CRYSTAL STRUCTURE DETERMINATION OF 2,6-DI-*O*-ACETYL-4-*O*-(2,3,4,6-TETRA-*O*-ACETYL-α-D-GLUCOPYRANOSYL)-3-*O*-(2,3,4-TRI-*O*-ACETYL-α-L-RHAMNOPYRANOSYL)-β-D-GLUCOPYRANOSYL FLUORIDE (**24**)

Formula	$C_{36}H_{49}FO_{23}$
Formula weight	868.77
Space group	$P2_1$
Unit-cell dimensions at 120 K	$a = 11.987(2)$, $b = 9.296(2)$, $c = 19.781(4)$ Å, $\beta = 105.17(2)°$
Unit-cell volume, V	2127.4(8) Å^3
Formula units per unit cell, Z	2
Calculated density, D_x	1.356(1) g·cm^{-3}
Radiation	MoK_α
Wavelength	0.71069 Å
$F(000)$ value	916
Temperature, T	120(1) K
Crystal shape	Prismatic
Crystal size	0.13 × 0.36 × 0.16 mm
Diffractometer	Enraf–Nonius CAD4
Determination of unit cell	Least squares
Number of reflections used	15
θ-range	6.7–11.2°
Intensity data collection	ω-scan technique
Maximum $\sin(\theta)/\lambda$	0.600 Å^{-1}
Range of h, k, and l	−14–14, 0–11, and 0–23
Standard reflections	(1 3 −3) and (4 0 1)
Intensity instability	<1.5%
Internal agreement	$R_{int} = 0.015$
Number of observed reflections	4211
Number of unique reflections	4089
Number of significant reflections	2606 (*i.e.*, 64%)
Criterion for significance	$I > 5\sigma(I)$
Absorption correction	Numerical integration
Linear absorbtion coefficient	1.1 cm^{-1}
Transmission factor range	0.982–0.988
Structure determination technique	Direct methods (Mithril)
Number of largest E-values	340
Number of triple relations	2673
Number of negative quartets	45
Number of solutions	60
Determination of hydrogen atoms	Geometric
Assumed C–H distance	1.00 Å
Assumed C–C–H angle	109.5°
Structure refinement	Full-matrix least squeares
Minimisation of	Sum of $\psi\Delta F^2$
Anisotropic thermal model for	O and F atoms
Isotropic thermal model for	C and H atoms
Parameters fixed for	H atoms (riding on non-H atoms)
Number of refined parameters	360
Weighting scheme	$1/(\sigma(F)^2 + 0.0002\,\lvert F\rvert^2)$
Origin fixation	y of F fixed to 0.000
Final R	0.044
Final ωR	0.051
Final max. shift/sigma	0.15
Final max. and min. in $\Delta\rho$	0.4 and −0.3 e$^-$.Å^{-3}

pyranosyl)-β-D-glucopyranoside (**10**). — Compound **8** (0.25 g, 0.65 mmol) was treated with **3** (475 mg, 1.29 mmol), as described for the preparation of **9**, to give **10** (374 mg, 0.57 mmol, 88%), m.p. 186–187° (from ethanol), $[\alpha]_D^{23}$ +50° (*c* 1, chloroform), R_F 0.32 (ethyl acetate–hexane, 1:2). See Tables III and IV for the ^{1}H- and ^{13}C-n.m.r. data.

Anal. Calc. for $C_{33}H_{38}O_{14}$: C, 60.18; H, 5.82. Found: C, 59.88; H, 5.77.

Methyl 3-O-α-L-rhamnopyranosyl-α-D-glucopyranoside (**6**). — A solution of **4** (0.10 g, 0.15 mmol) in methanolic 0.1% sodium methoxide (10 mL) was kept for 24 h at room temperature, then treated with Amberlite IRC-50 (H^+) resin, filtered, and concentrated. A solution of the syrupy residue in aqueous 90% trifluoroacetic acid (1 mL) was kept for 5 h at 0° and then concentrated, and ethanol was distilled from the residue. Elution of the residue from a column of Sephadex G-15 with methanol–water (1:1), filtration through active charcoal, and concentration gave **6** (48 mg, 0.14 mmol, 93%) as a syrup, $[\alpha]_D^{23}$ +37° (*c* 1.4, water), R_F 0.25 (dichloromethane–methanol, 3:1). See Tables I and II for the n.m.r. data.

Methyl 3-O-α-D-rhamnopyranosyl-α-D-glucopyranoside (**7**). — Deprotection of **5** (0.10 g, 0.15 mmol), as described for **4**, yielded **7** (44 mg, 0.13 mmol, 85%) as a syrup, $[\alpha]_D^{23}$ +137° (*c* 1.3, water), R_F 0.24 (dichloromethane–methanol, 3:1). See Tables I and II for the n.m.r. data.

Methyl 3-O-α-L-rhamnopyranosyl-β-D-glucopyranoside (**11**). — Deprotection of **9** (0.13 g, 0.20 mmol), as described for **4**, yielded **11** (62 mg, 0.18 mmol, 92%) as a syrup, $[\alpha]_D^{23}$ −61° (*c* 1, water), R_F 0.30 (dichloromethane–methanol, 3:1). See Tables I and II for the n.m.r. data.

Methyl 3-O-α-D-rhamnopyranosyl-β-D-glucopyranoside (**12**). — A mixture of **10** (0.10 g, 0.15 mmol) and methanolic 0.1% sodium methoxide (10 mL) was stirred for 24 h at room temperature. As some **10** remained, more (10 mL) methanolic 0.1% sodium methoxide was added, and the solution was stirred for 24 h, then treated with Amberlite IRC-50 (H^+) resin, filtered, and concentrated. A solution of the residue in aqueous 90% trifluoroacetic acid (3 mL) was kept for 5 h at 0° and then concentrated, and ethanol was distilled from the residue. Elution of the residue from a column of Sephadex G-15 with methanol–water (1:1), then filtration through active charcoal, and concentration gave **12** (45 mg, 0.13 mmol, 87%) as a syrup, $[\alpha]_D^{23}$ +45° (*c* 1, water), R_F 0.27 (dichloromethane–methanol, 3:1). See Tables I and II for the n.m.r. data.

Methyl 2,6-di-O-acetyl-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-β-D-glucopyranoside (**16**). — To a stirred solution of **15** (0.3 g, 0.49 mmol) in dichloromethane (6 mL) containing molecular sieves (3 Å, 1 g), silver triflate (253 mg, 0.98 mmol), and 1,1,3,3-tetramethylurea (0.12 mL, 0.98 mmol) was added, under nitrogen at room temperature, a solution of **2** (348 mg, 0.98 mmol) in dichloromethane (1 mL). The mixture was stirred for 5 h under nitrogen and filtered, the insoluble material was washed with dichloromethane (25 mL), and the filtrate and washings were combined, washed with saturated aqueous sodium hydrogencarbonate (2 × 25 mL) and water (2 × 25 mL),

TABLE X

FRACTIONAL ATOMIC CO-ORDINATES ($\times 10^4$) AND EQUIVALENT ISOTROPIC THERMAL PARAMETERS ($\times 10^4$ Å^2) OF THE NON-HYDROGEN ATOMS FOR THE GLYCOSYL FLUORIDE **24**[a]

Atom	x	y	z	U
F(1B)	3794(3)	0	1587(2)	274(11)
C(1A)	5325(5)	952(6)	3513(3)	176(12)
C(2A)	5973(5)	−461(6)	3543(3)	169(12)
C(3A)	7212(5)	−189(6)	3501(3)	178(12)
C(4A)	7756(5)	902(6)	4067(3)	175(12)
C(5A)	7070(5)	2286(6)	3923(3)	209(13)
O(6A)	5928(3)	1986(4)	3995(2)	196(13)
O(1A)	5121(3)	1445(4)	2814(2)	180(12)
O(2A)	6011(3)	−1065(4)	4223(2)	188(13)
O(3A)	7869(3)	−1505(4)	3630(2)	213(13)
O(4A)	8930(3)	1187(5)	4030(2)	232(13)
C(6A)	7554(5)	3494(7)	4427(3)	255(14)
C(7A)	5871(5)	−2522(7)	4254(3)	209(13)
C(8A)	5898(5)	−2957(7)	4987(3)	293(14)
O(7A)	5729(4)	−3300(4)	3760(2)	262(14)
C(9A)	7674(5)	−2444(7)	3085(3)	221(13)
C(10A)	8361(5)	−3775(7)	3270(3)	322(15)
O(8A)	7029(4)	−2193(5)	2525(2)	353(15)
C(11A)	9768(5)	1029(7)	4635(3)	278(14)
C(12A)	10898(5)	1577(8)	4561(4)	371(16)
O(9A)	9604(4)	535(6)	5158(2)	436(17)
C(1B)	3011(5)	1150(7)	1550(3)	237(13)
C(2B)	3090(5)	1604(6)	2296(3)	198(12)
C(3B)	4188(4)	2454(6)	2624(3)	158(11)
C(4B)	4454(5)	3552(6)	2115(3)	179(12)
C(5B)	4358(5)	2942(6)	1387(3)	199(12)
O(6B)	3268(3)	2205(4)	1122(2)	219(12)
O(2B)	2055(3)	2440(4)	2238(2)	218(12)
O(4B)	3598(3)	4642(4)	2076(2)	169(12)
C(6B)	5390(5)	2048(7)	1317(3)	229(13)
C(7B)	1768(5)	2693(7)	2846(3)	256(13)
C(8B)	678(5)	3544(7)	2731(4)	367(16)
O(7B)	2335(4)	2246(6)	3406(2)	369(15)
O(10B)	6211(3)	3041(5)	1161(2)	266(14)
C(13B)	7189(5)	3317(7)	1650(3)	314(14)
C(14B)	7872(7)	4452(9)	1404(4)	555(20)
O(11B)	7455(4)	2749(7)	2217(3)	637(21)
C(1C)	3978(5)	6066(6)	2048(3)	177(12)
C(2C)	3124(5)	7029(7)	2293(3)	204(12)
C(3C)	1969(5)	7158(7)	1755(3)	211(12)
C(4C)	2114(5)	7440(7)	1029(3)	227(13)
C(5C)	2935(5)	6344(7)	854(3)	218(12)
O(6C)	4034(3)	6459(4)	1370(2)	203(13)
O(2C)	2926(3)	6359(5)	2911(2)	238(13)
O(3C)	1364(3)	8385(5)	1939(2)	236(13)
O(4C)	1005(3)	7272(5)	539(2)	262(13)
C(6C)	3165(5)	6617(7)	146(3)	287(14)
C(7C)	3059(5)	7134(7)	3499(3)	256(13)

TABLE X *(continued)*

Atom	x	y	z	U
C(8C)	2847(6)	6203(8)	4068(3)	347(15)
O(7C)	3302(4)	8390(5)	3550(2)	328(15)
C(9C)	387(5)	8132(8)	2144(3)	330(15)
C(10C)	−111(6)	9502(8)	2327(4)	401(17)
O(8C)	3(5)	6954(5)	2166(3)	626(23)
C(11C)	610(5)	8377(7)	100(3)	272(14)
C(12C)	−533(6)	8009(9)	−394(4)	481(19)
O(9C)	1134(4)	9470(5)	102(3)	409(16)
O(10C)	3639(4)	5371(5)	−99(2)	329(15)
C(13C)	2890(7)	4539(9)	−551(4)	494(18)
C(14C)	3475(8)	3247(12)	−747(5)	854(28)
O(11C)	1879(6)	4780(8)	−732(3)	891(27)

[a]The thermal parameters were estimated as 1/3 trace (*U*). The atomic labelling used is shown in Fig. 1.

dried ($MgSO_4$), and concentrated. Preparative t.l.c. (dichloromethane–methanol, 40:1) of the residue gave **16** (263 mg, 0.30 mmol, 61%) as a syrup, $[\alpha]_D^{23}$ +18° (*c* 1.6, chloroform), R_F 0.41 (ethyl acetate–hexane, 2:1). See Tables III, IV, and VII for the n.m.r. data.

Anal. Calc. for $C_{37}H_{52}O_{24}$: C, 50.45; H, 5.95. Found: C, 50.10; H, 5.92.

*Methyl 2,6-di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-*D*-glucopyranosyl)-3-*O*-(2,3,4-tri-*O*-acetyl-α-*D*-rhamnopyranosyl)-β-*D*-glucopyranoside* (**17**). — Compound **15** (0.3 g, 0.49 mmol) was treated with **3** (348 mg, 0.98 mmol) as described for the preparation of **16**. Preparative t.l.c. (dichloromethane–methanol, 40:1) of the product gave **17** (248 mg, 0.28 mmol, 57%), m.p. 167–168° (from ethanol), $[\alpha]_D^{23}$ +46° (*c* 1, chloroform), R_F 0.42 (ethyl acetate–hexane, 2:1). See Tables III, IV, and VII for the n.m.r. data.

TABLE XI

SELECTED BOND DISTANCES IN Å (e.s.d.'s <0.007 Å) FOR THE GLYCOSYL FLUORIDE **24**[a]

	α-L-*Rha*	→3,4)-β-D-*Glc*	α-D-*Glc*
C-1–C-2	1.519	1.514	1.531
C-2–C-3	1.530	1.527	1.514
C-3–C-4	1.525	1.525	1.514
C-4–C-5	1.513	1.524	1.518
C-5–C-6	1.440	1.447	1.444
O-6–C-1	1.412	1.382	1.408
C-1–O-1	1.416	1.412*	1.406
C-2–O-2	1.447	1.443	1.446
C-3–O-3	1.441	1.443	1.446
C-4–O-4	1.453	1.430	1.434
C-5–C-6	1.513	1.526	1.518

[a]Related values for the three pyranose rings are given on each line. The distance marked with an asterisk is the C-1–F distance in the central ring.

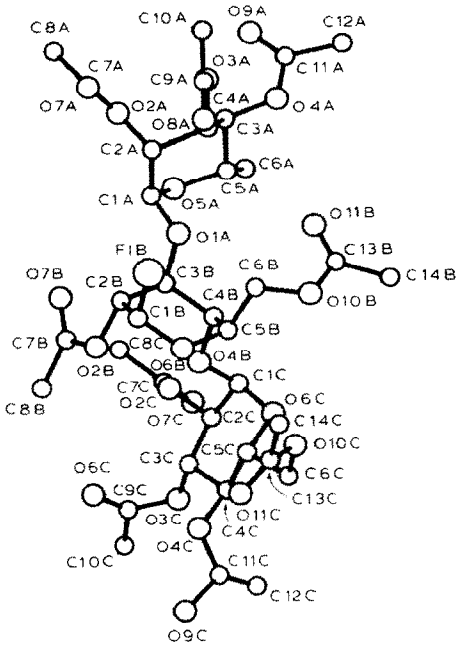

Fig. 1. The molecular conformation found for the glycosyl fluoride **24** and the atomic labels used for the crystal structure determination.

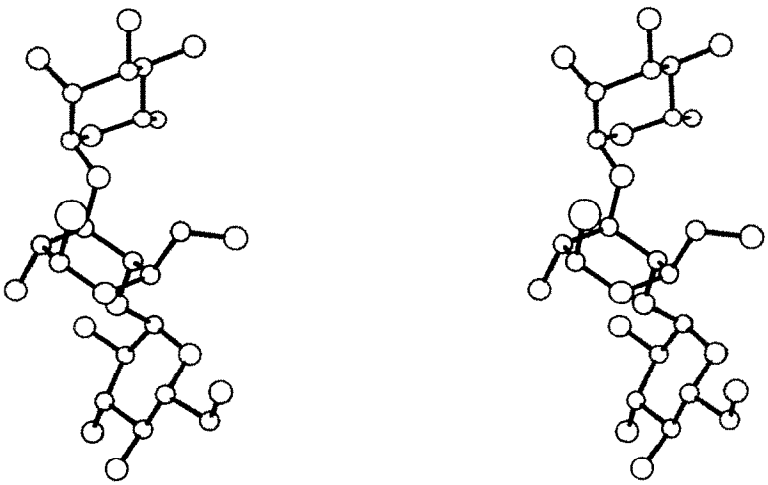

Fig. 2. Stereoplot of the conformation of the glycosyl fluoride **24**. For clarity, the acetyl substituents have been omitted.

Anal. Calc. for $C_{37}H_{52}O_{24}$: C, 50.43; H, 5.95. Found: C, 50.19; H, 5.94.

Methyl 4-O-α-D-glucopyranosyl-3-O-α-L-rhamnopyranosyl-β-D-glucopyranoside (**18**). — *O*-Deacetylation of **16** (55 mg, 0.062 mmol) in methanolic 0.1% sodium methoxide (10 mL) gave, after removal of sodium ions with Amberlite IRC-50 (H^+) resin, filtration through active charcoal, and concentration, **18** (31 mg, 0.061 mmol, 98%) as a syrup, $[\alpha]_D^{23}$ +28° (*c* 0.6, water); R_F 0.23 (ethyl acetate–methanol–acetic acid–water, 6:2:1:1). See Tables I and II for the n.m.r. data.

Methyl 4-O-α-D-glucopyranosyl-3-O-α-D-rhamnopyranosyl-β-D-glucopyranoside (**19**). — *O*-Deacetylation of **17** (64 mg, 0.073 mmol) in methanolic 0.1% sodium methoxide (10 mL), as described for **16**, gave **19** (35 mg, 0.070 mmol, 96%) as a syrup, $[\alpha]_D^{23}$ +63° (*c* 0.5, water); R_F 0.24 (ethyl acetate–methanol–acetic acid–water, 6:2:1:1). See Tables I and II for the n.m.r. data.

1,2,6-Tri-O-acetyl-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-β-D-glucopyranose (**20**). — Compound **13** (0.80 g, 1.26 mmol) was treated with **2** (888 mg, 2.51 mmol) as described for the preparation of **16**. Preparative t.l.c. (dichloromethane–methanol, 40:1) of the product gave **20** (595 mg, 0.65 mmol, 52%) as a syrup. T.l.c. (ethyl acetate–hexane, 2:1) of an impure fraction gave more **20** (196 mg, 0.21 mmol; total yield, 69%), $[\alpha]_D^{23}$ +29° (*c* 0.5, chloroform), R_F 0.43 (ethyl acetate–hexane, 2:1). See Tables III, IV, and VII for the n.m.r. data.

Anal. Calc. for $C_{38}H_{52}O_{25}$: C, 50.22; H, 5.77. Found: C, 49.97; H, 5.91.

1,2,6-Tri-O-acetyl-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-D-rhamnopyranosyl)-β-D-glucopyranose (**21**). — Compound **13** (0.80 g, 1.26 mmol) was treated with **3** (888 mg, 2.51 mmol) as described for the preparation of **16**. Preparative t.l.c. (dichloromethane–methanol, 40:1) of the product gave **21** (605 mg, 0.67 mmol, 53%), m.p. 149–150° (from ethanol), $[\alpha]_D^{23}$ +68° (*c* 0.7, chloroform), R_F 0.43 (ethyl acetate–hexane, 2:1). See Tables III and IV for the n.m.r. data.

Anal. Calc. for $C_{38}H_{52}O_{25}$: C, 50.22; H, 5.77. Found: C, 49.71; H, 5.74.

2,6-Di-O-acetyl-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-α-D-glucopyranosyl bromide (**22**). — To a solution of **20** (275 mg, 0.30 mmol) in chloroform (20 mL, eluted through basic aluminium oxide) was added titanium tetrabromide (377 mg, 1.06 mmol). The mixture was boiled under reflux for 1 h under nitrogen and then poured into ice–water (25 mL), and the organic phase was washed with water (2 × 20 mL), saturated aqueous sodium hyrogencarbonate (2 × 20 mL), and water (2 × 20 mL), dried ($MgSO_4$), and concentrated, to give **22** (279 mg, 99%) as a syryp, R_F 0.64 (ethyl acetate–hexane, 2:1). See Tables III and IV for the n.m.r. data.

2,6-Di-O-acetyl-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-D-rhamnopyranosyl)-α-D-glucopyranosyl bromide (**23**). — Compound **21** (200 mg, 0.22 mmol) was treated with titanium bromide, as described for the preparation of **22**, to give **23** (200 mg, 97%) as a syrup, R_F 0.64 (ethyl acetate–hexane, 2:1). See Table III and IV for the n.m.r. data.

2,6-Di-O-acetyl-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-β-D-glucopyranosyl fluoride (**24**). — To a solution of crude **22** (279 mg, 0.30 mmol) in dry acetonitrile (6 mL) was added silver fluoride (1 g, 7.88 mmol), and the mixture was stirred for 1 h at room temperature and then filtered. The insoluble material was washed with dichloromethane (25 mL), and the combined filtrate and washings were washed with saturated aqueous sodium hydrogencarbonate (2 × 25 mL) and water (2 × 25 mL), dried ($MgSO_4$), and concentrated. Crystallization of the residue (258 mg) from ethanol gave **24** (171 mg, 0.20 mmol, 66%). Preparative t.l.c. (ethyl acetate–hexane, 2:1) of the material in the mother liquor gave more **24** (17 mg, 0.02 mmol; total yield, 72%), m.p. 173–174° (from ethanol), $[\alpha]_D^{23}$ +25.5° (*c* 0.5, chloroform), R_F 0.48 (ethyl acetate–hexane, 2:1). See Tables III, IV, and VII for the n.m.r. data.

Anal. Calc. for $C_{36}H_{49}FO_{23}$: C, 49.77; H, 5.68, F, 2.18. Found: C, 49.72; H, 5.71.

2,6-Di-O-acetyl-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-D-rhamnopyranosyl)-β-D-glucopyranosyl fluoride (**25**). — Crude **23** (200 mg, 0.21 mmol) was treated with silver fluoride as described for the preparation of **24**. Preparative t.l.c. (dichloromethane–methanol, 40:1) of the product gave **25** (151 mg, 0.17 mmol, 80%), m.p. 122–124° (from ethanol), $[\alpha]_D^{23}$ +79° (*c* 0.4, chloroform), R_F 0.49 (ethyl acetate–hexane, 2:1). See Tables III and IV for the n.m.r. data.

Anal. Calc. for $C_{36}H_{49}FO_{23}$: C, 49.77; H, 5.68; F, 2.18. Found: C, 49.22; H, 5.68.

2-O-Acetyl-1,6-anhydro-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-L-rhamnopyranosyl)-β-D-glucopyranose (**26**). — To a solution of **24** (70 mg, 0.08 mmol) in ethanol (4 mL) was added a solution of potassium hydroxide (112 mg, 2 mmol) in water (4 mL). After heating for 30 min on a steam bath, the mixture was neutralised with conc. hydrochloric acid and concentrated, and toluene (5 mL) was evaporated twice from the residue. Acetic anhydride (1 mL) and pyridine (1 mL) were added, and the mixture was left for 5 h at room temperature. Conventional work-up gave a syrup (55 mg) which crystallised from ethanol to give **26** (44 mg, 0.054 mmol, 68%), m.p. 169–170°, $[\alpha]_D^{23}$ −0.1° (*c* 0.2, chloroform), R_F 0.47 (ethyl acetate–hexane 2:1). See Tables III and IV for the n.m.r. data.

Anal. Calc. for $C_{34}H_{46}O_{22}$: C, 50.62; H, 5.74. Found: C, 50.39; H, 5.74.

2-O-Acetyl-1,6-anhydro-4-O-(2,3,4,6-tetra-O-acetyl-α-D-glucopyranosyl)-3-O-(2,3,4-tri-O-acetyl-α-D-rhamnopyranosyl)-β-D-glucopyranose (**27**). — Compound **25** (65 mg, 0.075 mmol) was treated with potassium hydroxide and then acetylated with acetic anhydride and pyridine as described for the preparation of **26**. Preparative t.l.c. (dichloromethane–methanol, 40:1) of the product (54 mg) gave **27** (30 mg, 0.037 mmol, 50%), m.p. 156–157° (from ethanol), $[\alpha]_D^{23}$ +47° (*c* 0.4, chloroform), R_F 0.48 (ethyl acetate–hexane, 2:1). See Tables III and IV for the n.m.r. data.

Anal. Calc. for $C_{34}H_{46}O_{22}$: C, 50.62; H, 5.74. Found: C, 50.66; H, 5.72.

*1,6-Anhydro-4-*O*-α-*D*-glucopyranosyl-3-*O*-α-*L*-rhamnopyranosyl-β-*D*-glucopyranose* (**28**). — *O*-Deacetylation of **26** (20 mg, 0.025 mmol) in methanolic 0.1% sodium methoxide (5 mL) gave, after removal of sodium ions with Amberlite IRC-50 (H^+) resin, filtration through active charcoal, and concentration, **28** (11.5 mg, 0.023 mmol, 98%) as a syrup, R_F 0.27 (ethyl acetate–methanol–acetic acid–water, 6:2:1:1). See Tables I and II for the n.m.r. data.

*1,6-Anhydro-4-*O*-α-*D*-glucopyranosyl-3-*O*-α-*D*-rhamnopyranosyl-β-*D*-glucopyranose* (**29**). — *O*-Deacetylation of **27** (15 mg, 0.019 mmol) in methanolic 0.1% sodium methoxide (3 mL), as described for **26**, gave **29** (8 mg, 0.017 mmol, 91%) as a syrup, R_F 0.28 (ethyl acetate–methanol–acetic acid–water, 6:2:1:1). See Tables I and II for the n.m.r. data.

*4-*O*-α-*D*-Glucopyranosyl-3-*O*-α-*L*-rhamnopyranosyl-α- and -β-*D*-glucopyranose* (**30**). — A solution of **20** (15 mg, 0.016 mmol) in methanolic 0.1% sodium methoxide (2 mL) was left for 15 min. Solid carbon dioxide was added and the mixture was neutralised with M acetic acid. Concentration gave a syrup consisting of **30**, glucose, and rhamnose in the ratios 2.8:1:1 (^{1}H-n.m.r. data). The αβ-ratio for **30** was 1:1.5; R_F 0.20 (ethyl acetate–methanol–acetic acid–water, 6:2:1:1). See Tables I and II for the n.m.r. data.

*4-*O*-α-*D*-Glucopyranosyl-3-*O*-α-*D*-rhamnopyranosyl-α- and -β-*D*-glucopyranose* (**31**). — A solution of **21** (15 mg, 0.016 mmol) in methanolic 0.1% sodium methoxide (2 mL) was treated as described for **20**, to give a syrup consisting of **31**, glucose, and rhamnose in the ratios 9:1:1 (^{1}H-n.m.r. data). The αβ-ratio for **31** was 1:1.5; R_F 0.18 (ethyl acetate–methanol–acetic acid–water, 6:2:1:1). See Tables I and II for the n.m.r. data.

*2,6-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-*D*-glucopyranosyl)-3-*O*-(2,3,4-tri-*O*-acetyl-α-*L*-rhamnopyranosyl)-α- and -β-*D*-glucopyranose* (**32**). — The preparation of **24** from **22** (279 mg, 0.30 mmol) gave also **32** (13 mg, 0.015 mmol, 5%), which was isolated by preparative t.l.c. (ethyl acetate–hexane, 2:1). The αβ-ratio for **32** was 4:1, R_F 0.26 (ethyl acetate–hexane, 2:1). See Tables III and IV for the n.m.r. data.

*4-*O*-α-*D*-Glucopyranosyl-3-*O*-α-*L*-rhamnopyranosyl-β-*D*-glucopyranosyl fluoride* (**33**). — (*a*) *O*-Deacetylation of **24** (15 mg, 0.017 mmol) in methanol-d_4 with a catalytic amount of sodium methoxide was followed by ^{1}H-n.m.r. spectroscopy. After 3 h, **24** had disappeared, and the mixture was neutralised with M acetic acid and concentrated, to give a syrup consisting of **30, 33, 18**, and **28** in the ratios 10:3:3:1 [^{1}H-n.m.r. data: δ 5.21 ($J_{1,2}$ 1.9 Hz, H-1a), 5.45 ($J_{1,2}$ 4.0 Hz, H-1c), 5.43 ($J_{1,2}$ 5.3, $J_{1,F}$ 52.5 Hz, H-1b)].

(*b*) A solution of **24** (15 mg, 0.017 mmol) in methanolic 0.1% sodium methoxide (2 mL) was left for 15 min. Solid carbon dioxide was added and the mixture was concentrated to give a syrup consisting of **28, 18**, and **30** in the ratios 2:1.25:1 (^{1}H-n.m.r. data).

O-Deacetylation of **25** (15 mg) in methanolic 0.1% sodium methoxide (2 mL)

for 15 min, followed by the addition of solid carbon dioxide and concentration, gave a syrup consisting of **31**, **29**, and **19**. No fluoride was detected.

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REFERENCES

1 L. KENNE, B. LINDBERG, K. PETERSSON, E. KATZENELLENBOGEN, AND E. ROMANOWSKA, *Eur. J. Biochem.*, 91 (1978) 279–284.
2 K. BOCK AND J. F. BOLAÑOS GUZMAN, *Abstr. Eur. Carbohydr. Symp., IVth, Darmstadt, F.R.G.*, 1987, C-47.
3 S. KIM, H. CHANG, AND W. J. KIM, *J. Org. Chem.*, 50 (1985) 1751–1752.
4 P. M. COLLINS, D. GARDINER, S. KUMAR, AND W. G. OVEREND, *J. Chem. Soc., Perkin Trans 1*, (1972) 2596–2610.
5 P. L. DURETTE, L. HOUGH, AND A. C. RICHARDSON, *J. Chem. Soc., Perkin Trans 1*, (1974) 88–96.
6 C. ALTONA AND C. A. G. HAASNOOT, *Org. Magn. Reson.*, 13 (1980) 417–429.
7 J. AUGE AND S. DAVID, *Tetrahedron*, 40 (1984) 2101–2106.
8 B. COXON, *Methods Carbohydr. Chem.*, 6 (1972) 513–539.
9 K. BOCK, A. BRIGNOLE, AND B. W. SIGURSKJOLD, *J. Chem. Soc., Perkin Trans 2*, (1987) 1711–1713.
10 D. CREMER AND J. A. POPLE, *J. Am. Chem. Soc.*, 97 (1975) 1354–1358.
11 R. NORRESTAM, *Acta Crystallogr., Sect. A*, 37 (1981) 764–765.
12 R. NORRESTAM, K. BOCK, AND H. THØGERSEN, *Acta Crystallogr., Sect. B*, 37 (1981) 1689–1693.