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Note

Regioselective methylation of methyl glycopyranosides with diazomethane in the presence of transition-metal chlorides and of boric acid

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Abstract

Partial methylation of the methyl pyranosides of a number of pentoses, hexoses, 6-deoxyhexoses, methyl uronates and their methyl ethers with diazomethane in the presence of transition-metal chlorides and boric acid was studied. It was found for methyl glycosides of pentoses and 6-deoxyhexoses that tin(II), antimony(III), and titanium(IV) chlorides as well as boric acid promoted substitution mainly of OH-3, but with cerium(III) and zinc(II) salts mainly substitution of OH-2 was observed. Methylation of methyl β-L-rhamnopyranoside demonstrated higher reactivity of OH-2 in all cases. The methylation of methyl glycosides of hexoses in the presence of tin(II), antimony(III) and cerium(III) chlorides gave mainly 3-methyl ethers. The 3-methyl ethers, which are not involved in further complexation, accumulated up to 50–80% of the reaction mixture (95–100% of monomethyl ether fraction). Convenient preparative syntheses of methyl ethers for a number of sugars are suggested.

Keywords: Methyl ethers; Methyl glycopyranosides; Partial methylation; Diazomethane; Transition metals

1. Introduction

It is known [1,2] that diazomethane methylates certain hydroxyl groups in monosaccharides and nucleosides in the presence of transition-metal salts. Toman et al. [3] showed that methylation of methyl α-L-rhamnopyranoside (**12**) with diazomethane in the presence of stannous chloride dihydrate and titanium tetrachloride led preferentially to the 3-methyl ether (**14**). In contrast, preferential formation of the 2-methyl ether (**13**) was observed when cerium trichloride was used as a catalyst. Similar results were obtained on methylation of methyl 4-*O*-methyl-α-L-rhamnopyranoside (**15**) [3] as well as methyl 6-*O*-trityl-α-D-mannopyranoside [4] in the presence of stannous chloride dihydrate. These data indicated the preferential complexation of the cis-2,3-diol system with a transition-metal atom. Later, these authors [5] showed that methylation of methyl α-L-fucopyranoside (**19**) under the same conditions also resulted in preferable substitution of OH-2 and OH-3 despite the fact that these hydroxyl groups were a trans-2,3-diol system.

Alcohols, unlike carboxylic acids and phenols, do not react appreciably with diazomethane because of their weak acidity. It is

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known, however, that a strong Lewis acid such as boron trifluoride etherate is a good catalyst for methylation [6] of hydroxyl groups with diazomethane. At the same time weaker Lewis acids, such as transition-metal chlorides, were found to be ineffective catalysts for the methylation of isolated single hydroxyl groups, probably because they form unstable acyclic complexes. It is known that cis-vicinal hydroxyl groups in D-ribose [2], L-rhamnose [3] and D-mannose [4] residues are easily monomethylated with diazomethane in the presence of transition metal salts. On the basis of these experimental data, an intermediate cyclic complex of two vicinal hydroxyl groups of sugar with a tin atom was proposed [2,7]. Such thermodynamically more stable complexes can easily be involved in methylation [7].

This paper is devoted to a study of the effects of transition-metal chlorides and of boric acid on the reactivity of monosaccharide hydroxyl groups in the methylation of a range of glycopyranosides with diazomethane as well as the prospects of the kinetic approach to regioselective syntheses of monosaccharide methyl ethers. It is interesting that lanthanum trichloride, europium trichloride, gadolinium trichloride and yttrium trichloride, unlike cerium trichloride, did not show any activity as catalysts for methylation with diazomethane.

The methylation was performed in two variants: (1) with 1.5 equiv of diazomethane, to determine relative reactivity constants for complexed hydroxyl groups; (2) in certain examples with an excess of diazomethane, to study the possibility of regioselective syntheses of methyl ethers.

The methylation of methyl pyranosides of pentoses, 6-deoxyhexoses and methyl uronates.—As can be seen from Table 1, assuming that O-methylation is a direct consequence of complexation of hydroxyl groups with a metal atom, all hydroxyl groups of methyl glycosides, generally, are involved in complexation with the catalysts studied. The methylation results of methyl glycosides in the presence of Sb(III), Sn(II) and Ti(IV) chlorides appear to be similar and show mainly the higher reactivity of OH-3. Probably, Sb(III), Sn(II) as well as Ti(IV) atoms are involved in intermediate bidentate complexes with two vicinal hydroxyl groups of glycosides like known complexes of stannous chloride with **12** [9] and **19** [5]. On methylation of methyl glycosides with an excess of diazomethane in the presence of antimony and tin chlorides owing to subsequent methylation of the 2- and 4-methyl ethers, the accumulation of 3-methyl ether took place. These data confirm the necessity of two vicinal hydroxyl groups for complexation with a transition-metal atom, since OH-2 and OH-4 in 3-methyl ethers are not appreciably methylated.

It is interesting that, even for methyl α- and β-D-xylopyranosides (**1** and **3**) (Scheme 1), which have no cis-vicinal hydroxyls, the methylation in the presence of transition-metal salts proceeds. A higher content of 2-methyl ether (**4**), 57.3% (70.6% of the monomethyl ether fraction), was obtained on methylation of **3** in methanol in the presence of cerium trichloride.

The methylation of methyl α-L-arabinopyranoside (**8**) (Scheme 2) in 1,4-dioxane in the presence of boric acid (Table 1) formed 3- and 4-methyl ethers (**10** and **11**) in high yield in almost equal amount. On changing this solvent to methanol, the yield of **11** decreased about three times. A similar effect but to a smaller degree was observed for the β anomer. The distance between oxygen atoms of hydroxyl groups for the complexation with borate anion must be ~230–255 pm [8], whereas for the complexation with tin(II) chloride it must be ~280–300 pm [9]. Therefore, methyl pentosides and boric acid probably can form intermediate bidentate complexes with participation of cis-vicinal hydroxyl groups mainly, while large atoms such as Sn(II), Sb(III) and other transition-metal ions are probably able to coordinate both cis- and trans-vicinal hydroxyl groups.

On the methylation of methyl α- and β-L-rhamnopyranosides (**12** and **16**) (Schemes 3 and 4) mainly cis-vicinal hydroxyl groups were involved in the reaction. However, the methylation results of β anomer unlike α anomer demonstrated higher reactivity of OH-2 in all cases studied. On methylation of **16** in the presence of boric acid, the content of **17** in the

Table 1
Partial methylation of methyl pyranosides of pentoses, 6-deoxyhexoses and methyl uronates

Compound	Catalyst	Glycoside (%)	Methyl ethers (%)						
			C-2	C-3	C-4	C-2,3	C-2,4	C-3,4	C-2,3,4
1	H_3BO_3 [a]	90.2	4.1	4.3	1.4				
1	$ZnCl_2$	83.7	6.4	6.0	3.9				
1	$FeCl_3$	14.3	28.0	37.0	5.2	9.5	4.3	1.7	
1	$TiCl_4$	55.7	13.7	17.6	7.8	3.9	1.3		
1	$SbCl_3$	73.4	5.4	19.3	0.3	1.6			
1	$SbCl_3$ [b]			67.1		23.1	4.0	5.8	
1	$SnCl_2{\cdot}2H_2O$	83.7	2.2	12.2	1.0	0.6	0.1	0.2	
1	$SnCl_2{\cdot}2H_2O$ [b]		3.2	74.2	1.1	9.7	5.8	6.0	
1	$CeCl_3$	39.3	24.4	13.1	19.9	2.4		0.9	
							C-2,4 + C-3,4		
3	H_3BO_3 [a]	90.4	3.2	4.1	2.3				
3	$ZnCl_2$	70.5	15.6	8.9	5.0				
3	$FeCl_3$	44.2	28.6	15.0	5.0	4.3	2.9		
3	$TiCl_4$	41.2	4.6	27.9		15.5	10.8		
3	$SbCl_3$	40.2	11.5	34.7	1.0	9.5	3.1		
3	$SbCl_3$ [b]			57.6		24.6	16.4		1.4
3	$SnCl_2{\cdot}2H_2O$	72.1	6.9	15.5	1.1	2.9	1.5		
3	$SnCl_2{\cdot}2H_2O$ [b]	3.8	5.1	51.0	0.6	24.2	15.3		
3	$CeCl_3$	40.8	37.0	10.2	10.0	1.1	0.9		
3	$CeCl_3$ [a,b]	12.6	57.3	11.1	12.7	4.4	1.9		
8	H_3BO_3 [b]			48.4	46.9		1.8	2.9	
8	H_3BO_3 [a]	34.6	3.8	45.9	15.7				
8	$ZnCl_2$	86.4	5.8	3.4	4.4				
8	$FeCl_3$	33.2	9.1	33.1	20.3	1.1	3.2		
8	$TiCl_4$	61.6	3.0	25.7	3.2	2.3	3.1	1.1	
8	$SbCl_3$	50.7	7.2	26.5	7.8	1.8	4.2	1.8	
8	$SbCl_3$ [b]			50.8		14.6	22.5	10.4	1.7
8	$SnCl_2{\cdot}2H_2O$	79.9	1.4	10.7	2.2	1.4	2.9	1.5	
8	$SnCl_2{\cdot}2H_2O$ [b]			58.7		9.3	18.6	12.0	1.4
8	$CeCl_3$ [b]	2.2	30.8	22.3	32.3	2.3	7.7	2.4	
							C-2.4 + C-3.4		
6	H_3BO_3	37.4		40.4	22.2				
6	H_3BO_3 [a]	20.3		61.8	14.6	2.2	1.1		
6	$ZnCl_2$	90.3	4.6	2.1	3.0				
6	$FeCl_3$	61.9	0.8	17.2	12.1	2.6	5.4		
6	$TiCl_4$	27.6		39.9	4.7	7.3	19.7		0.8
6	$SbCl_3$	49.7	1.4	28.8	2.9	7.2	10.0		
6	$SbCl_3$ [b]			52.0		21.9	24.4		1.7
6	$SnCl_2{\cdot}2H_2O$	80.9	2.0	9.7	2.7	2.2	2.5		
6	$SnCl_2{\cdot}2H_2O$ [b]	1.4	0.8	48.7		27.7	20.0		1.4
6	$CeCl_3$	70.9	9.8	8.8	10.5				
12	H_3BO_3		30.2	66.7		3.1			
12	$ZnCl_2$	62.6	20.8	10.9	5.7				
12	$FeCl_3$	43.3	27.9	27.7		0.6	0.5		
12	$TiCl_4$	76.6	3.0	18.2	0.4	1.5	0.3		
12	$SbCl_3$	31.4	16.8	47.4		2.2	1.1	1.1	
12	$SbCl_3$ [b]			64.2		29.5	3.6	2.7	
12	$SbCl_3$ [a]	88.9	3.6	7.5					
12	$SnCl_2{\cdot}2H_2O$	74.8	4.6	19.9		0.7			
12	$SnCl_2{\cdot}2H_2O$ [b]		0.3	69.7		19.8	6.3	3.9	
12	$SnCl_2{\cdot}2H_2O$ [a]	84.2	6.1	9.3		0.4			
12	$CeCl_3$	68.4	17.3	10.7	3.6				
16	H_3BO_3 [b]		84.0	8.3		6.8	0.9		
16	$ZnCl_2$	39.8	45.6	13.3	1.3				

Table 1 (Continued)

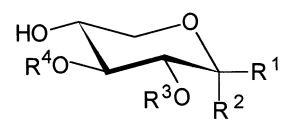
Compound	Catalyst	Glycoside (%)	Methyl ethers (%)						
			C-2	C-3	C-4	C-2,3	C-2,4	C-3,4	C-2,3,4
16	$FeCl_3$ [b]	1.5	75.2	14.4		4.9	4.0		
16	$TiCl_4$	5.0	30.2	24.4		32.0	8.2	0.2	
16	$SbCl_3$	66.4	22.1	6.5		4.1	0.9		
16	$SbCl_3$ [b]	1.6	2.5	17.0		68.3	8.9	1.7	
16	$SnCl_2 \cdot 2H_2O$	70.6	15.6	12.8		0.8	0.2		
16	$SnCl_2 \cdot 2H_2O$ [b]	0.8	0.7	47.5		38.7	11.0	1.3	
16	$CeCl_3$	43.0	48.1	8.9					
19	H_3BO_3 [b]	0.7		79.3	9.2	8.9	1.0	1.0	
19	$ZnCl_2$	95.7	2.1	1.7	0.5				
19	$FeCl_3$	23.1	23.3	24.7	20.1	3.3	4.4	1.1	
19	$TiCl_4$ [b]	0.8		66.8	0.8	23.4	6.2	2.0	
19	$SbCl_3$	70.1	2.1	23.8	0.4	3.3	4.4	1.1	
19	$SbCl_3$ [b]	0.6		68.0		19.4	8.9	3.1	
19	$SbCl_3$ [a]	75.1	1.2	18.7	4.4	0.6			
19	$SnCl_2 \cdot 2H_2O$	71.0	3.8	19.6	3.5	0.8	0.7	0.5	
19	$SnCl_2 \cdot 2H_2O$ [b]		0.2	61.5	7.0	15.6	10.7	5.0	
19	$CeCl_3$	39.4	29.8	12.0	17.5	0.6	0.4	0.3	
						C-2,3 + C-2,4			
23	H_3BO_3	46.2	21.7	31.5	0.3	0.3			
23	$ZnCl_2$	67.6	12.7	12.7	6.8	0.2			
23	$FeCl_3$	41.0	25.4	27.3	2.4	3.9			
23	$TiCl_4$	66.5	5.9	19.5	1.7	6.4			
23	$SbCl_3$	47.2	19.2	29.0	3.4	1.0		0.2	
23	$SbCl_3$ [b]		2.6	51.7		38.8		6.9	
23	$SnCl_2 \cdot 2H_2O$	63.2	9.4	21.1	1.9	4.0		0.4	
23	$SnCl_2 \cdot 2H_2O$ [b]			55.7		22.9		20.6	0.8
23	$CeCl_3$	76.8	12.5	7.7	3.0	5.9		1.5	
40	$SbCl_3$	76.4	1.8	16.2	2.0	2.5	1.1		
40	$SbCl_3$ [b]		2.1	80.8		11.1	3.6	2.4	
42	$SbCl_3$	80.7	3.5	14.0		0.9	0.9		
42	$SbCl_3$ [b]		2.7	77.4		9.5	8.4	2.0	
60	$SbCl_3$	88.5	2.0	7.3	2.2				
60	$SbCl_3$ [b]		1.2	63.5		16.9	18.4		

[a] In MeOH.
[b] Added 5×10^{-4} mol CH_2N_2.

reaction mixture rose to 84.0 or 91% of the monomethyl ether fraction.

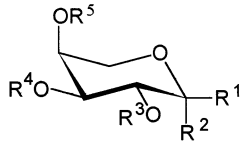
Interpretation of the data on partial methylation of methyl glycosides seems to be rather complicated. To simplify it, partial methylation of a number of pentose and 6-deoxyhexose methyl glycoside monomethyl ethers has been studied (Table 2). In this case, only one cyclic complex may be formed, and the relative reactivity of the hydroxyl groups involved in the complexation is determined by the ratio of dimethyl ethers formed.

The methylation of 2-methyl ethers of methyl glycosides of α- and β-L-rhamnose (**13**



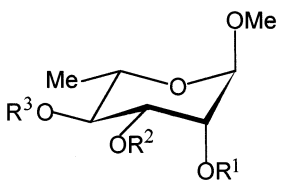
	R^1	R^2	R^3	R^4
1	H	OMe	H	H
2	H	OMe	H	Me
3	OMe	H	H	H
4	OMe	H	Me	H
5	OMe	H	H	Me

Scheme 1. Methyl ethers of methyl D-xylopyranosides.



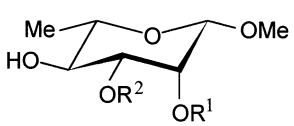
	R^1	R^2	R^3	R^4	R^5
6	H	OMe	H	H	H
7	H	OMe	H	Me	H
8	OMe	H	H	H	H
9	OMe	H	Me	H	H
10	OMe	H	H	Me	H
11	OMe	H	H	H	Me

Scheme 2. Methyl ethers of methyl L-arabinopyranosides.



	R^1	R^2	R^3
12	H	H	H
13	Me	H	H
14	H	Me	H
15	H	H	Me

Scheme 3. Methyl ethers of methyl α-L-rhamnopyranoside.



	R^1	R^2
16	H	H
17	Me	H
18	Me	Me

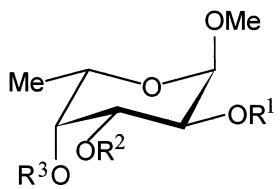
Scheme 4. Methyl ethers of methyl β-L-rhamnopyranoside.

and **17**) and α-L-fucose (**20**) (Scheme 5) in the presence of antimony chloride gave mainly 2,3-dimethyl ethers. A similar result has been obtained in methylation under the same conditions of **4**, which has no methyl group at C-5. However, on methylation using the same conditions of methyl 2-*O*-methyl-α-L-arabinopyranoside (**9**) in which OH-4 is axial, the reactivities of OH-3 and OH-4 were almost equal. These data undoubtedly show that steric factors do not play a general role in the methylation of monosaccharides with diazomethane. Treatment of 3-methyl ethers with diazomethane under the same conditions demonstrates the lower reactivity of isolated hydroxyl groups.

Methylation of methyl hexopyranosides.— Partial methylation of methyl hexosides is more a complicated example of consecutive and parallel reactions because the hydroxyl group at C-6 can additionally participate in the complexation. As shown in Table 3, on methylation of methyl glycosides of D-glucose, D-galactose and D-mannose (Schemes 6–10) with an excess of diazomethane in the presence of antimony(III) and tin(II) chlorides, 3-methyl ethers were favoured and the yields for α anomers were higher than for β anomers.

The methylation of methyl pyranosides of D-glucose and D-galactose in the presence of boric acid shows high reactivity of OH-4 and OH-6, probably caused by easy formation of a borate intermediate complex of 1,3-diols involving these hydroxyl groups. It is interesting that further reaction for methyl β-D-galactopyranoside (**52**) decreased the yield of the 6-methyl ether (**56**) to 5%, probably caused by additional complexation of boric acid with cis-vicinal OH-3 and OH-4 hydroxyl groups. In the latter case, the content of 4-methyl ether (**55**) was found to be 39.3 or 88.3% of the monomethyl ether fraction.

The methylation of methyl hexopyranoside monomethyl ethers (Table 4) demonstrated higher regioselectivity in the substitution of hydroxyl groups. In the methylation of methyl 2-*O*-methyl-α-D-glucopyranoside (**32**) in the



	R^1	R^2	R^3
19	H	H	H
20	Me	H	H
21	H	Me	H
22	H	H	Me

Scheme 5. Methyl ethers of methyl α-L-fucopyranoside.

presence of antimony chloride, the 2,3-dimethyl ether (**35**) was formed in surprisingly high yield—93.2% of total mixture or 98.9% of the dimethyl ether fraction. The methylation of methyl 2,6-di-*O*-methyl-α-D-glucopyranoside (**36**) under the same conditions proceeded slowly; the yield of 2,3,6-trimethyl ether (**39**) was 37.0% but was 97.9% of the trimethyl ether fraction. This agrees well with the data on **32** methylation. The methylation of methyl 6-*O*-methyl-α-D-glucopyranoside (**34**) in the presence of antimony(III) and tin(II) chlorides demonstrated also high regioselectivity in the formation of 3,6-dimethyl ether (**37**).

The methylation of methyl 2-*O*-methyl-β-D-galactopyranoside (**53**) in the presence of antimony chloride, like **32**, led to the selective formation of the 2,3-dimethyl ether (**57**) (89.3% of the dimethyl ether fraction). The methylation of **55** in the presence of tin(II) chloride formed only 2,4- and 3,4-dimethyl ethers (**58** and **59**) (78.0% of the former and 17.2% of the latter). This result agrees with Chittenden's report [10] of the high reactivity of OH-2 in benzyl 4,6-benzylidene-β-D-galactopyranoside with diazomethane in the presence of tin(II) chloride.

Since methyl ethers of different degree of substitution of some glycosides are easily distinguished by their R_f values on silica gel, their separation is a simple procedure. Therefore, the major product from a particular degree of substitution can be isolated easily, despite its low yield in the total mixture. Based on the results obtained, we propose preparative syntheses of a number of mono- and dimethyl ethers of pentoses, hexoses, 6-deoxyhexoses and methyl uronate methyl glycosides, which are described in Section 2.

2. Experimental

General methods.—Melting points were determined on a Boethius micro hot-stage apparatus and were uncorrected. Optical rotations were measured with a Perkin–Elmer model 141. Chloroform was used as a solvent for methyl ethers of pentoses, 6-deoxyhexoses and methyl uronates, MeOH was used for methyl ethers of hexoses. ^{13}C NMR spectra (at 62.90 MHz) were recorded on a Bruker WM-250. Deuterium oxide was used as a solvent for partially methylated derivatives and MeOH was used as an internal standard (δ of MeOH vs. δ of Me_4Si 49.6 ppm). TLC was performed on Silica Gel L (5–40 μm; Chemapol) with the following solvents: 95:5 $CHCl_3$–MeOH (a), 9:1 $CHCl_3$–MeOH (b) and 1:1 $CHCl_3$–acetone (c) and detection by charring with sulfuric acid. Column chromatography was performed on Silica Gel L (100–160 μm;

Table 2
Partial methylation of monomethyl ethers of methyl pyranosides of pentoses and 6-deoxyhexoses [a]

Compound	Catalyst	Methyl ethers (%)						
		C-2	C-3	C-4	C-2,3	C-2,4	C-3,4	C-2,3,4
13	$SbCl_3$				86.8	11.6		1.6
13	$CeCl_3$	87.9			5.3	2.4		4.4
15	$SbCl_3$					27.0	72.8	0.2
15	$CeCl_3$			78.9		10.0	11.1	
9	$SbCl_3$				47.9	46.9		5.2
9	$CeCl_3$	70.9			12.3	16.8		
11	$SbCl_3$					73.5	20.1	6.4
11	$CeCl_3$			61.3		22.7	14.0	2.0
4	$SbCl_3$				84.9	13.2		1.9
4	$CeCl_3$	76.3			18.3	5.4		
17	$SbCl_3$	8.4			80.3	9.5		1.8
20	$SbCl_3$	33.2			61.3	5.5		
22	$SbCl_3$			3.5		79.5	17.0	
5	$SbCl_3$		81.4		9.6		9.0	
14	$SbCl_3$		94.0		2.3		0.8	2.9

[a] Added 5×10^{-4} mol CH_2N_2.

Table 3
Partial methylation of methyl hexopyranosides

Compound	Catalyst	Glycoside (%)	Methyl ethers (%)				
			C-2	C-3	C-4	C-6	di + tri
31	$CeCl_3$	88.0	2.9	4.7	1.4	3.0	
31	$CeCl_3$ [a]	24.8	6.9	30.9	8.6	13.7	15.1
31	H_3BO_3	85.0	1.0	3.1	6.3	4.6	
31	H_3BO_3 [a]	3.4		1.6	46.0	25.1	23.9
31	$SbCl_3$	74.0	1.0	18.6	1.8	1.8	2.8
31	$SbCl_3$ [a]			71.0	0.8		28.2
31	$SnCl_2 \cdot 2H_2O$	47.8	0.9	37.2	2.2	0.9	11.0
31	$SnCl_2 \cdot 2H_2O$ [a]			59.3			40.7
44	$CeCl_3$	61.2	8.4	16.0	3.3	8.4	2.7
44	H_3BO_3	89.6	0.3	1.2	5.1	3.8	
44	H_3BO_3 [a]	10.8		2.0	51.6	25.6	10.0
44	$SbCl_3$	91.2	1.0	6.7	0.3	0.8	
44	$SbCl_3$ [a]	1.3	1.0	53.3	0.4	0.1	43.9
44	$SnCl_2 \cdot 2H_2O$	54.0	6.2	28.4	0.9	0.8	9.7
44	$SnCl_2 \cdot 2H_2O$ [a]		0.2	48.5	0.2		51.1
48	$CeCl_3$	51.2	6.8	25.4	2.0	11.0	3.6
48	H_3BO_3	66.4	0.6	2.6	13.7	16.3	0.4
48	H_3BO_3 [a]		0.4	0.2	31.4	29.8	38.2
48	$SbCl_3$	78.1	1.2	16.6		4.1	
48	$SbCl_3$ [a]		4.8	78.4	1.1		15.7
48	$SnCl_2 \cdot 2H_2O$	85.5	0.9	11.1		0.3	2.2
48	$SnCl_2 \cdot 2H_2O$ [a]		3.7	80.9			15.4
52	$CeCl_3$	63.0	7.6	13.4	3.3	9.0	3.7
52	H_3BO_3	35.5		6.9	30.8	21.5	5.3
52	H_3BO_3 [a]	0.9		2.0	48.0	28.6	20.5
52	H_3BO_3 [b]			0.2	39.3	5.0	55.5
52	$SbCl_3$	41.4	2.3	40.4	1.8	2.3	11.7
52	$SbCl_3$ [a]		0.2	72.0		0.2	27.6
52	$SnCl_2 \cdot 2H_2O$	22.4	4.9	54.9	3.3		28.6
52	$SnCl_2 \cdot 2H_2O$ [a]			63.8			36.2
25	$CeCl_3$	11.8	31.4	20.6	7.6	10.8	17.8
25	H_3BO_3	23.6	2.5	19.2	19.4	14.6	20.7
25	$SbCl_3$	78.2	4.1	11.7	1.7	2.9	1.4
25	$SbCl_3$ [a]		5.1	58.7		1.2	35.0
25	$SnCl_2 \cdot 2H_2O$	82.0	4.1	12.2	0.2	1.0	0.5
25	$SnCl_2 \cdot 2H_2O$ [a]	1.7	1.2	55.9		1.0	40.2

[a] Added 5×10^{-4} mol CH_2N_2.
[b] Added 8×10^{-4} mol CH_2N_2.

Chemapol). GC analyses were carried out with a Tsvet-106 gas chromatograph with an FID detector and double glass columns (2 m × 3 mm i.d.), using Ar (60 mL/min) as a carrier gas. The liquid stationary phases were: A, 2% QF-1 (160 °C); B, 1.5% NPGS (175 °C); C, 2% QF-1 (170 °C) and D, 1.5% NPGS (190 °C) on Chromatone N AW HMDS (125–160 μm; Chemapol). Relative retention times of the peracetates of the methyl glycosides and their methyl ethers are given in Tables 5 and 6. Me α-D-Glc, Me α-D-Gal and Me α-D-Man were commercial samples. The following glycosides were prepared according to known methods: Me α- and β-D-Xyl [11], Me α-L-Ara [11] by method [12], Me β-L-Ara [11], Me α-D-Lyx [13], Me α-L-Rha [14], Me β-L-Rha [15], Me α-L-Fuc [16], Me 6-deoxy-α-D-Glc [17], Me (Me α-D-GlcUA) [18], Me (Me β-D-GalUA) [19], Me β-D-Glc [20], Me β-D-Gal [21] by method [20], Me 2- and 4-*O*-Me-α-L-Ara [22], Me 4-*O*-Me-

Table 4
Partial methylation of methyl ethers of methyl hexopyranosides

Compound	Catalyst	Methyl ethers (%)												
		C-2	C-4	C-6	C-2,3	C-2,4	C-2,6	C-3,4	C-3,6	C-4,6	C-2,3,4	C-2,3,6	C-2,4,6	C-3,4,6
32	$SbCl_3$	45.4			52.1	1.5	0.2					0.8		
32	$SbCl_3$ [a]	1.0			93.2	1.0						4.8		
32	$SnCl_2{\cdot}2H_2O$ [a]				73.4	9.1					2.0	15.5		
32	H_3BO_3 [a]	20.6			3.7	52.7	19.8				1.4	1.3	0.5	
34	$SbCl_3$ [a]			6.7			6.7		78.9			7.4		0.3
34	$SnCl_2{\cdot}2H_2O$ [a]						5.5		75.9			12.0	3.0	3.6
35	$SbCl_3$ [a]						62.2					37.0	0.8	
38	$SbCl_3$ [a]									55.9			16.2	27.9
53	$SbCl_3$ [a]				50.3	5.5	0.5				1.5	40.7	1.5	
53	H_3BO_3 [a]	53.8			14.3	19.9	12.0							
55	$SbCl_3$ [a]		20.9			71.8		4.3			3.0[b]			
55	$SnCl_2{\cdot}2H_2O$ [a]		4.8			78.0		17.2						
56	$SbCl_3$			18.8			6.4		61.0	1.8	1.8[b]	9.2		1.0
56	$SbCl_3$ [a]						0.3		68.0		7.3[b]	23.4		1.0
50	$SbCl_3$		71.2			21.2		7.1		0.5				
26	$SbCl_3$ [a]	27.5			28.2	35.4	5.0				3.9[c]			
28	$SbCl_3$ [a]					21.4		78.6						
28	$SnCl_2{\cdot}2H_2O$ [a]		7.4			21.7		70.9						
29	$CeCl_3$ [a]			3.1			68.3		15.0	4.7	8.8[c]			
29	H_3BO_3			42.3			15.4		42.3					
29	$SbCl_3$			27.1			22.7		45.8	1.1	4.0[c]			
29	$SbCl_3$ [a]			1.3			2.3		55.2		41.2[c]			
29	$SnCl_2{\cdot}2H_2O$			59.3			13.7		24.8	0.3	1.9[c]			

[a] Added 5×10^{-4} mol CH_2N_2.
[b] Sum of 2,3,4- and 2,4,6-trimethyl ethers of methyl β-D-galactopyranoside.
[c] Sum of trimethyl ethers of methyl α-D-mannopyranoside.

α-L-Rha [23], Me 2-*O*-Me-α-D-Glc [24], Me 2-, 4- and 6-*O*-Me-β-D-Gal [25], Me 6-*O*-Me-α-D-Glc [26], Me 2-*O*-Me-α-D-Man [27], Me 4-*O*-Me-α-D-Man [28] and Me 6-*O*-Me-α-D-Man [29]. Other methyl ethers were prepared by deacetylation of the corresponding acetates: Me 2-*O*-Me-β-D-Xyl [30] from Me 3,4-di-*O*-Ac-2-*O*-Me-β-D-Xyl [31], Me 2-*O*-Me-α-L-Rha [3] from Me 3,4-di-*O*-Ac-2-*O*-Me-α-L-Rha [23], Me 2,6-di-*O*-Me-α-D-Glc [32] from Me 3,4-di-*O*-Ac-2,6-di-*O*-Me-α-D-Glc [24] and Me 4,6-di-*O*-Me-α-D-Glc [33] from Me 2,3-di-*O*-Ac-4,6-di-*O*-Me-α-D-Glc [24].

Partial methylation of methyl glycosides; general procedure.—To solutions of methyl glycosides (0.1 mmol) and catalyst (2×10^{-6} mol) (for $CeCl_3$, $ZnCl_2$ and H_3BO_3 amounts were $\times 2$) in 1,4-dioxane (0.4 mL) (MeOH was used for methylhexosides), diazomethane in CH_2Cl_2 [6] (0.3 mL, 0.15 mmol for initial stage of reaction, 1 mL, 0.5 mmol for final stage of methylation) was added slowly at

Table 5
Relative retention times of acetates of methyl ethers of methyl pyranosides of pentoses, 6-deoxyhexoses and methyl uronates

Methyl glycoside	GC-column [a]	Glycoside	Methyl ethers						
			C-2	C-3	C-4	C-2,3	C-2,4	C-3,4	C-2,3,4
α-Xyl (**1**)	A	1.56	1.00 (5.4 min)	0.72	0.83	0.31	0.56	0.22	0.14
α-Xyl (**1**)	B	1.34	1.00 (6 min)	0.78	0.78	0.39	0.59	0.27	0.15
β-Xyl (**3**)	A	1.64	0.67	1.00 (5.4 min)	0.83	0.29	0.40	0.40	0.11
β-Xyl (**3**)	B	1.55	0.67	1.00 (6 min)	0.85	0.30	0.42	0.42	0.11
α-Ara (**8**)	A	1.88	0.69	0.87	1.00 (4.8 min)	0.24	0.26	0.50	0.14
α-Ara (**8**)	B	1.74	0.71	1.00 (6.3 min)	0.90	0.31	0.31	0.57	0.19
β-Ara (**6**)	A	1.64	1.00 (3.3 min)	0.58	1.00	0.24	0.42	0.42	0.12
β-Ara (**6**)	B	1.75	1.00 (6.0 min)	0.75	0.90	0.38	0.50	0.50	0.20
α-Lyx (**23**)	A	3.11	1.83	1.00 (3.0 min)	1.61	0.61	0.61	0.33	0.17
α-Lyx (**23**)	B	2.00	1.37	1.00 (5.1 min)	1.14	0.57	0.57	0.34	0.20
α-Rha (**12**)	A	1.61	1.00 (4.2 min)	0.57	0.89	0.41	0.36	0.16	0.09
α-Rha (**12**)	B	1.41	1.00 (7.5 min)	0.67	0.74	0.53	0.39	0.20	0.14
β-Rha (**16**)	B	1.82	1.00 (4.9 min)	1.21	0.91	0.73	0.48	0.33	0.18
α-Fuc (**19**)	A	2.92	1.89	1.00 (3.0 min)	2.01	0.43	0.88	0.67	0.30
α-Fuc (**19**)	B	1.88	1.44	1.00 (4.0 min)	1.28	0.48	0.80	0.60	0.24
α-Qui (**40**)	B	1.43	1.00 (7.5 min)	0.84	0.79	0.40	0.57	0.24	0.08
α-GlcUA (**42**)	C	1.49	1.21	1.00 (11.6 min)	0.88	0.56	0.74	0.33	0.18
β-GalUA (**60**)	C	1.40	0.68	1.00 (23.1 min)	1.08	0.30	0.44	0.74	0.19

[a] Column: A, 2% QF-1 (160 °C); B, 1.5% NPGS (175 °C); C, 2% QF-1 (170 °C) on Chromatone N AW HMDS.

Table 6
Relative retention times of methyl ethers of methyl hexopyranoside acetates [a]

Methyl ether	Glycoside									
	α-Glc (**31**), column		β-Glc (**44**), column		α-Gal (**48**), column		β-Gal (**52**), column		α-Man (**25**), column	
	C	D	C	D	C	D	C	D	C	D
Glycoside	1.73	1.54	2.34	2.15	1.49	1.78	2.46	2.22	2.50	2.54
C-2	1.07	1.18	1.00 (9.6 min)	1.00 (13.5 min)	1.00 (15.0 min)	1.42	1.00 (12.9 min)	1.00 (14.7 min)	1.50	1.82
C-3	1.00 (18 min)	1.00 (15 min)	1.97	1.64	0.59	1.00 (10.8 min)	1.44	1.49	1.00	1.31
C-4	1.33	1.10	1.69	1.42	1.36	1.50	2.46	1.85	1.79	1.61
C-6	0.71	0.61	1.00	0.89	0.66	0.78	1.12	1.00	1.00 (7.2 min)	1.00 (8.6 min)
C-2,3	0.40	0.55	0.47	0.50	0.25	0.54	0.34	0.47	0.67	0.98
C-2,4	0.87	0.86	0.78	0.72	0.66	0.94	0.77	0.71	0.70	1.00
C-2,6	0.44	0.48	0.44	0.42	0.44	0.64	0.46	0.47	0.62	0.75
C-3,4	0.39	0.40	0.78	0.72	0.50	0.74	1.44	1.12	0.35	0.53
C-3,6	0.40	0.40	0.78	0.69	0.22	0.42	0.60	0.65	0.35	0.53
C-4,6	0.44	0.40	0.59	0.50	0.44	0.53	0.82	0.65	0.56	0.58
C-2,3,4	0.13	0.21	0.16	0.20	0.16	0.36	0.26	0.30	0.20	0.35
C-2,3,6	0.14	0.22	0.19	0.20	0.11	0.24	0.15	0.20	0.25	0.40
C-2,4,6	0.29	0.32	0.28	0.27	0.21	0.36	0.26	0.28	0.23	0.35
C-3,4,6	0.11	0.14	0.28	0.27	0.15	0.26	0.46	0.40	0.10	0.21
C-2,3,4,6	0.05	0.08	0.05	0.10	0.06	0.12	0.08	0.10	0.06	0.16

[a] Column: C, 2% QF-1 (170 °C); D, 1.5% NPGS (190 °C) on Chromatone N AW HMDS.

room temperature. After 2 h, the mixtures were evaporated to dryness under reduced pressure, the residues were acetylated with acetic anhydride and pyridine, the products were isolated in the usual manner and chloroform solutions were used for GC.

*Methyl 3-*O*-methyl-α-*L*-rhamnopyranoside* (**14**). *Typical procedure for the preparation of* **2, 5, 7, 14, 18, 21** *and* **24**.—To a solution of **12** (1 g, 5.6 mmol) and $SbCl_3$ (0.1 mmol) in 1,4-dioxane (10 mL), diazomethane in CH_2Cl_2 [6] ~0.5 M (40 mL, 20 mmol) was added slowly at room temperature until a yellow color persisted. The solution was kept for 2 h at room temperature and was evaporated to dryness under vacuum. The residue was chromatographed on a column (30 × 1.5 cm) of silica gel with gradient of MeOH in $CHCl_3$. Syrup, 0.58 g (54%); R_f 0.44 (solvent a); $[\alpha]_D^{20}$ −60.3° (*c* 0.6), lit. −61° (*c* 1.3, $CHCl_3$) [3]; ^{13}C NMR: δ 101.6 (C-1), 80.5 (C-3), 71.6 (C-4), 69.2 (C-5), 66.5 (C-2), 56.9 (MeO-3), 55.4 (MeO-1), 17.4 (C-6).

*Methyl 3-*O*-methyl-α-*L*-fucopyranoside* (**21**). From **19** (1.0 g); 0.65 g (60%); R_f 0.38 (solvent a); mp 96–97 °C (from EtOAc–hexane), lit. 96–97 °C [5]; $[\alpha]_D^{20}$ −142.5° (*c* 0.4), lit. −135.8° (*c* 0.62, MeOH) [5]; ^{13}C NMR: δ 100.1 (C-1), 79.6 (C-3), 68.1 (C-4), 67.6 (C-2), 67.0 (C-5), 56.6 (MeO-3), 55.8 (MeO-1), 16.1 (C-6).

*Methyl 3-*O*-methyl-β-*L*-arabinopyranoside* (**7**). From **6** (1.0 g); 0.46 g (42%); R_f 0.36 (solvent a); mp 57–58 °C (from EtOAc–hexane); $[\alpha]_D^{20}$ + 199.7° (*c* 1.5); ^{13}C NMR: δ 100.4 (C-1), 78.8 (C-3), 67.8 (C-2), 65.5 (C-4), 63.1 (C-5), 56.7 (MeO-3), 55.8 (MeO-1).

*Methyl 3-*O*-methyl-α-*D*-xylopyranoside* (**2**). From **1** (1.0 g); syrup, 0.64 g (59%); R_f 0.36 (solvent a); $[\alpha]_D^{20}$ + 117.6° (*c* 1.2); ^{13}C NMR: δ 100.3 (C-1), 83.8 (C-3), 71.6 (C-2), 69.6 (C-4), 61.8 (C-5), 60.7 (MeO-3), 55.8 (MeO-1).

*Methyl 3-*O*-methyl-β-*D*-xylopyranoside* (**5**). From **3** (1.0 g); 0.47 g (43%); R_f 0.42 (solvent a); mp 107–108 °C (from EtOAc–hexane), lit. 106–107 °C [30]; $[\alpha]_D^{20}$ −71.2° (*c* 0.6), lit. −74° (*c* 1.0, $CHCl_3$) [30]; ^{13}C NMR: δ 104.7 (C-1), 85.9 (C-3), 73.0 (C-2), 69.4 (C-4), 65.7 (C-5), 60.5 (MeO-3), 57.7 (MeO-1).

*Methyl 3-*O*-methyl-α-*D*-lyxopyranoside* (**24**). From **23** (1.0 g); syrup, 0.49 g (45%); R_f 0.35 (solvent a); $[\alpha]_D^{20}$ + 46.4° (*c* 2.4); ^{13}C NMR: δ 102.0 (C-1), 80.9 (C-3), 66.8 (C-4), 65.9 (C-2), 63.1 (C-5), 57.3 (MeO-3), 55.8 (MeO-1).

*Methyl 2,3-di-*O*-methyl-β-*L*-rhamnopyranoside* (**18**). From **16** (0.2 g); syrup, 0.15 g (65%); R_f 0.60 (solvent a); $[\alpha]_D^{20}$ + 94,3° (*c* 0.8); ^{13}C NMR: δ 102.4 (C-1), 82.9 (C-3), 76.8 (C-2), 72.2 (C-5), 72.0 (C-4), 61.6 (MeO-2), 57.6 (MeO-1), 57.4 (MeO-3), 17.4 (C-6).

*Methyl 2-*O*-methyl-β-*L*-rhamnopyranoside* (**17**). To a solution of **16** (0.2 g, 1.1 mmol) and H_3BO_3 (0.04 mmol) in 1,4-dioxane (2 mL) diazomethane in CH_2Cl_2 (5 mL, 2.5 mmol) was added slowly at room temperature. The solution was kept for 2 h at room temperature. Isolation was carried out as for **14**; 0.16 g (74%); R_f 0.33, (solvent a); mp 141–142 °C (from EtOAc–hexane); $[\alpha]_D^{20}$ + 111.9° (*c* 0.4); ^{13}C NMR: δ 102.4 (C-1), 81.0 (C-2), 73.7 (C-5), 73.1 (C-3), 72.9 (C-4), 62.0 (MeO-2), 57.5 (MeO-1), 17.3 (C-6).

*Methyl 2-*O*-methyl-β-*D*-xylopyranoside* (**4**). To a solution of **3** (0.2 g, 1.2 mmol) and $CeCl_3$ (0.04 mmol) in MeOH (4 mL), diazomethane in CH_2Cl_2 (10 mL, 5 mmol) was added slowly at room temperature. The solution was kept for 2 h at room temperature. Isolation was carried out as for **14**; 0.11 g (51%); R_f 0.40 (solvent a); mp 111–112 °C (from EtOAc–hexane), lit. 110–111.5 °C [30]; $[\alpha]_D^{20}$ −69.8° (*c* 0.9), lit. −69° (*c* 1.0, $CHCl_3$) [30]; ^{13}C NMR: δ 104.5 (C-1), 83.3 (C-2), 75.9 (C-3), 69.9 (C-4), 65.7 (C-5), 60.7 (MeO-2), 57.7 (MeO-1).

*Methyl 3-*O*-methyl-α-*D*-glucopyranoside* (**33**). *Typical procedure for the preparation of* **27**, **30**, **33**, **35**, **37**, **41**, **43**, **45**, **49**, **54** *and* **61**.—To a solution of **31** (1.0 g, 5.2 mmol) and $SbCl_3$ (0.1 mmol) in MeOH (10 mL), diazomethane in CH_2Cl_2 (40 mL, 20 mmol) was added slowly at room temperature. The solution was kept for 2 h at room temperature. Isolation was carried out as for **14**; syrup, 0.7 g (65%); R_f 0.30 (solvent b); $[\alpha]_D^{20}$ + 158.4° (*c* 1.7), lit. +164° (*c* 0.86, water) [34]; ^{13}C NMR: δ 99.9 (C-1), 83.7 (C-3), 72.3 (C-5), 71.5 (C-2), 69.7 (C-4), 61.2 (C-6), 60.6 (MeO-3), 55.7 (MeO-1).

*Methyl 2,3-di-*O*-methyl-α-*D*-glucopyranoside* (**35**). From **32** (0.5 g); 0.42g (79%); R_f 0.53 (solvent b); mp 83–84 °C (from EtOAc–

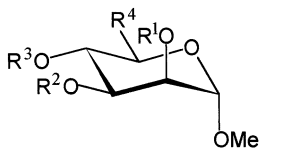
hexane), lit. 82–85 °C [35]; $[\alpha]_D^{20}$ + 156.0° (*c* 1.2), lit. + 150.2° (water) [35]; ^{13}C NMR: δ 97.3 (C-1), 83.0 (C-3), 80.6 (C-2), 72.2 (C-5), 69.8 (C-4), 61.2 (C-6), 60.6 (MeO-3), 58.5 (MeO-2), 55.4 (MeO-1).

Methyl 3,6-di-O-*methyl*-α-D-*glucopyranoside* (**37**). From **34** (0.5 g); 0.37 g (69%); R_f 0.55 (solvent b); mp 72–73 °C (from EtOAc–hexane); $[\alpha]_D^{20}$ + 151.7° (*c* 2.4); ^{13}C NMR: δ 100.1 (C-1), 83.6 (C-3), 71.7 (C-6), 71.4 (C-2), 70.9 (C-5), 69.9 (C-4), 60.6 (MeO-3), 59.2 (MeO-6), 55.9 (MeO-1).

Methyl 6-deoxy-3-O-*methyl*-α-D-*glucopyranoside* (**41**). From **40** (0.5 g); 0.40 g (74%); R_f 0.40 (solvent a); mp 83–84 °C (from EtOAc–hexane); $[\alpha]_D^{20}$ + 153.1° (*c* 0.9); ^{13}C NMR: δ 99.9 (C-1), 83.4 (C-3), 75.2 (C-4), 71.7 (C-2), 68.3 (C-5), 60.6 (MeO-3), 55.8 (MeO-1), 17.3 (C-6).

Methyl (methyl 3-O-*methyl*-α-D-*glucopyranosid)uronate* (**43**). From **42** (0.5 g); 0.34 g (64%); R_f 0.48 (solvent a); mp 84–85 °C (from EtOAc–hexane), lit. 85–90 °C [36]; $[\alpha]_D^{20}$ + 132° (*c* 1.0), lit. + 150° (*c* 1.0, MeOH) [36]; ^{13}C NMR: δ 172.2 (C-6), 100.4 (C-1), 83.1 (C-3), 71.5 (C-4), 71.5 (C-5), 71.1 (C-2), 60.9 (MeO-3), 56.2 (MeO-1), 53.7 (MeO-6).

Methyl 3-O-*methyl*-β-D-*glucopyranoside* (**45**). From **44** (0.35 g); syrup, 0.19 g (51%); R_f 0.25 (solvent b); $[\alpha]_D^{20}$ − 24.7° (*c* 0.7), lit. − 30.2° (*c* 5.0, MeOH) [37]; ^{13}C NMR: δ 103.9 (C-1), 86.1 (C-3), 76.5 (C-5), 73.2 (C-2), 69.8 (C-4), 61.4 (C-6), 60.5 (MeO-3), 57.9 (MeO-1).



	R1	R2	R3	R4
23	H	H	H	H
24	H	Me	H	H
25	H	H	H	CH_2OH
26	Me	H	H	CH_2OH
27	H	Me	H	CH_2OH
28	H	H	Me	CH_2OH
29	H	H	H	CH_2OMe
30	H	Me	H	CH_2OMe

Scheme 6. Methyl ethers of methyl α-D-xylopyranoside and methyl α-D-mannopyranoside.

Methyl 3-O-*methyl*-α-D-*galactopyranoside* (**49**). From **48** (0.4 g); syrup, 0.3 g (70%); R_f 0.30 (solvent b); $[\alpha]_D^{20}$ + 157.8° (*c* 0.4), lit. + 160° (*c* 0.58, MeOH) [38]; ^{13}C NMR: δ 99.9 (C-1), 79.5 (C-3), 71.3 (C-5), 68.0 (C-2), 65.7 (C-4), 62.0 (C-6), 56.8 (MeO-3), 55.7 (MeO-1).

Methyl 3-O-*methyl*-β-D-*galactopyranoside* (**54**). From **52** (0.4 g); syrup, 0.27 g (63%); R_f 0.23 (solvent b); $[\alpha]_D^{20}$ + 28.3° (*c* 0.4), lit. + 32.6° (*c* 1.0, water) [39]; ^{13}C NMR: δ 104.6 (C-1), 82.7 (C-3), 75.7 (C-5), 70.5 (C-2), 64.9 (C-4), 61.8 (C-6), 57.8 (MeO-1), 56.9 (MeO-3).

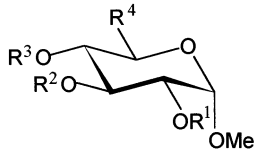
Methyl (methyl 3-O-*methyl*-β-D-*galactopyranosid)uronate* (**61**). From **60** (0.4 g); 0.24 g (56%); R_f 0.43 (solvent a); mp 156–157 °C (from EtOAc–hexane); $[\alpha]_D^{20}$ − 37.5° (*c* 0.5); ^{13}C NMR: δ 171.1 (C-6), 104.2 (C-1), 82.0 (C-3), 74.8 (C-5), 69.7 (C-2), 66.1 (C-4), 58.0 (MeO-1), 57.0 (MeO-3), 53.6 (MeO-6).

Methyl 3-O-*methyl*-α-D-*mannopyranoside* (**27**). From **25** (1.0 g); syrup, 0.55 g (51%); R_f 0.25 (solvent b); $[\alpha]_D^{20}$ + 62.5° (*c* 0.6), lit. + 53.1° (*c* 0.54, MeOH) [38]; ^{13}C NMR: δ 102.1 (C-1), 81.3 (C-3), 73.6 (C-5), 66.7 (C-2), 66.7 (C-4), 61.9 (C-6), 57.2 (MeO-3), 55.5 (MeO-1).

Methyl 3,6-di-O-*methyl*-α-D-*mannopyranoside* (**30**). From **29** (0.4 g); syrup, 0.20 g (47%); R_f 0.57 (solvent b); $[\alpha]_D^{20}$ + 63.9° (*c* 0.5); ^{13}C NMR: δ 101.4 (C-1), 80.6 (C-3), 72.1 (C-6), 71.7 (C-5), 66.5 (C-2), 66,5 (C-4), 59.1 (MeO-6), 57.0 (MeO-3), 55.5 (MeO-1).

Regioselective methylation of methyl β-D-glucopyranoside (**44**) *in the presence of boric acid.*—To a solution of **44** (0.4 g, 2.1 mmol) and H_3BO_3 (0.08 mmol) in MeOH (10 mL), diazomethane in CH_2Cl_2 (20 mL, 10 mmol) was added slowly at room temperature. The solution was kept 2 h at room temperature and was evaporated to dryness under vacuum. Column chromatography (silica gel 30 × 1 cm) with gradient of acetone in chloroform gave two major products.

Methyl 4-O-*methyl*-β-D-*glucopyranoside* (**46**).—Syrup, 0.19 g (44%); R_f 0.30 (solvent c); $[\alpha]_D^{20}$ − 12.6° (*c* 0.4); ^{13}C NMR: δ 103.8 (C-1), 80.0 (C-4), 76.1 (C-3), 75.6 (C-5), 73.8 (C-2), 61.3 (C-6), 60.4 (MeO-4), 57.7 (MeO-1).

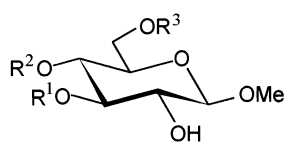


	R^1	R^2	R^3	R^4
31	H	H	H	CH_2OH
32	Me	H	H	CH_2OH
33	H	Me	H	CH_2OH
34	H	H	H	CH_2OMe
35	Me	Me	H	CH_2OH
36	Me	H	H	CH_2OMe
37	H	Me	H	CH_2OMe
38	H	H	Me	CH_2OMe
39	Me	Me	H	CH_2OMe
40	H	H	H	Me
41	H	Me	H	Me
42	H	H	H	COOMe
43	H	Me	H	COOMe

Scheme 7. Methyl ethers of methyl α-D-glucopyranoside, methyl 6-deoxy-α-D-glucopyranoside, and methyl (methyl α-D-glucopyranosid)uronate.

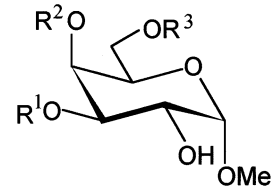
Methyl 6-O-methyl-β-D-glucopyranoside (**47**).—0.09 g (21%); R_f 0.23 (solvent c); mp 132–133 °C (from EtOAc), lit. 133–135 °C [40]; $[\alpha]_D^{20}$ −24.0° (*c* 0.3), lit. −27.0° (water) [40]; ^{13}C NMR: δ 103.9 (C-1), 76.5 (C-3), 75.2 (C-5), 73.7 (C-2), 71.9 (C-6), 70.5 (C-4), 59.3 (MeO-6), 57.8 (MeO-1).

Regioselective methylation of methyl α-D-galactopyranoside 48 *in the presence of boric acid.*—Methylation and isolation were carried out as above for **44** and gave two major products:



	R^1	R^2	R^3
44	H	H	H
45	Me	H	H
46	H	Me	H
47	H	H	Me

Scheme 8. Methyl ethers of methyl β-D-glucopyranoside.

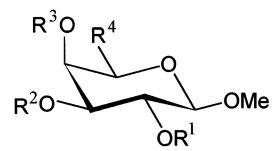


	R^1	R^2	R^3
48	H	H	H
49	Me	H	H
50	H	Me	H
51	H	H	Me

Scheme 9. Methyl ethers of methyl α-D-galactopyranoside.

Methyl 4-O-methyl-α-D-galactopyranoside (**50**).0.11 g (26%); R_f 0.23 (solvent c); mp 124–125 °C (from EtOAc), lit. 122–124 °C [41]; $[\alpha]_D^{20}$ + 170.0° (*c* 0.3), lit. + 178.0° (*c* 1.08, $CHCl_3$) [41]; ^{13}C NMR: δ 100.0 (C-1), 80.4 (C-4), 71.7 (C-5), 70.7 (C-3), 69.3 (C-2), 62.0 (MeO-4), 61.4 (C-6), 55.7 (MeO-1).

Methyl 6-O-methyl-α-D-galactopyranoside (**51**).0.10 g (23%); R_f 0.15 (solvent c); mp 141–142 °C (from EtOAc), lit. 138 °C [42]; $[\alpha]_D^{20}$ + 198.8° (*c* 0.3), lit. + 165° (*c* 1, water) [42]; ^{13}C NMR: δ 100.2 (C-1), 72.5 (C-6), 70.1 (C-4), 70.0 (C-3), 69.4 (C-5), 68.8 (C-2), 59.0 (MeO-6), 55.9 (MeO-1).



	R^1	R^2	R^3	R^4
52	H	H	H	CH_2OH
53	Me	H	H	CH_2OH
54	H	Me	H	CH_2OH
55	H	H	Me	CH_2OH
56	H	H	H	CH_2OMe
57	Me	Me	H	CH_2OH
58	Me	H	Me	CH_2OH
59	H	Me	Me	CH_2OH
60	H	H	H	COOMe
61	H	Me	H	COOMe

Scheme 10. Methyl ethers of methyl β-D-galactopyranoside and methyl (methyl β-D-galactopyranosid)uronate.

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