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An efficient synthesis of new 1′-*C*-methyl-α-*O*-disaccharides using 1-methylenesugars as the glycosyl donors

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Abstract—A series of new 1′-*C*-methyl-α-disaccharides were firstly synthesized by the directly Lewis acid-catalyzed *O*-glycosidation of 1-methylenesugars used as glycosyl donors. The *O*-glycosidation afforded stereospecifically the corresponding 1′-methyl-α-*O*-glycosides whose configurations were tentatively assigned by the NMR spectra, COSY and the C–H coupling constant $^{3}J_{H-2',Me-1'}$. The *O*-glycosidation of the acetyl protected 1-methylenesugars showed that the acetyl group at the C-2-*O* position was not effective to control the stereochemistry of the product by neighboring group participation because of the formation of a tertiary oxycarbenium ion as a stable intermediate.

1. Introduction

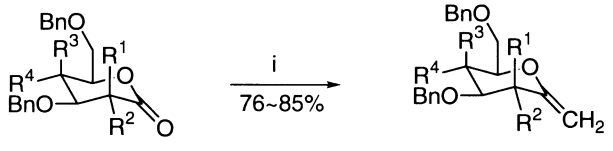
Carbohydrates play profound roles in mediating the cell–cell recognition, moderating the behavior of enzymes and other proteins, and fulfilling various functions in the immune response due to their great deal of information-carrying potential.[1] With the understanding of the interactions between carbohydrates and their receptors, a number of carbohydrate analogues and mimetics have been successfully synthesized.[2] However, challenges still remain in carbohydrate research field, such as, designing and synthesizing highly bioactive and low-toxic glycomimetics for the elucidation of the carbohydrate recognition by biomolecules in natural system and for the development of potential drug candidates, and developing new methodology of glycosylation for the synthesis of complex saccharides.[3]

1-Methylenesugars have been successfully used as precursors for *C*-glycoside syntheses employing by hydroboration,[4] hydroboration/Suzuki cross coupling reaction,[5] radical reaction,[6] iodonium ion promoted reaction,[7–9] epoxidation/ring-opening reaction[10] and Lewis acid catalyzed reaction.[11] However, their *O*-glycosidations in which the 1-methylenesugars are used as glycosyl donors have not been explored extensively.[12] In view of the electron rich enol ether structure of 1-methylenesugar and its high sensitivity to electrophiles, we turned our attention to develop the application of 1-methylenesugar to the synthesis of 1′-*C*-methyl-*O*-glycosides by the direct *O*-glycosylation catalyzed by Lewis acid. We now describe a novel synthesis of 1′-*C*-methyl-*O*-disaccharides using 1-methylenesugars **2** as the *O*-glycosyl donors and partly protected glucosides **3** and **4** as the glycosyl acceptors.

2. Results and discussions

The requisite 2,3,4,6-tetra-*O*-benzyl-1-methylenesugars **2a–c** were prepared by the methylenation of their corresponding sugar lactones **1a–c**[13] with Tebbe's reagent[4,6,14] (Scheme 1).

The *O*-glycosidation employing 2,3,4,6-tetra-*O*-benzyl-1-methylenesugar **2** as a typical glycosyl donor was illustrated in Scheme 2. The mixture of 2,3,4,6-tetra-*O*-benzyl-1-methylenesugar **2** and a glycosyl acceptor (1.1 equiv.),



1a~c **2a~c**

	R^1	R^2	R^3	R^4
a (Glc)	H	OBn	H	OBn
b (Gal)	H	OBn	OBn	H
c (Man)	OBn	H	H	OBn

Scheme 1. *Reagents and conditions*: (i) Cp_2TiMe_2 (2.1 equiv.), toluene, 65–70°C, 14 h.

Keywords: sugar lactones; 1-methylenesugars; 1′-*C*-methyl-α-disaccharides; *O*-glycosidation; neighboring group participation.

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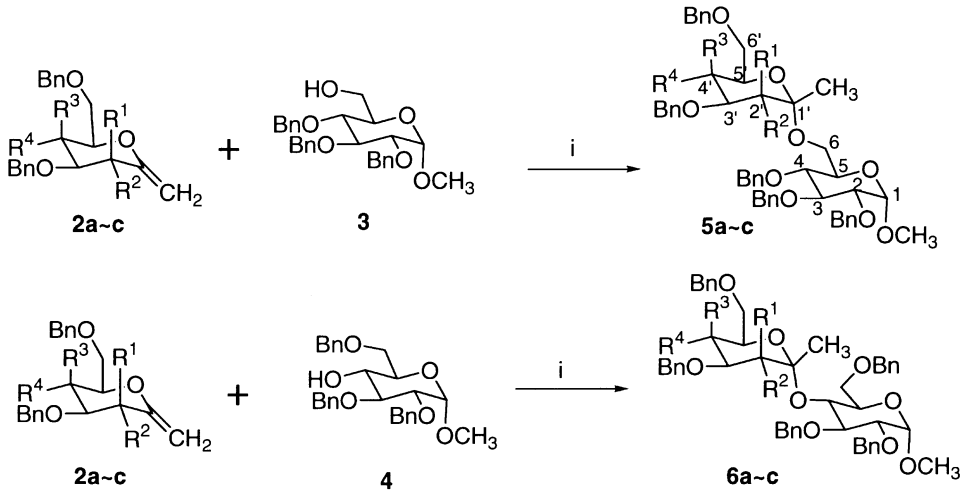


Scheme 2. *Reagents and conditions*: (i) TfOH (0.05 equiv.), MS 4A, CH_2Cl_2, Ar, −78°C, 1 h.

Table 1. Glycosidation of **2** with **3** and **4** using TfOH as a catalyst

	R^1	R^2	R^3	R^4	Yield of **5** (%)	Yield of **6** (%)
a (Glc)	H	OBn	H	OBn	98.1	80.1
b (Gal)	H	OBn	OBn	H	93.9	71.4
c (Man)	OBn	H	H	OBn	90.4	75.2

methyl 2,3,4-tri-*O*-benzyl-glucoside **3**[15] or methyl 2,3,6-tri-*O*-benzyl-glucoside **4**,[16] were treated with a catalytic amount (0.05 equiv.) of triflouromethanesulfonic acid (TfOH) in the presence of molecular sieves 4A (MS 4A) at −78 to −20°C to afford *O*-glycosylation products exclusively. ^{1}H NMR indicated the formation of one anomeric isomer which was determined to be α-configuration by the C–H coupling constant $^3J_{H,C}$ between 2′-H and the carbon of 1′-Me.[17] According to this procedure, a series of 1′-*C*-methyl-*O*-disaccharides **5** and **6** were obtained in 71–98% yields, respectively (Table 1), providing a feasible and general method for synthesizing 1′-*C*-methyl-*O*-α-disaccharide compounds.

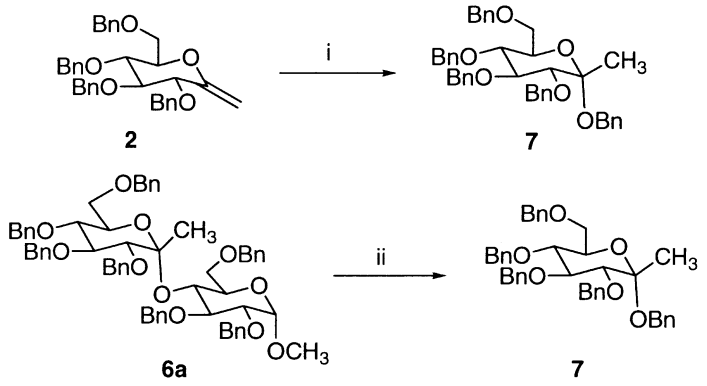
As shown in Table 1, the three 1-methylenesugars **2a**, **2b** and **2c** exhibited similar glycosidation reactivity as the glycosyl donors. The *O*-glycosylations of the glycosyl acceptor **3** with the methylenesugars **2** afforded the corresponding disaccharides **5** in more than 90% yields, though the glycosylation of the compound **4** gave the disaccharides **6** in 70–80% yields. The difference in the yield of the glycosylations might be attributed to the different reactivities and steric requiements between the primary 6-OH in the compound **3** and the secondary 4-OH in **4**.

Considering that the methylenesugars **2** with enol ether structure were sensitive to electrophilic reagents,[7–9,11,18] it was necessary to explore an efficient Lewis acid catalyst under the proper conditions for the *O*-glycosidation of **2**. The conditions for the glycosidation catalyzed by various

Table 2. The glycosidation of **2a** and **3** using various Lewis acids as a catalyst

Entry	Cat. (equiv.)	Solvent	Temp.	Time	**5** (%)	**7** (%)	**8** (%)	**2** recovered
1	TsOH (0.1)	CH_2Cl_2	r.t.	29 h	5.1		1.8	87.7%
2	TsOPy (0.1)	CH_2Cl_2	reflux	5 h	no reaction			
3	MsOH (0.1)	CH_2Cl_2	r.t.	24 h	27.9		9.9	57.5%
4	MsOH (0.3)	CH_2Cl_2	r.t.	3 h	61.8	14.6	10.5	
5	TfOH (0.05)	CH_2Cl_2	0°C	5 min	83.0	4.5	2.5	
6[a]	TfOH (0.05)	CH_2Cl_2	0°C	10 min	68.4	5.0	20.0	
7	TfOH (0.05)	CH_2Cl_2	−78°C	30 min	98.1			
8	TfOH (0.2)	Et_2O	−78°C	30 min	93.2			
9[a]	TfOH (0.05)	CH_2Cl_2	−78°C	30 min	89.8		3.8	
10	TfOH (0.05)	Toluene	0°C	20 min	79.7	8.5	6.1	
11[a]	TfOH (0.05)	Toluene	0°C	20 min	66.4	4.3	18.8	
12	$ZrCl_4$ (0.2)	CH_2Cl_2	reflux	12 h	no reaction			
13	$ZnCl_2$ (0.2)	CH_2Cl_2	r.t.	48 h	30.7		15.9	47%
14	$ZnCl_2$ (0.5)	CH_2Cl_2	reflux	10 h	70.4	4.8	8.7	
15	$AlCl_3$ (0.5)	CH_2Cl_2	r.t.	6 h	15.6	8.4	22.2	45%
16	$TiCl_4$ (0.1)	CH_2Cl_2	r.t.	24 h	3.5		5.2	87.1%
17	$SnCl_4$ (0.1)	CH_2Cl_2	r.t.	2 h	78.1	3.4	5.2	
18	$SnCl_4$ (0.2)	CH_2Cl_2	r.t.	15 min	77.2	5.7	4.2	
19[a]	$SnCl_4$ (0.2)	CH_2Cl_2	r.t.	15 min	58.8	12.1	17.1	
20	$SnCl_4$ (0.2)	Toluene	r.t.	15 min	75.1	11.8	6.0	
21	TMSOTf (0.1)	CH_2Cl_2	0°C	15 min	78.0	8.5	–	
22	BF_3 Et_2O (0.1)	CH_2Cl_2	0°C	1 h	76.1	10.9	trace	

[a] Without molecular sieves.



Scheme 3. *Reagents and conditions*: (i) TfOH (0.05 equiv.), MS 4A, CH_2Cl_2, r.t., 3 h; (ii) TfOH (0.25 equiv.), MS 4A, CH_2Cl_2, r.t., 2 h.

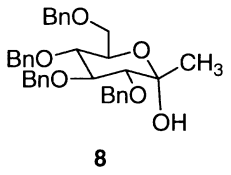


Figure 1.

Lewis acids were examined using **2a** and **3** and the results are summarized in Table 2. It was found that the glycosidation reaction in the presence of weak Lewis acids, such as $ZrCl_4$ (Entry 12) did not occur even at refluxing temperature in dichloromethane (CH_2Cl_2) for 12 h. However, when stronger Lewis acids were used, the reaction could proceed more rapidly accompanied with the increase of the by-products **7** (see Scheme 3) and **8** (Fig. 1). For example, in the presence of a catalytic amount of strong Lewis acid (TfOH, 0.05 equiv.), the reaction could finish within 5 min at 0°C in a good yield (83%) (Entry 5), indicating that TfOH was strong enough for the glycosidation of **2**. Under milder conditions at −78°C in the presence of 0.05 equiv. of TfOH, the reaction afforded the product **5a** in an excellent yield of 98% (Entry 7). Moreover, the use of molecular sieves was necessary to keep anhydrous reaction conditions, reducing the formation of the by-product **8** (Entry 6, 9, 11 and 19).

It was found that the by-product **7** could result from the decomposition of both the 1-methylenesugars **2** and the 1′-*C*-methyldisaccharides **5** and **6** (Scheme 3). The compound **7** was isolated in 12% yield when the 1-methylenesugars **2** was treated with 0.05 equiv. of TfOH at room temperature for 3 h. The TLC detection showed that under strong conditions the 1′-*C*-methyldisaccharides **5** and **6** decomposed to give the by-product **7**. For example, the compound **7** (~9%) was obtained from the 1′-*C*-methyldisaccharide **6a** under the treatment with 0.25 equiv. of TfOH at room temperature for 2 h.

The ^1H NMR, ^{13}C NMR and 2D-COSY experiments and mass spectral data of the disaccharides were in full accordance with their structures. Table 3 summarizes the NMR spectral data of 1′-*C*-methyl and two anomeric carbons (C-1, C-1′), and the C–H coupling constants $^3J_{H-2',Me-1'}$ between 2′-H and the carbon of 1′-*C*-methyl in the compounds **5**, **6**, **11a** and **18**. It was shown that the signals of the anomeric C-1′ connected with a methyl group appeared in more downfield than those of the C-1 linked with a proton. Moreover, the resonance of C-1′ in the compound **5** having a 1,6-*O*-glycosyl linkage shifted upfield in comparison with the corresponding compound **6** having a 1,4-*O*-glycosyl linkage. Similarly, in both ^1H NMR and ^{13}C NMR spectra, the chemical shifts of 1′-*C*-methyl group in the compound **5** were observed in more upfield than those in the corresponding compound **6**.

The three-bond carbon-proton coupling constants ($^3J_{H-3,C-1}$) which is related to the C_1–C_2–C_3-H dihedral angle have been applied to the conformational analysis of

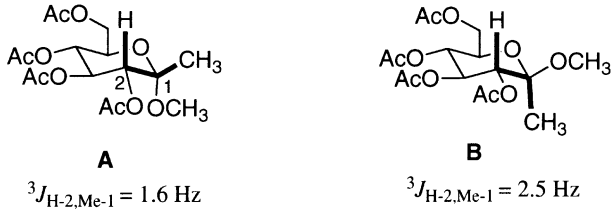
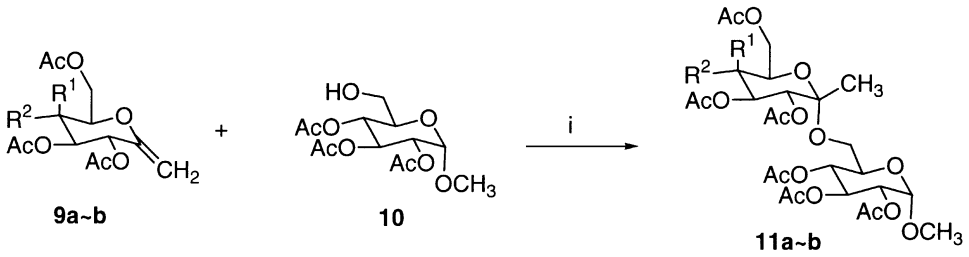


Figure 2.

Table 3. NMR data of 1′-CH_3 and the two anomeric carbons (C-1 and C-1′) and the three bond C–H coupling constants $^3J_{H-2',Me-1'}$

Compounds	C***H***$_3$(ppm)	***C***H$_3$ (ppm)	***C***-1′(ppm)	***C***-1(ppm)	$^3J_{H-2',Me-1'}$ (Hz)
5a	1.25	20.87	100.36	97.43	1.73
5b	1.22	20.97	100.81	97.71	1.90
5c	1.34	20.06	101.21	96.14	–
6a	1.29	21.48	102.15	96.39	1.60
6b	1.31	21.65	102.68	97.35	1.56
6c	1.55	20.13	103.19	97.65	–
11a	1.25	20.02	99.09	97.54	1.65
18	1.46	21.21	100.98	97.75	1.96



Scheme 4. *Reagents and conditions*: (i) TfOH (0.5 equiv.), MS 4A, CH_2Cl_2, 0°C, 1 h.

sugar molecules.[17] With this method, Hehre et al.[19] have assigned the α- and β-anomeric configurations of the methyl 2,3,4,6-tetra-*O*-acetyl-glucosides **A** and **B** (Fig. 2) by comparing their $^3J_{H-2,Me-1}$. The carbon-proton coupling constants $^3J_{H-2,Me-1}$ of the α-anomer **A** (1.6 Hz) and the β-anomer **B** (2.5 Hz) indicated a synclinal and an antiperiplanar arrangements between 2-H and 1-Me, respectively. Thus, the α-configurations of the disaccharides **5a**–**b** and **6a**–**b** were tentatively determined according to the relationship of the C–H coupling constants $^3J_{H-2',Me-1'}$ and the H–$C_{2'}$–$C_{1'}$–Me dihedral angle.[17,19] The $^3J_{H-2',Me-1'}$ of **5** and **6** observed as less than 2 Hz showed that the 1′-*C*-methyl and 2′-H arranged in synclinal configuration (Table 3).[19] In case where **5c** and **6c** were mannoside, the equatorial 2′-H might form similar dihedral angles (~60°) with α-1′-CH_3 and with β-1′-CH_3, and it was difficult to assign the anomeric configuration.[17]

Generally, the stereoselectivity of *O*-glycosylation is strongly dependent on the nature of the protecting groups, especially an acyl group attached to C-2 of glycosyl donor exhibits effective.[20] For example, an acyl group such as acetyl or benzoyl at C-2-*O* position usually directs the formation of 1,2-*trans* linked *O*-glycosides due to the neighboring group participation in the reaction. If a non-participating group such as benzyl or methyl attached at C-2-*O*, α-linked *O*-glycoside is predominantly formed owing to anomeric effects. In addition, the α-selectivity could be affected by the nature of solvent, namely, a solvent of low polarity is benefit to the α-selectivity. It should be noteworthy that the change of solvent did not affect the stereoselectivity in the glycosidations of 1-methylenesugars (Entry 7 and 8 in Table 2), although usual *O*-glycosylation gave a mixture of two anomers in the case of glycosyl donor protected by non-participating group in moderate polar solvent such as Et_2O, THF or 1,4-dioxane.[20]

The unusual evidence of the stereoselective *O*-glycosidation of the benzyl protected 1-methylenesugars prompted us to extend the reaction to the acetyl protected moiety. The β-anomers of 1′-*C*-methyl-*O*-disaccharides, in the cases of glucose and galactose, might be obtained if the neighboring group participation were present in the reaction. The *O*-glycosidation of 2,3,4,6-tetra-*O*-acetyl-1-methylenesugar derivatives **9a**–**b**[21] and methyl 2,3,4-tri-*O*-acetyl-α-D-glucoside **10**[22] were carried out in the presence of 0.5 equiv. of TfOH to form the anomerically single α-disaccharides **11a**–**b** in moderate yields as shown in Scheme 4 and Table 4.

The structures of the disaccharides **11** were confirmed by the analyses of ^{1}H NMR, ^{13}C NMR, 2D-COSY and mass spectra. Interestingly, the coupling constant $^3J_{H-2',Me-1'}$ (1.65 Hz) of the compound **11a** (Table 3) was similar to that of the α-anomer **A** of the model compound (1.6 Hz) in Fig. 2 and to that of the corresponding benzyl disaccharide **5a** (1.73 Hz) which was tentatively deduced to be an α-isomer. This result strongly supported an α-anomeric configuration in the compound **11a**, in other words, the 2-*O*-acetyl group of **11a** did not show any neighboring group participation in the glycosylation reaction.

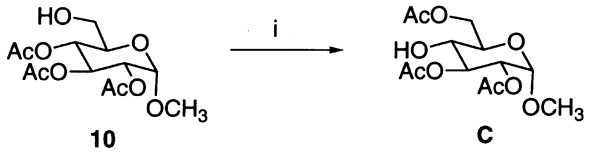
Table 4. The *O*-glycosidation of the acetyl 1-methylenesugars **9** and **10**

Product	R^1	R^2	Yield (%)
11a (Glc)	H	OAc	51.2
11b (Gal)	OAc	H	82.2

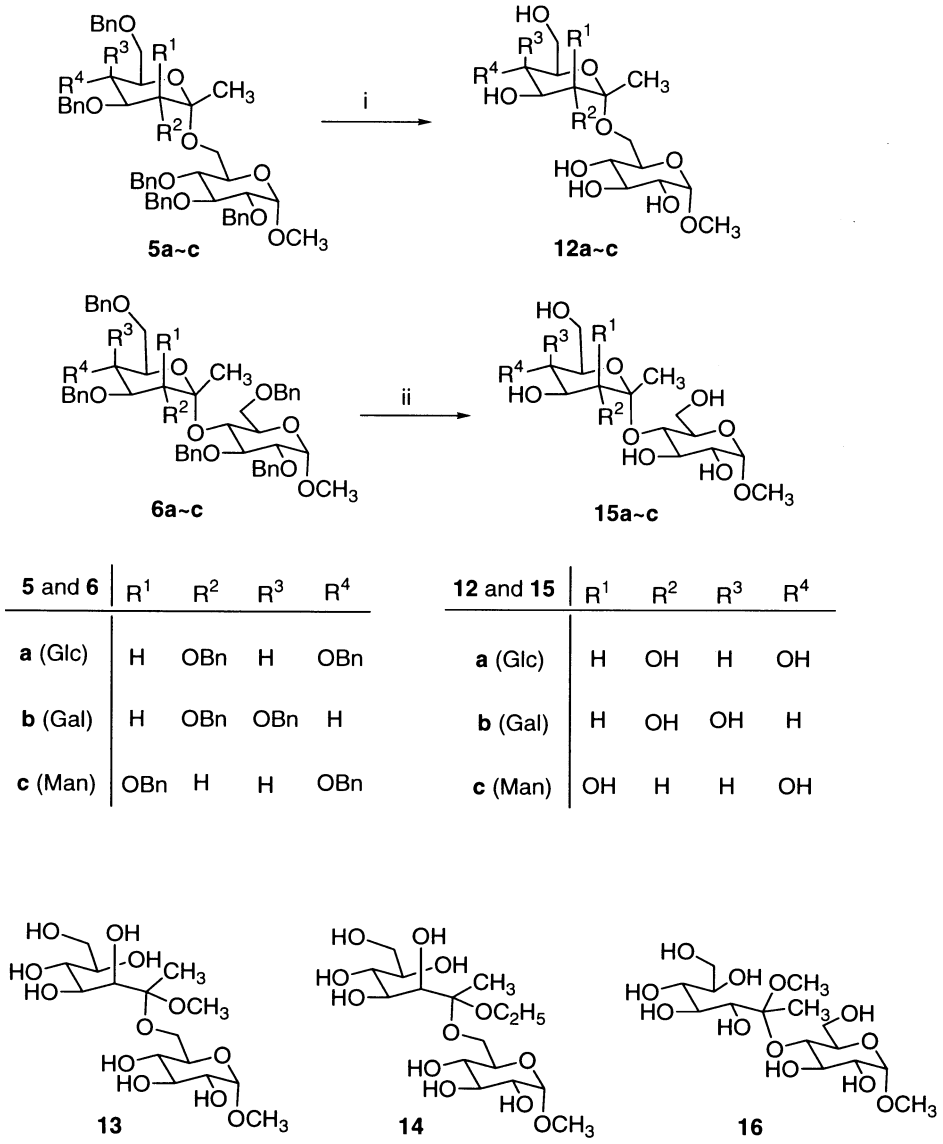
Comparing with the glycosidation of the benzyl 1-methylenesugars **2** (in Scheme 2), the *O*-glycosidations of the acetyl 1-methylenesugars **9** were carried out under stronger conditions (TfOH, 0.5 equiv., 0°C) (Scheme 4), indicating that the glycosidation reactivity of the acetyl 1-methylenesugars **9** was lower than that of the benzyl ones due to the electron withdrawing acetyl group. It was also found that under these strong conditions the *O*-glycosidation of **9** and **10** was accompanied by the acetyl group migration from 4- to 6-position in compound **10**. The acetyl migration was testified by treating **10** under the identical conditions as shown in Scheme 4 in the absence of the compound **9**, and the compound **C** was obtained (Scheme 5).

In order to further compare the anomeric configurations in the compounds **5** and **6** with that in the compound **11**, the disaccharides **5** and **6** were transformed to their acylated derivatives by firstly debenzylation and then acylation.

Compounds **5** and **6** were debenzylated by catalytic hydrogenation with palladium on charcoal [$Pd(OH)_2$/C, 20 wt%] as the catalyst (Scheme 6). The catalytic hydrogenation of the compounds **5a** and **5b** in methanol furnished the



Scheme 5. *Reagents and conditions*: (i) TfOH (0.5 equiv.), MS 4A, CH_2Cl_2, 0°C, 1 h.



5 and 6	R^1	R^2	R^3	R^4
a (Glc)	H	OBn	H	OBn
b (Gal)	H	OBn	OBn	H
c (Man)	OBn	H	H	OBn

12 and 15	R^1	R^2	R^3	R^4
a (Glc)	H	OH	H	OH
b (Gal)	H	OH	OH	H
c (Man)	OH	H	H	OH

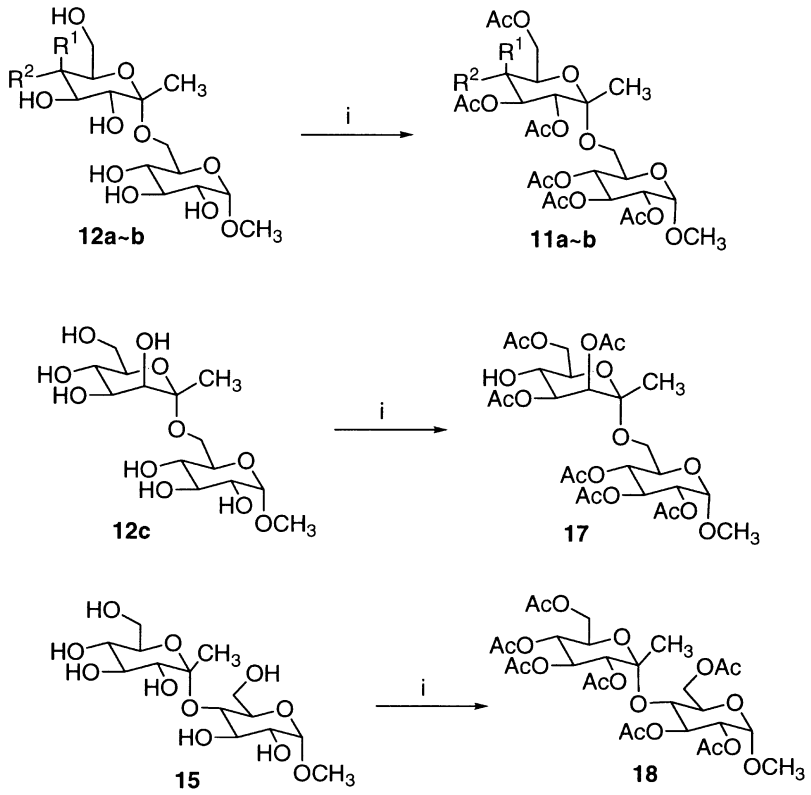
Scheme 6. *Reagents and conditions*: (i) $Pd(OH)_2/C$ (20 wt%), solvents, H_2, r.t.; (ii) $Pd(OH)_2/C$ (20 wt%), *t*-BuOH, H_2, r.t.

compounds **12a** and **12b** in quantitative yields, respectively (Entry 1 and 2 in Table 5). However, in the case of **5c**, in addition to the debenzylated product **12c** (74.7%), a concomitant sugar ring-opened product **13** (22.3%) was formed in methanol solution (Entry 3 in Table 5). The use of a bulky and low reactive alcohol as the solvent was found to be benefit to the formation of the desired products **12c** (Entry 3, 5 and 7 in Table 5). Thus, the debenzylation of **5c**

Table 5. The debenzylation of the disaccharides **5a–c** and **6a–c** by catalytic hydrogenation

Entry	Compd.		Conditions		Product (Yield)	Ring opened product[a] (Yield)
1	**5a**	MeOH	H_2 (1 atm)	12 h	**12a** (~100%)	
2	**5b**	MeOH	H_2 (1 atm)	12 h	**12b** (~100%)	
3	**5c**	MeOH	H_2 (1 atm)	24 h	**12c** (74.7%)	**13** (22.3%)
4	**5c**	EtOH	H_2 (20 atm)	10 h	**12c** (94.2%)	**14** (3.6%)
5	**5c**	^{i}PrOH	H_2 (1 atm)	16 h	**12c** (90.7%)	
6	**5c**	^{i}PrOH	H_2 (20 atm)	10 h	**12c** (95.6%)	
7	**5c**	^{t}BuOH	H_2 (1 atm)	48 h	**12c** (98.5%)	
8	**6a**	MeOH	H_2 (1 atm)	16 h	**15a** (80.1%)	**16** (16.9%)
9	**6a**	MeOH	H_2 (20 atm)	10 h	**15a** (89.2%)	**16** (9.5%)
10	**6a**	^{t}BuOH	H_2 (1 atm)	24 h	**15a** (91.4%)	
11	**6b**	^{t}BuOH	H_2 (1 atm)	24 h	**15b** (80.5%)	
12	**6c**	^{t}BuOH	H_2 (1 atm)	24 h	**15c** (40.0%)	

[a] The structures of **13**, **14** and **16** were determined by the analyses of their NMR spectra and MS (FAB), and were further confirmed by their acetylated derivatives whose ^{1}H NMR spectra showed one CH_3, two OCH_3 (in the case of **14**, one OCH_3 and one OC_2H_5) and eight CH_3CO groups.

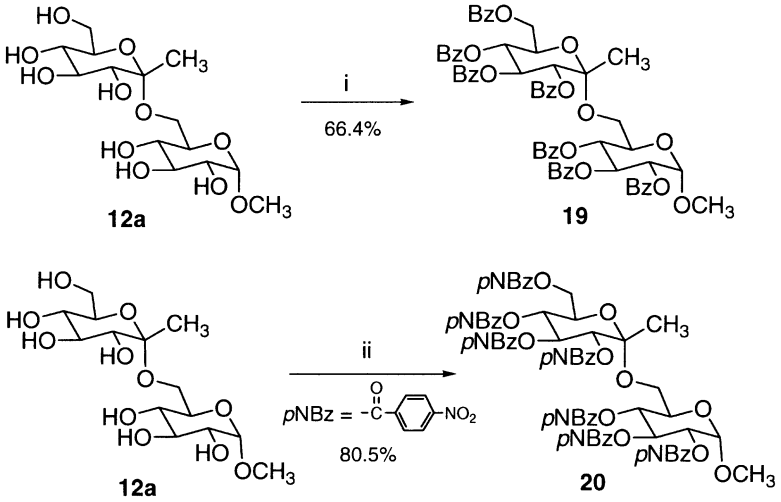


Scheme 7. *Reagents and conditions*: (i) Ac_2O, pyridine, r.t., overnight.

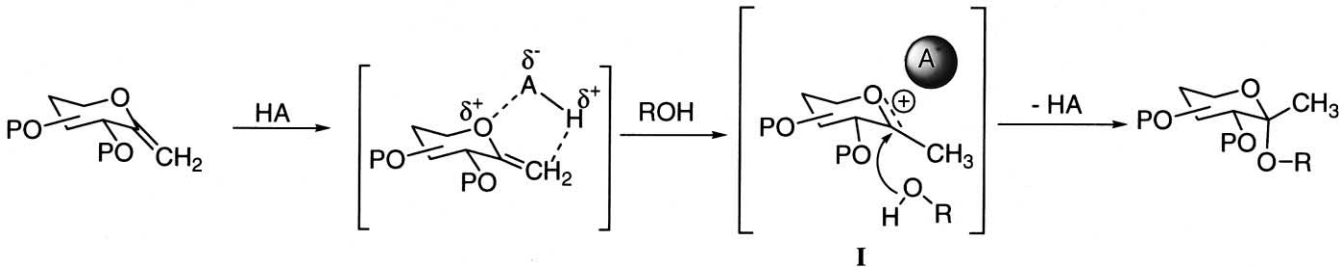
Table 6. The acetylation of the disaccharides **12** and **15**

	R^1	R^2	Yield (%)
11a (Glc)	H	OAc	97.4
11b (Gal)	OAc	H	96.4
17	–	–	75.3
18	–	–	66.3

afforded **12c** in almost quantitative yield (98.4%) in ^{t}BuOH solution (Entry 7 in Table 5). Furthermore, the increase of the hydrogen pressure with shortening reaction time could reduce the yield of the ring-opened by-products (Entry 4, 6 and 9 in Table 5). The compounds **6** with a 1,4-*O*-glycosyl linkage seemed more unstable to the catalytic hydrogenation condition than compounds **5**. While compound **6a** provided the debenzylated product **15a** in the yield of 91.4% in ^{t}BuOH solution (Entry 10), the compound **6c** gave the corresponding debenzylated product **15c** only in 40.0% yield (Entry 12). Moreover, when methanol was used as the solvent, only in the case of **6a** the debenzylated product **15a** was obtained accompanying by the ring-opened by-product **16** (Entry 8 and 9 in Table 5). The results indicated that 1′-*C*-methyldisaccharides having a ketoside were less stable than the normal aldosyl disaccharides, probably due to the steric hindrance caused by the replacement of a proton with a methyl in the anomeric carbon 1′-C. The



Scheme 8. *Reagents and conditions*: (i) BzCl, pyridine, r.t., 24 h; (ii) *p*NBzCl, pyridine, DMAP, r.t., 24 h, then 50°C, 12 h.



Scheme 9. P—protecting group, HA—Lewis acid.

disaccharides intend to release the strains in the 1′-anomeric carbon by opening the glycosidic sugar ring via a nucleophilic solvolysis in the presence of the hydrogenation catalyst.

The acetylations of the compounds **12a**–**b** were carried out by the treatment with acetic anhydride in pyridine to afford the corresponding acetylated derivatives which were proved to be identical to the compounds **11a**–**b** by the comparison of their ^{1}H NMR and ^{13}C NMR spectra. Under the same conditions the compounds **12c** and **15** were acetylated to provide **17** and **18**, respectively (Scheme 7 and Table 6). Similarly, the compound **12a** was benzoylated with benzoyl chloride in pyridine to give the compound **19**, and *p*-nitrobenzoylated with *p*-nitrobenzoyl chloride promoted by *N*,*N*-dimethylaminopyridine (DMAP) to afford the derivative **20** (Scheme 8).

Considering the α-stereoselective *O*-glycosidation of the 1-methylenesugar and the results described so far, the Lewis acid-catalyzed *O*-glycosidation of the 1-methylenesugar may likely proceeded in the following pathway as shown in Scheme 9.

With this proposed reaction process, it was reasonable to understand the α-stereoselectivity in the *O*-glycosidations of 1-methylenesugars and no neighboring group participation in the *O*-glycosidation of the acetyl protected methylenesugar **9.** The combination of the 1-methylenesugar (an electron rich enol ether) with catalytic Lewis acid (HA) led to the intermediate **I**, a stable tertiary oxycarbenium ion. The tertiary oxycarbenium ion would be further stabilized by the interaction with the counter ion (A^-) in the steric favorable β-approach, resulting in that the oxycarbenium ion might not need any more stabilization from the neighboring group participation of 2-*O*-acetyl group in **9**. Consequently, the alcohol component (ROH) attacked the anomeric carbon in the α-stereospecific way to form the α-*O*-glycosides exclusively. On the other hand, taking into account the steric hindrance and the anomeric effects caused by the methyl group in 1′-*C*-methyl-disaccharides,[23–25] the repulsion by dipole–dipole or electron pair–electron pair interaction caused β-isomer to be disfavored, preferably forming the thermodynamic stable α-isomer.

3. Conclusion

The stereoselective synthesis of 1′-*C*-methyl-α-disaccharides are accessible via the direct *O*-glycosidation of 1-methylenesugars under the mild conditions of 0.05 equiv. of TfOH at −78°C. With this reaction, a series of glucose, galactose, and mannose type of 1′-*C*-methyl-α-disaccharides having 1,6- and 1,4-*O*-glycosyl linkage were firstly prepared, and the neighbouring group participation was not observed in the *O*-glycosidation of acetyl protected 1-methylenesugars. The present process would be a facile method for synthesizing α-ketosyl saccharides. Further investigation of using 1-methylenesugars as the precursor for the synthesis of saccharides is under way in our group.

4. Experimental

4.1. General methods

Melting points were measured on a YANACO Micro Melting Point Apparatus and are uncorrected. IR spectra were recorded on a Jasco FT/IR-800 Fourier-transform infrared spectrometer. ^{1}H NMR, ^{13}C NMR and COSY spectra were measured on a JEOL JNM-GSX400 (400 MHz) pulse Fourier-transform NMR spectrometer in $CDCl_3$ or CD_3OD solutions using tetramethylsilane (Me_4Si) as an internal standard, and the three bond coupling constants $^{3}J_{C,H}$ were measured on a JEOL ECP 600 (600 MHz) NMR spectrometer in $CDCl_3$ solution with an internal standard of tetramethylsilane (Me_4Si). Mass spectra (MS) and high resolution mass spectra (HRMS) were carried out on a JEOL JMS-SX102A mass spectrometer using FAB (Fast Atomic Bombardment). Optical rotations were measured with a Jasco DIP-370 digital polarimeter. Thin-layer chromatography (TLC) was performed on precoated plates (Merck TLC aluminum sheets silica 60 F_{254}) with detection by UV light or with phosphomolybdic acid in EtOH/H_2O followed by heating. Column chromatography was performed using SiO_2 (Wakogel C-200, Wako).

4.1.1. General procedure 1: synthesis of the 1′-*C*-methyl-α-*O*-disaccharides 5 and 6. A solution of **2** (0.1 mmol), **3** (or **4**) (0.11 mmol) and molecular sieves 4A (MS 4A) (100 mg) in dry CH_2Cl_2 (2 mL) was stirred under argon atmosphere at room temperature for 15 min. The solution was cooled to −78°C, and 0.5 μL (0.05 equiv.) of TfOH was added. The reaction mixture was stirred at −78°C for 1 h, then warmed up to −20°C gradually. The reaction was monitored by TLC (Et_2O: Hexane=1:1) and quenched with one drop of triethylamine (Et_3N). After the removal of the solvent, the residue was applied on a silica gel column chromatography using Et_2O: hexane (1:2, then 1:1.5) as the eluent to afford the products **5** (or **6**). The results are listed in Table 1.

4.1.2. General procedure 2: the exploration of the reaction conditions of synthesizing 1′-*C*-methyl-α-*O*-disaccharides using 2a and 3. A mixture of **2a** (53.6 mg, 0.1 mmol), **3** (51.1 mg, 0.11 mmol), MS 4A (100 mg) and the dry solvents (2 mL) was stirred under argon atmosphere at room temperature for 15 min. The mixture was cooled to the certain temperature, and a given amount of catalyst was added in one portion. The reaction mixture was stirred at same temperature for certain time, and worked up following the **General Procedure 1**. The reaction results are summarized in Table 2.

4.1.3. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-benzyl-α-D-glucopyranosyl)-(*1′→6*)-2,3,4-tri-*O*-benzyl-α-D-glucoside (5a). Following the **General procedure 1**, the compound **5a** (98.2 mg, 98.1%) was prepared from 53.6 mg (0.1 mmol) of **2a** and 51.1 mg (0.11 mmol) of **3**. Colorless syrup; $[\alpha]_D^{23}$=146.9° (*c* 1.0, $CHCl_3$); IR (neat): 3063.33, 3030.54, 2928.30, 1604.97, 1587.61, 1496.94, 1454.50, 1359.98, 1209.51, 1072.55, 1028.18, 910.51, 736.90, 698.32 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.25 (s, 3H, CH_3), 3.26 (t, 1H, *J*=9.16 Hz, 4-H), 3.30 (d, 1H, *J*=9.76 Hz, 2′-H), 3.35 (s, 3H, CH_3O), 3.36–3.39 (m, 1H, 6-H), 3.48 (dd, 1H, *J*=9.76 Hz, *J*=3.66 Hz, 2-H), 3.56 (dd, 1H, *J*=10.99 Hz, *J*=1.83 Hz, 6′-H), 3.58–3.64 (m, 2H, 4′-H and 6′-H, overlapped), 3.69 (dd, 1H, *J*=9.95 Hz, *J*=0.8 Hz, 6-H), 3.84–3.88 (m, 1H, 5-H), 3.89–91 (m, 1H, 5′-H), 3.97 (t, 1H, *J*=9.46 Hz, 3-H), 4.04 (t, 1H, *J*=9.47 Hz, 3′-H), 4.44 (d, 1H, *J*=12.21 Hz, CH_2Ph), 4.50 (d, 1H, *J*=11.29 Hz, CH_2Ph), 4.55–4.59 (m, 3H, 1-H and CH_2Ph, overlapped), 4.65 (d, 1H, *J*=11.90 Hz, CH_2Ph), 4.66 (d, 1H, *J*=11.29 Hz, CH_2Ph), 4.73–4.97 (m, 8H, CH_2Ph), 7.12–7.14 (m, 2H, ArH), 7.24–7.35 (m, 33H, ArH); ^{13}C NMR ($CDCl_3$): δ 20.87 (1′-CH_3), 54.98 (OCH_3), 60.77 (6-C), 68.87 (6′-C), 69.96 (5′-C), 71.13 (5-C), 73.13 (CH_2Ph), 73.16 (CH_2Ph), 74.36 (CH_2Ph), 74.76 (CH_2Ph), 75.13 (CH_2Ph), 75.26 (CH_2Ph), 75.76 (CH_2Ph), 78.57 (4′-C), 78.64 (4-C), 80.11 (2-C), 82.37 (3-C), 82.93 (3′-C), 84.12 (2′-C), 97.43 (1-C), 100.36 (1′-C), 127.28 (Ph), 127.30 (Ph), 127.43 (Ph), 127.46 (Ph), 127.51 (Ph), 127.55 (Ph), 127.57 (Ph), 127.68 (Ph), 127.77 (Ph), 127.80 (Ph), 127.83 (Ph), 127.94 (Ph), 127.95 (Ph), 127.98 (Ph), 128.23 (Ph), 128.09 (Ph), 128.16 (Ph), 128.21 (Ph), 128.22 (Ph), 128.25 (Ph), 128.28 (Ph), 128.31 (Ph), 128.37 (Ph), 138.18 (Ph), 138.28 (Ph), 138.35 (Ph), 138.40 (Ph), 138.64 (Ph), 138.72 (Ph), 138.78 (Ph); HRMS (FAB): cacld for $C_{63}H_{68}O_{11}Na$ 1023.4660, found 1023.4669.

4.1.4. Methyl *O*-(1′-*C*-methyl-2′,3′,4,′6′-tetra-*O*-benzyl-α-D-galactopyranosyl)-(*1′→6*)-2,3,4-tri-*O*-benzyl-α-D-glucoside (5b). Following the **General procedure 1**, the compound **5b** (94.0 mg, 93.9%) was prepared from 53.6 mg (0.1 mmol) of **2b** and 51.1 mg (0.11 mmol) of **3**. Colorless syrup; $[\alpha]_D^{23}$=+51.3° (*c* 1.0, $CHCl_3$); IR (neat): 3063.33, 3030.54, 2918.65, 1604.97, 1585.68, 1496.94, 1454.50, 1361.91, 1209.45, 1053.26, 912.44, 734.97, 698.32 cm^{-1}; ^1H NMR ($CDCl_3$):δ 1.22 (s, 3H, CH_3), 3.19 (s, 3H, CH_3O), 3.21 (t, 1H, *J*=9.46 Hz, 4-H), 3.33 (dd, 1H, *J*=10.38 Hz, *J*=8.24 Hz, 6-H), 3.43–3.55 (m, 3H, 2-H and two 6′-H, overlapped), 3.69 (dd, 1H, *J*=10.37 Hz, *J*=1.52 Hz, 6-H), 3.81–3.85 (m, 1H, 5-H), 3.83 (d, 1H, *J*=10.07 Hz, 2′-H), 3.93–4.01 (m, 4H, 3-H, 3′-H, 4′-H and 5′-H, overlapped), 4.37 (d, 1H, *J*=12.21 Hz, CH_2Ph), 4.43 (d, 1H, *J*=11.60 Hz, CH_2Ph), 4.50 (d, 1H, *J*=10.99 Hz, CH_2Ph), 4.52 (d, 1H, *J*=3.05 Hz, 1-H), 4.59–4.84 (m, 8H, CH_2Ph), 4.92–4.97 (m, 3H, CH_2Ph), 7.21–7.34 (m, 35H, ArH); ^{13}C NMR ($CDCl_3$): δ 20.97 (CH_3), 54.66 (CH_3O), 60.86 (6-C), 68.90 (6′-C), 69.76 (5′-C), 69.90 (5-C), 72.17 (CH_2Ph), 73.01 (CH_2Ph), 73.11 (CH_2Ph), 74.47 (CH_2Ph), 74.81 (3-C), 74.99 (CH_2Ph), 75.07 (CH_2Ph), 75.71 (CH_2Ph), 78.89 (4-C), 79.85 (4′-C or 3′-C), 80.05 (2-C), 80.24 (2′-C), 82.25 (3′-C or 4′-C), 97.35 (1-C), 100.81 (1′-C), 127.29 (Ph), 127.40 (Ph), 127.42 (Ph), 127.45 (Ph), 127.50 (Ph), 127.53 (Ph), 127.55 (Ph), 127.61 (Ph), 127.71 (Ph), 127.77 (Ph), 127.91 (Ph), 127.93 (Ph), 128.07 (Ph), 128.12 (Ph), 128.32 (Ph), 128.37 (Ph), 128.40 (Ph), 138.17 (Ph), 138.21 (Ph), 138.27 (Ph), 138.57 (Ph), 138.63 (Ph), 138.76 (Ph), 138.93 (Ph); HRMS (FAB): cacld for $C_{63}H_{68}O_{11}Na$ 1023.4660, found 1023.4667.

4.1.5. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-benzyl-α-D-mannopyranosyl)-(*1′→6*)-2,3,4-tri-*O*-benzyl-α-D-glucoside (5c). Following the **General procedure 1**, the compound **5c** (90.5 mg, 90.4%) was prepared from 53.6 mg (0.1 mmol) of **2b** and 51.1 mg (0.11 mmol) of **3**. Colorless syrup; $[\alpha]_D^{23}$=+43.1° (*c* 1.0, $CHCl_3$); IR (neat): 3063.33, 3030.54, 2909.01, 1604.97, 1587.61, 1496.94, 1454.50, 1365.77, 1208.70, 1095.70, 910.50, 734.97, 698.32 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.34 (s, 3H, CH_3), 3.29 (s, 3H, OCH_3), 3.29 (t, 1H, *J*=9.46 Hz, 4-H), 3.48 (d, 1H, *J*=9.77 Hz, 6-H), 3.49 (dd, 1H, *J*=9.77 Hz, *J*=2.74 Hz, 2-H), 3.56 (dd, *J*=10.29 Hz, *J*=2.13 Hz, 6′-H), 3.61 (dd, 1H, *J*=10.99 Hz, *J*=4.88 Hz, 6′-H), 3.65 (dd, 1H, *J*=10.37 Hz, *J*=1.53 Hz, 6-H), 3.66–3.75 (m, 2H, 5-H and 5′-H, overlapped with 2′-H), 3.71 (d, 1H, *J*=2.75 Hz, 2′-H, overlapped with 5-H and 5′-H), 3.92 (t, 1H, *J*=9.77 Hz, 4′-H), 3.97 (t, 1H, *J*=9.16 Hz, 3-H), 4.08 (dd, 1H, *J*=9.15 Hz, *J*=2.75 Hz, 3′-H), 4.60 (d, 1H, *J*=3.67 Hz, 1-H), 4.40–5.00 (m, 14 H, CH_2Ph), 7.12–7.38 (m, 35H, ArH); ^{13}C NMR ($CDCl_3$):δ 20.06 (CH_3), 54.87 (CH_3O), 59.99 (6-C), 69.35 (6′-C), 69.73 (5-C), 72.03 (CH_2Ph), 72.79 (5′-C), 72.98 (CH_2Ph), 73.08 (CH_2Ph), 74.56 (3-C), 74.67 (2C, CH_2Ph), 74.77 (CH_2Ph), 75.70 (CH_2Ph), 78.04 (4-C), 78.25 (2′-C), 79.93 (2-C), 80.92 (3′-C), 82.35 (4′-C), 97.54 (1-C), 101.21 (1′-C), 127.20 (Ph), 127.36 (Ph), 127.47 (Ph), 127.49 (Ph), 127.51 (Ph), 127.56 (Ph), 127.59 (Ph), 127.60 (Ph), 127.82 (Ph), 127.88 (Ph), 127.94 (Ph), 127.95 (Ph), 128.06 (Ph), 128.11 (Ph), 128.29 (Ph), 128.33 (Ph), 128.40 (Ph), 138.12 (Ph), 138.21 (Ph), 138.50 (Ph), 138.66 (Ph), 138.71 (Ph), 138.85 (Ph); HRMS (FAB): cacld for $C_{63}H_{68}O_{11}Na$ 1023.4660, found 1023.4683.

4.1.6. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-benzyl-α-D-glucopyranosyl)-(*1′→4*)-2,3,6-tri-*O*-benzyl-α-D-glucoside (6a). Following the **General procedure 1**, the compound **6a** (80.2 mg, 80.1%) was prepared from 53.6 mg (0.1 mmol) of **2a** and 51.1 mg (0.11 mmol) of **4**. Colorless syrup; $[\alpha]_D^{23}$=+18.2° (*c* 1.0, $CHCl_3$); IR (neat): 3063.33, 3030.54, 2903.22, 1604.97, 1587.61, 1496.94, 1454.50, 1361.91,1207.59, 1049.40, 912.44, 734.97, 698.32 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.29 (s, 3H, CH_3), 3.22 (d, 1H, *J*=9.76 Hz, 2′-H), 3.37 (s, 3H, CH_3O), 3.47 (dd, 1H, *J*=9.77 Hz, *J*=3.66 Hz, 2-H), 3.51 (dd, 1H, *J*=10.68 Hz, *J*=1.83 Hz, 6-H), 3.61 (t, 1H, *J*=9.16 Hz, 4′-H), 3.63–3.67 (m, 3H, 5-H, 6-H and 6′-H, overlapped with 4′-H),

3.84 (t, 1H, *J*=9.76 Hz, 3-H), 3.83–3.87 (m, 2H, 5′-H and 6′-H, overlapped with 3-H), 4.02 (t, 1H, *J*=9.46 Hz, 4-H), 4.16 (t, 1H, *J*=9.46 Hz, 3′-H), 4.36–4.55 (m, 8H, CH_2Ph), 4.57 (d, 1H, *J*=3.35 Hz, 1-H), 4.64 (d, 1H, *J*=12.20 Hz, CH_2Ph), 4.76–4.92 (m, 4H, CH_2Ph), 5.18 (d, 1H, *J*=11.60 Hz, CH_2Ph), 7.02–7.31 (m, 35H, ArH); ^{13}C NMR ($CDCl_3$): δ 21.48 (CH_3), 55.31 (CH_3O), 68.96 (6-C), 69.42 (6′-C), 70.79 (5-C), 71.32 (5′-C), 73.13 (CH_2Ph), 73.15 (CH_2Ph), 73.24 (4-C), 73.42 (CH_2Ph), 74.91 (CH_2Ph), 75.21 (CH_2Ph), 75.33 (CH_2Ph), 75.40 (CH_2Ph), 78.88 (4′-C), 79.46 (2-C), 81.20 (3-C), 82.64 (3′-C), 83.51 (2′-C), 97.71 (1-C), 102.15 (1′-C), 126.62 (Ph), 126.82 (Ph), 127.28 (Ph), 127.40 (Ph), 127.54 (Ph), 127.57 (Ph), 127.64 (Ph), 127.78 (Ph), 127.82 (Ph), 127.87 (Ph), 127.94 (Ph), 127.98 (Ph), 128.02 (Ph), 128.05 (Ph), 128.07 (Ph), 128.13 (Ph), 128.17 (Ph), 128.22 (Ph), 128.28 (Ph), 128.33 (Ph), 128.37 (Ph), 128.43 (Ph), 129.05 (Ph), 137.88 (Ph), 138.06 (Ph), 138.14 (Ph), 138.40 (Ph), 138.46 (Ph), 138.66 (Ph), 140.23 (Ph); HRMS (FAB): cacld for $C_{63}H_{68}O_{11}Na$ 1023.4660, found 1023.4673.

4.1.7. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-benzyl-α-D-galactopyranosyl)-(*1′→4*)-2,3,6-tri-*O*-benzyl-α-D-glucoside (6b). Following the **General procedure 1**, the compound **6b** (71.5 mg, 71.4%) was prepared from 53.6 mg (0.1 mmol) of **2b** and 51.1 mg (0.11 mmol) of **4**. Colorless syrup; $[\alpha]_D^{23}=+24.3°$ (*c* 1.0, $CHCl_3$); IR (neat): 3063.33, 3030.54,2912.87, 1604.97, 1585.68, 1496.94, 1454.50, 1361.91, 1194.08, 1145.55, 916.30, 733.04, 696.39 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.31 (s, 3H, CH_3), 3.37 (s, 3H, OCH_3), 3.39 (dd, 1H, *J*=8.85 Hz, *J*=5.49 Hz, 6′-H), 3.48 (dd, 1H, *J*=6.71 Hz, *J*=3.36 Hz, 2-H), 3.54 (d, 1H, *J*=8.24 Hz, 6′-H), 3.57–3.64 (m, 2H, 6-H and 5-H), 3.77–3.85 (m, 3H, 3-H, 2′-H and 6-H), 3.97–4.00 (m, 2H, 4′-H and 5′-H), 4.04 (t, 1H, *J*=8.85 Hz, 4-H), 4.09 (dd, 1H, *J*=10.38 Hz, *J*=1.83 Hz, 3′-H), 4.36–4.75 (m, 12H, CH_2Ph, overlapped with 1-H), 4.57 (d, 1H, *J*=2.75 Hz, 1-H, overlapped with CH_2Ph), 4.94 (d, 1H, *J*=11.29 Hz, CH_2Ph), 5.17 (d, 1H, *J*=11.29 Hz, CH_2Ph), 7.05–7.36 (m, 35H, ArH); ^{13}C NMR ($CDCl_3$): δ 21.65 (CH_3), 55.28 (OCH_3), 68.90 (6′-C), 69.39 (6-C), 69.87 (5′-C), 70.86 (5-C), 72.30 (CH_2Ph), 72.65 (4-C), 73.08 (CH_2Ph), 73.18 (CH_2Ph), 73.41 (CH_2Ph), 74.58 (CH_2Ph), 74.68 (CH_2Ph), 75.14 (two C, 4′-C and CH_2Ph), 79.39 (2′-C), 79.48 (two C, 2-C and 3′-C), 81.17 (3-C), 97.65 (1-C), 102.68 (1′-C), 126.56 (Ph), 126.74 (Ph), 126.78 (Ph), 127.24 (Ph), 127.31 (Ph), 127.39 (Ph), 127.48 (Ph), 127.50 (Ph), 127.54 (Ph), 127.59 (Ph), 127.67 (Ph), 127.76 (Ph), 127.81 (Ph), 127.85 (Ph), 127.89 (Ph), 127.95 (Ph), 127.99 (Ph), 128.03 (Ph), 128.07 (Ph), 128.10 (Ph), 128.21 (Ph), 128.29 (Ph), 128.36 (Ph), 128.46 (Ph), 129.23 (Ph), 137.84 (Ph), 138.03 (Ph), 138.30 (Ph), 138.36 (Ph), 138.63 (Ph), 138.90 (Ph), 140.20 (Ph); HRMS (FAB): cacld for $C_{63}H_{68}O_{11}Na$ 1023.4660, found 1023.4666.

4.1.8. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-benzyl-α-D-mannopyranosyl)-(*1′→4*)-2,3,6-tri-*O*-benzyl-α-D-glucoside (6c). Following the **General procedure 1**, the compound **6c** (75.3 mg, 75.2%) was prepared from 53.6 mg (0.1 mmol) of **2c** and 51.1 mg (0.11 mmol) of **4**. Colorless syrup; $[\alpha]_D^{23}=+14.1°$ (*c* 1.0, $CHCl_3$); IR (neat): 3063.33, 3030.54, 2907.08, 2866.57, 1604.97, 1585.68, 1496.94, 1454.50, 1363.84, 1096.10, 1051.33, 912.44, 734.97 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.55 (s, 3H, CH_3), 3.38 (s, 3H, CH_3O), 3.51 (d, 1H, *J*=2.74 Hz, 2′-H), 3.54 (dd, 1H, *J*=9.46 Hz, *J*=3.05 Hz, 2-H), 3.61–3.71 (m, 4H, 5-H, one 6-H and two 6′-H), 3.71 (t, 1H, *J*=9.15 Hz, 3-H, overlapped with 6′-H), 3.84–3.94 (m, 3H, 6-H, 4′-H and 5′-H, overlapped), 4.10 (d, 1H, *J*=11.29 Hz, CH_2Ph), 4.15 (t, 1H, *J*=9.15 Hz, 4-H, overlapped with 3′-H), 4.17 (dd, 1H, *J*=8.85 Hz, *J*=2.44 Hz, 3′-H, overlapped with 4-H), 4.33 (d, 1H, *J*=11.90 Hz, CH_2Ph), 4.45–4.63 (m, 9H, CH_2Ph), 2.62 (d, 1H, *J*=3.05 Hz, 1-H, overlapped with CH_2Ph), 4.70 (d, 1H, *J*=11.91 Hz, CH_2Ph), 4.85 (d, 1H, *J*=10.38 Hz, CH_2Ph), 5.12 (d, 1H, *J*=11.60 Hz, CH_2Ph), 7.17–7.33 (m, 35H, ArH); ^{13}C NMR ($CDCl_3$): δ 20.13 (CH_3), 55.16 (OCH_3), 68.67 (6-C), 69.86 (6′-C), 70.34 (5-C), 71.97 (4-C), 72.06 (CH_2Ph), 72.76 (5′-C), 73.06 (CH_2Ph), 73.13 (CH_2Ph), 73.26 (CH_2Ph), 74.75 (CH_2Ph), 74.94 (4′-C), 75.18 (CH_2Ph), 75.56 (CH_2Ph), 79.92 (2-C or 2′-C), 79.97 (2′-C or 2-C), 81.09 (3′-C), 81.74 (3-C), 97.74 (1-C), 103.19 (1′-C), 126.52 (Ph), 127.12 (Ph), 127.26 (Ph), 127.31 (Ph), 127.35 (Ph), 127.45 (Ph), 127.53 (Ph), 127.60 (Ph), 127.69 (Ph), 127.79 (Ph), 127.85 (Ph), 128.02 (Ph), 128.08 (Ph), 128.11 (Ph), 128.17 (Ph), 128.20 (Ph), 128.32 (Ph), 128.37 (Ph), 138.02 (Ph), 138.33 (Ph), 138.39 (Ph), 138.45 (Ph), 138.52 (Ph), 138.91 (Ph), 139.20 (Ph); HRMS (FAB): cacld for $C_{63}H_{68}O_{11}Na$ 1023.4660, found 1023.4659.

4.1.9. Decomposition of 2,3,4,6-tetra-*O*-benzyl-1-methyl-enesugar (2a) in the presence of TfOH. To the solution of **2a** (54 mg, 0.1 mmol) and MS 4A (100 mg) in 2 mL of dry CH_2Cl_2 was added 0.5 μL (0.05 equiv.) of TfOH at room temperature. The solution was stirred for 3 h and then one drop of Et_3N was added to neutralize the acid. The mixture was concentrated and the residue was applied to a silica gel column chromatography (Et_2O: Hexane=1:2) to give the compound **7** (8.0 mg, 12.0%).

4.1.10. Decomposition of 6a by TfOH. To a solution of **6a** (100 mg, 0.1 mmol) and MS 4A (100 mg) in 2 mL of dry CH_2Cl_2 was added 2.3 μL (0.25 equiv.) of TfOH at room temperature. The solution was stirred for 2 h, neutralized by Et_3N and concentrated in vacuum. The residue was submitted to a silica gel column chromatography eluting with Et_2O: Hexane (1:2, then 1:1) to afford the compounds **7** (5.8 mg, 9.0%) and **4** (4.5 mg, 8.4%).

4.1.11. Compound 7 (benzyl 2,3,4,6-tetra-*O*-benzyl-1-*C*-methyl-α-D-glucoside). Colorless syrup; $[\alpha]_D=+34.20°$ (*c* 1.0, $CHCl_3$); IR (neat): 3063.33, 3030.54, 2921.10, 2870.58,, 1604.35, 1585.68, 1496.94, 1454.50, 1363.84, 1090.80, 1048.39, 973.44, 736.60 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.39 (s, 3H, CH_3), 3.39 (d, 1H, *J*=9.36 Hz, 2-H), 3.61–3.76 (m, 4H, two 6-H, 5-H and 3-H or 4-H), 4.13 (t, 1H, *J*=9.31 Hz, 4-H or 3-H), 4.50–6.62 (m, 5H, CH_2Ph), 4.72 (d, 1H, *J*=11.60 Hz, CH_2Ph), 4.81–4.97 (m, 4H, CH_2Ph), 7.13–7.16 (m, 2H, ArH), 7.22–7.37 (m, 23H, ArH); ^{13}C NMR ($CDCl_3$): δ 21.32 (CH_3), 62.59 (6-C), 68.84 (5-C), 71.71 (CH_2Ph), 73.37 (CH_2Ph), 74.95 (CH_2Ph), 75.35 (CH_2Ph), 75.45 (CH_2Ph), 78.77 (4-C), 83.09 (3-C), 84.41 (2-C), 100.89 (1-C), 127.15 (Ph), 127.17 (Ph), 127.49 (Ph), 127.56 (Ph), 127.64 (Ph), 127.76 (Ph), 127.91 (Ph), 128.19 (Ph), 128.24 (Ph), 128.28 (Ph), 128.32 (Ph), 128.34 (Ph), 128.36 (Ph),

138.27 (Ph), 138.44 (Ph), 138.63 (Ph), 138.83 (Ph); HRMS (FAB) calcd for $C_{42}H_{44}O_6Na$ 667.3036, found: 667.3041.

4.1.12. Compound 8 (2,3,4,6-tetra-*O*-benzyl-1-*C*-methyl-α-D-glucose). White solid, mp: 92–93°C; $[\alpha]_D$=+24.70° (*c* 1.0, $CHCl_3$); IR (KBr): 3464.57, 3063.33, 3030.54, 2932.16, 2903.22, 2868.50, 1603.04, 1585.68, 1496.94, 1454.50, 1404.35, 1363.84, 1199.87, 1153.57, 1086.06, 1043.62, 1028.18, 976.10, 871.93, 850.71, 760.05, 738.83, 698.32 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.39 (s, 3H, CH_3), 2.86 (s, 1H, OH), 3.35 (d, 1H, *J*=9.46 Hz, 2-H), 3.64 (t, 1H, *J*=9.77 Hz, 4-H), 3.64–3.66 (d, 1H, 6-H, overlapped with 4-H), 3.70 (dd, 1H, *J*=10.68 Hz, *J*=4.27 Hz, 6-H), 3.98 (t, 1H, *J*=9.15 Hz, 3-H), 3.99–4.05 (m, 1H, 5-H), 4.50 (d, 1H, *J*=12.21 Hz, CH_2Ph), 4.55 (d, 1H, *J*=10.99 Hz, CH_2Ph), 4.59 (d, 1H, *J*=12.21 Hz, CH_2Ph), 4.69 (d, 1H, *J*=10.99 Hz, CH_2Ph), 4.82 (d, 1H, *J*=10.98 Hz, CH_2Ph), 4.88 (s, 2H, CH_2Ph), 4.92 (d, 1H, *J*=11.29 Hz, CH_2Ph), 7.14–7.16 (m, 2H, ArH), 7.24–7.33 (m, 18H, ArH); ^{13}C NMR ($CDCl_3$): δ 26.57 (CH_3), 68.83 (6-C), 71.53 (5-C), 73.41 (CH_2Ph), 74.82 (CH_2Ph), 75.56 (CH_2Ph), 75.66 (CH_2Ph), 78.45 (4-C), 83.19 (3-C), 83.62 (2-C), 97.35 (1-C), 127.57 (Ph), 127.63 (Ph), 127.72 (Ph), 127.80 (Ph), 127.82 (Ph), 127.89 (Ph), 127.95 (Ph), 128.27 (Ph), 128.32 (Ph), 128.33 (Ph), 128.40 (Ph), 137.88 (Ph), 138.22 (Ph), 138.26 (Ph), 138.65 (Ph); HRMS (FAB) calcd for $C_{35}H_{38}O_6Na$ 577.2566, found: 577.2564.

4.1.13. General procedure 3: synthesis of the 1′-*C*-methyl-α-*O*-disaccharides 11. A mixture of **9** (0.1 mmol), **10** (0.15 mmol), MS 4A (100 mg) and dry CH_2Cl_2 (2 mL) was stirred under argon atmosphere at room temperature for 15 min. The mixture was cooled to 0°C, and 4.5 μL (0.5 equiv.) of TfOH was added. The reaction mixture was stirred at 0°C for 1 h. The reaction was monitored by TLC (AcOEt: Hexane=2:1) and quenched with triethylamine. After removing the solvent, the residue was applied on a silica gel column chromatography using AcOEt: hexane (1:1, then 1.5:1) as the eluent to afford the products **11**.

4.1.14. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-acetyl-α-D-glucopyranosyl)-(*1′→6*)-2,3,4-tri-*O*-acetyl-α-D-glucoside (11a). 34 mg (0.1 mmol) of **9a** and 48 mg (0.15 mmol) of **10** were treated as described in the **General procedure 3** to afford 34 mg of the disaccharide **11a** (51.2%). Colorlessly sticky syrup; $[\alpha]_D^{25}$=+118.67° (*c* 1.67, $CHCl_3$); IR (neat): 2950.66, 1748.35, 1437.14, 1373.48, 1220.65, 1135.82, 1052.96, 958.74, 900.89 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.25 (s, 3H, CH_3), 1.89 (s, 3H, CH_3CO), 1.93 (s, 3H, CH_3CO), 1.95 (s, 3H, CH_3CO), 1.99 (s, 3H, CH_3CO), 2.01 (s, 3H, CH_3CO), 2.02 (s, 3H, CH_3CO), 2.04 (s, 3H, CH_3CO), 3.33–3.38 (m, 1H, 6-H), 3.40–3.50 (m, 1H, 6-H), 3.44 (s, 3H, OCH_3), 3.99–4.02 (m, 1H, 5-H), 4.04–4.07 (m, 2H, two 6′-H), 4.17–4.22 (m, 1H, 5′-H), 4.77 (dd, 1H, *J*=11.88 Hz, *J*=4.86 Hz, 2-H), 4.78 (t, 1H, *J*=10.38 Hz, 4-H), 4.88 (d, 1H, *J*=3.66 Hz, 1-H), 4.91 (d, 1H, *J*=10.37 Hz, 2′-H), 4.97 (t, 1H, *J*=10.07 Hz, 4′-H), 5.39 (t, 1H, *J*=9.77 Hz, 3′-H), 5.43 (t, 1H, *J*=10.07 Hz, 3-H); ^{13}C NMR ($CDCl_3$): δ 20.02 (1′-CH_3), 20.46 (CH_3), 20.51 (CH_3), 20.57 (two C, CH_3), 20.59 (CH_3), 20.66 (CH_3), 55.31 (OCH_3), 60.83 (6-C), 62.15 (6′-C), 67.92 (5-C), 68.35 (5′-C), 68.75 (4′-C), 69.75 (4-C), 69.94 (3-C), 70.75 (3′-C), 70.87 (2-C), 73.38 (2′-C), 96.14 (1-C), 99.09 (1′-C), 169.42 (C=O), 169.77 (two C, C=O), 169.81 (C=O), 169.96 (C=O), 170.07 (C=O),170.54 (C=O); HRMS (FAB): cacld for $C_{28}H_{40}O_{18}Na$: 687.2113, found 687.2121.

4.1.15. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-acetyl-α-D-galactopyranosyl)-(*1′→6*)-2,3,4-tri-*O*-acetyl-α-D-glucoside (11b). 34 mg (0.1 mmol) of **9b** and 48 mg (0.15 mmol) of **10** were treated as described in the **General procedure 3** to afford 54.6 mg of the disaccharide **11b** (82.2%). Colorlessly sticky syrup; $[\alpha]_D^{25}$=+140.69° (*c* 1.0, $CHCl_3$); IR (neat): 2949.52, 1749.65, 1437.14, 1373.48, 1226.88, 1055.19, 958.74, 902.80 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.35 (s, 3H, CH_3), 1.94 (s, 3H, CH_3CO), 2.01 (s, 3H, CH_3CO), 2.05 (s, 3H, CH_3CO), 2.07 (s, 3H, CH_3CO), 2.09 (s, 3H, CH_3CO), 2.10 (s, 3H, CH_3CO), 2.15 (s, 3H, CH_3CO), 3.43 (dd, 1H, *J*=9.07 Hz, *J*=2.14 Hz, 6-H), 3.48 (s, 3H, CH_3O), 3.55 (dd, 1H, *J*=10.07 Hz, *J*=8.54 Hz, 6-H), 3.98 (dd, 1H, *J*=11.29 Hz, 7.02 Hz, 6′-H) 4.05 (ddd, 1H, *J*=10.38 Hz, *J*=8.24 Hz, *J*=2.14 Hz, 5-H), 4.19 (dd, 1H, *J*=11.29 Hz, *J*=5.49 Hz, 6′-H), 4.41 (ddd, 1H, *J*=7.02 Hz, *J*=5.49 Hz, 1.53 Hz, 5′-H), 4.85 (dd, 1H, *J*=6.11 Hz, *J*=2.75 Hz, 4-H), 4.88 (dd, 1H, *J*=6.11 Hz, *J*=2.44 Hz, 3′-H), 4.93 (d, 1H, *J*=3.66 Hz, 1-H), 5.25 (d, 1H, *J*=10.68 Hz, 2′-H), 5.33 (dd, 1H, *J*= 10.68 Hz, *J*=3.36 Hz, 2-H), 5.42 (dd, 1H, *J*=3.36 Hz, *J*=1.53 Hz, 4′-H), 5.49 (t, 1H, *J*=9.77 Hz, 3-H); ^{13}C NMR ($CDCl_3$): δ 20.37 (1′-CH_3), 20.52 (CH_3), 20.58 (CH_3), 20.61 (CH_3), 20.65 (two C, CH_3), 20.70 (CH_3), 20.77 (CH_3), 55.30 (CH_3O), 60.79 (6-C), 62.14 (6′-C), 67.46 (5-C), 67.98 (5′-C), 68.41 (3-C), 68.51 (3′-C), 69.81 (4-C), 70.06 (4-C), 70.79 (2-C), 70.85 (2′-C), 96.27 (1-C), 99.68 (1′-C), 169.80 (C=O), 169.86 (C=O), 169.96 (C=O), 170.07 (C=O), 170.15 (C=O), 170.26 (C=O), 170.39 (C=O); HRMS (FAB): cacld for $C_{28}H_{40}O_{18}Na$: 687.2113, found 687.2118.

4.1.16. General procedure 4: debenzylation of the 1′-*C*-methyl-α-*O*-disaccharides 5 and 6. A mixture of the disaccharides **5** or **6** (1.0 mmol), $Pd(OH)_2/C$ (200 mg) and alcohol (20 mL) was stirred vigorously under H_2 atmosphere at room temperature. The reaction was monitored by TLC detection (CH_2Cl_2: CH_3OH=9:1). After the reaction completed the catalyst was removed by filtration and the solvent was evaporated in vacuum, the residue was submitted to a silica gel column chromatography using CH_2Cl_2: MeOH (2:1) as the eluent to give the debenzylated product **12** or **15**, respectively. The results are shown in Table 5.

4.1.17. Methyl *O*-(1′-*C*-methyl-α-D-glucopyranosyl)-(*1′→6*)-α-D-glucoside (12a). 1′-*C*-methyl-α-disaccharide **5a** (1.0 g, 1.0 mmol) was debenzylated in the solution of methanol as described in the **General Grocedure 4** to give **12a** (369 mg, 99.7%). Colorlessly glassy solid; $[\alpha]_D^{23}$=+126.19° (*c* 1.57, CH_3OH); ^1H NMR (CD_3OD): δ 1.34 (s, 3H, CH_3), 3.05 (d, 1H, *J*=9.53 Hz, 2′-H), 3.22–3.23 (m, 2H, two 6-H), 3.31–3.33 (m, 1H, 6′-H), 3.34 (s, 3H, CH_3O), 3.50–3.71 (m, 8H, 6′-H, 5-H, 5′-H, 4-H, 4′-H, 3′-H, 3-H, 2′-H and 2-H), 4.59 (d, 1H, *J*=4.03 Hz, 1-H); ^{13}C NMR (CD_3OD): δ 21.08 (1′-CH_3), 55.80 (CH_3O), 61.42 (6-C), 62.71 (6′-C), 71.89, 71.99, 72.16, 73.49, 74.02, 75.38, 75.62, 78.44 (2-C), 101.18 (1-C), 101.44 (1′-C)

(the other sugar carbons could not be determined); HRMS (FAB): cacld for $C_{14}H_{26}O_{11}Na$ 393.1373, found 393.1354.

4.1.18. Methyl *O*-(1′-*C*-methyl-α-D-galactopyranosyl)-(*1′→6*)-α-D-glucoside (12b). 1′-*C*-methyl-α-disaccharide **5b** (300 mg, 0.3 mmol) was debenzylated in methanol as described in the **General Procedure 4** to give **12b** (111 mg, 100%). Colorlessly glassy solid; $[\alpha]_D^{23}$=+145.59° (*c* 1.0, $CHCl_3$); ^1H NMR (CD_3OD): δ 1.44 (s, 3H, CH_3), 3.10–3.26 (m, 1H, 6-H), 3.41 (s, 3H, CH_3O), 3.41–3.44 (m, 1H, 6-H overlapped with CH_3O), 3.54 (d, 1H, *J*=9.89 Hz, 2′-H), 3.61 (t, 1H, *J*=9.16 Hz, 4-H), 3.66–3.74 (m, 5H, two 6′-H, 5-H, 5′-H and 3-H), 3.78 (dd, 1H, *J*=9.90 Hz, *J*=3.29 Hz, 2-H), 3.91 (dd, 1H, *J*=3.30 Hz, *J*=1.10 Hz, 4′-H), 3.96 (td, 1H, *J*=6.59 Hz, *J*=1.10 Hz, 3′-H), 4.69 (d, 1H, *J*=3.66 Hz, 1-H); ^{13}C NMR (CD_3OD): δ 21.05 (1′-CH_3), 55.67 (CH_3O), 61.51 (6-C), 62.65 (6′-C), 71.20 (5-C), 72.09 (5′-C), 72.23, 72.27, 72.65, 73.52, 75.17, 75.33, 101.24 (1-C), 101.77 (1′-C) (the other sugar carbons could not be determined); HRMS (FAB): cacld for $C_{14}H_{26}O_{11}Na$ 393.1373, found 393.1382.

4.1.19. Methyl *O*-(1′-*C*-methyl-α-D-mannopyranosyl)-(*1′→6*)-α-D-glucoside (12c). 1′-*C*-methyl-α-disaccharide **5c** (100 mg, 0.1 mmol) was debenzylated in *t*-BuOH (4 mL) as described in the **General Procedure 4** to give **12c** (36.4 mg, 98.4%). Colorlessly glassy solid; $[\alpha]_D^{25}$=+102.79° (*c* 0.5, CH_3OH); ^1H NMR (CD_3OD): δ 1.40 (s, 3H, CH_3), 3.26–3.29 (m, 1H, 6′-H), 3.39 (dd, 1H, *J*=9.35 Hz, *J*=3.85 Hz, 6′-H), 3.41 (s, 3H, CH_3O), 3.57–3.72 (m, 7H, two 6-H, 2′-H, 5-H, 5′-H, 3-H and 4-H), 3.77 (dd, 1H, *J*=4.40 Hz, *J*=2.96 Hz, 3′-H), 3.79–3.80 (m, 1H, 4′-H), 3.88 (dd, 1H, *J*=9.16 Hz, *J*=3.66 Hz, 2-H), 4.65 (d, 1H, *J*=3.66 Hz, 1-H); ^{13}C NMR (CD_3OD): δ 20.08 (1′-CH_3), 55.59 (CH_3O), 61.27 (6-C), 63.00 (6′-C), 68.12 (5-C), 72.03, 72.09, 73.03, 73.56, 74.81, 74.92, 75.43 (2-C), 101.11 (1-C), 102.36 (1′-C) (the other sugar carbons could not be determined); HRMS (FAB): cacld for $C_{14}H_{26}O_{11}Na$ 393.1373, found 393.1387.

4.1.20. Methyl *O*-(1′-*C*-methyl-α-D-glucopyranosyl)-(*1′→4*)-α-D-glucoside (15a). 1′-*C*-methyl-α-disaccharide **6a** (50 mg, 0.05 mmol) was debenzylated in *t*-BuOH (2 mL) as described in the **General Procedure 4** to give **15a** (16.9 mg, 91.4%). Colorlessly glassy solid; $[\alpha]_D^{22}$=+141.2° (*c* 1.0, CH_3OH); ^1H NMR (CD_3OD): δ 1.38 (s, 3H, CH_3), 3.14 (d, 1H, *J*=9.16 Hz, 2′-H), 3.27 (dd, 1H, *J*=8.80 Hz, *J*=1.10 Hz, 6′-H), 3.38–3.42 (m, 2H, 4-H and 6′-H), 3.40 (s, 3H, CH_3O), 3.52 (ddd, 1H, *J*=9.89 Hz, *J*=5.86 Hz, *J*=2.57 Hz, 5-H), 3.59–3.69 (m, 5H, 5′-H, 2-H, 3-H, 3′-H and 4′-H), 3.81 (dd, 2H, *J*=12.72 Hz, *J*=2.57 Hz, two 6-H), 4.67 (d, 1H, *J*=3.67 Hz, 1-H); ^{13}C NMR (CD_3OD): δ 22.38 (1′-CH_3), 55.66 (CH_3O), 61.86 (6-C), 62.99 (6′-C), 71.78 (5-C), 72.77 (5′-C), 73.05, 74.44, 74.53, 75.01, 75.54, 79.23 (2-C), 101.23 (1-C), 102.92 (1′-C) (the other sugar carbons could not be determined); HRMS (FAB): cacld for $C_{14}H_{26}O_{11}Na$ 393.1373, found 393.1370.

4.1.21. Methyl *O*-(1′-*C*-methyl-α-D-galactopyranosyl)-(*1′→4*)-α-D-glucoside (15b). 1′-*C*-methyl-α-disaccharide **6b** (50 mg, 0.05 mmol) was debenzylated in *t*-BuOH (2 mL) as described in the **General Procedure 4** to give **15b** (14.9 mg, 80.5%). Colorlessly glassy solid; $[\alpha]_D^{22}$=+172.7° (*c* 0.8, CH_3OH); ^1H NMR (CD_3OD): δ 1.57 (s, 3H, CH_3), 3.40 (s, 3H, CH_3O), 3.46 (dd, br, 1H, *J*=9.34 Hz, *J*=3.85 Hz, 5-H), 3.51–3.54 (m, 1H, 5′-H), 3.60 (d, 1H, *J*=9.89 Hz, 2′-H), 3.68 (dd, br, 2H, *J*=6.05 Hz, *J*=2.20 Hz, two 6′-H), 3.75–3.77 (m, 2H, 4-H and 3-H), 3.78 (dd, 1H, *J*=6.05 Hz, *J*=3.85 Hz, 2-H), 3.81–3.82 (m, 2H, two 6-H), 3.88 (dd, 1H, *J*=3.30 Hz, *J*=1.10 Hz, 4′-H), 3.97 (dd, 1H, *J*=6.05 Hz, *J*=1.10 Hz, 3′-H), 4.66 (d, 1H, *J*=3.85 Hz, 1-H); ^{13}C NMR (CD_3OD): δ 22.32 (1′-CH_3), 55.60 (CH_3O), 61.81 (6-C), 62.82 (6′-C), 71.15 (5-C), 71.98 (5′-C), 72.74, 73.00, 73.06, 74.21, 74.95, 76.01, 101.20 (1-C), 103.23 (1′-C) (the other sugar carbons could not be determined); HRMS (FAB): cacld for $C_{14}H_{26}O_{11}Na$ 393.1373, found 393.1367.

4.1.22. Methyl *O*-(1′-*C*-methyl-α-D-mannopyranosyl)-(*1′→4*)-α-D-glucoside (15c). 1′-*C*-methyl-α-disaccharide **6c** (50 mg, 0.05 mmol) was debenzylated in *t*-BuOH (2 mL) as described in the **General Procedure 4** to give **15c** (7.4 mg, 40.0%). Colorlessly glassy solid; $[\alpha]_D^{22}$=+132.5° (*c* 0.4, CH_3OH); ^1H NMR (CD_3OD): δ 1.40 (s, 3H, CH_3), 3.25–3.28 (m, 1H, 6′-H), 3.38 (dd, 1H, *J*=9.90 Hz, *J*=3.85 Hz, 6′-H), 3.40 (s, 3H, CH_3O), 3.57 (t, 1H, *J*=9.35 Hz, 4-H or 3-H), 3.59 (t, 1H, *J*=9.35 Hz, 3-H or 4-H), 3.61–3.72 (m, 5H, 2′-H, 5′-H, 5-H, 2-H and 4′-H), 3.76–3.80 (m, 2H, 3′-H and 6-H), 3.88 (dd, 1H, *J*=9.35 Hz, *J*=3.30 Hz, 6-H), 4.65 (d, 1H, *J*=3.85 Hz, 1-H); ^{13}C NMR (CD_3OD): δ 20.03 (1′-CH_3), 55.54 (CH_3O), 61.25 (6-C), 62.97 (6′-C), 68.08 (5′-C), 72.02 (5-C), 72.06, 72.99, 73.53, 74.79, 74.91, 75.39, 101.07 (1-C), 102.32 (1′-C) (the other sugar carbons could not be determined); HRMS (FAB): cacld for $C_{14}H_{26}O_{11}Na$ 393.1373, found 393.1361.

4.1.23. General procedure 5: acetylation of the methyl *O*-(1′-*C*-methyl-α-D-glucopyranosyl)-(*1′→6*)-α-D-glucoside (12a). 65 mg (0.17 mmol) of **12a** was dissolved in 2.0 mL of dry pyridine and 1.2 mL of acetic anhydride. The solution was stirred under the argon atmosphere at room temperature overnight, then poured into 100 g ice-water. The mixture was extracted with AcOEt (50 mL×2). The organic phase was washed with water (30 mL×5), and dried over Na_2SO_4. After removing the solvent the residue was applied on a silica gel column chromatography eluting with AcOEt: Hexane (1:1) to afford the acetylated product (110 mg, 97.4%). Colorlessly sticky syrup; $[\alpha]_D^{25}$=+19.02° (*c* 1.0, $CHCl_3$); its NMR spectra were identical to those of the compound **11a**.

4.1.24. Acetylation of the methyl *O*-(1′-*C*-methyl-α-D-galactopyranosyl)-(*1′→6*)-α-D-glucoside (12b). 12b (37 mg, 0.10 mmol) was acetylated following the **General Procedure 5** to give **11b** (64 mg, 96.4%). Colorlessly sticky syrup; $[\alpha]_D^{25}$=+140.33° (*c* 1.0, $CHCl_3$).

4.1.25. Acetylation of the methyl *O*-(1′-*C*-methyl-α-D-mannopyranosyl)-(*1′→6*)-α-D-glucoside (12c). 12c (17 mg, 0.05 mmol) was acetylated following the **General Procedure 5** to give the compound **17** (methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-acetyl-α-D-mannopyranosyl)-(*1′→6*)-2,3,4-tri-*O*-acetyl-α-D-glucoside) (25 mg, 75.3%).

Colorlessly sticky syrup; $[\alpha]_D^{25}=+102.55°$ (*c* 1.49, $CHCl_3$); IR (neat): 2951.45, 1747.72, 1437.14, 1373.48, 1219.16, 1167.08, 1126.57, 1051.33, 958.74, 931.73, 900.87 cm^{-1}; ^1H NMR ($CDCl_3$):δ 1.29 (s, 3H, CH_3), 1.95 (s, 3H, $COCH_3$), 2.01 (s, 3H, CH_3CO), 2.03 (s, 3H, CH_3CO), 2.06 (s, 3H, CH_3CO), 2.09 (s, 3H, CH_3CO), 2.11 (s, 3H, CH_3CO), 2.17 (s, 3H, CH_3CO), 3.46 (dd, 1H, *J*=10.07 Hz, *J*= 2.13 Hz, 6-H), 3.45 (s, 3H, CH_3O), 3.56 (dd, 1H, *J*= 9.76 Hz, *J*=8.23 Hz, 6-H), 4.02 (ddd, 1H, *J*=10.07 Hz, *J*=8.24 Hz, *J*=1.83 Hz, 5-H), 4.15–4.19 (m, 3H, 5′-H and two 6′-H), 4.84 (dd, 1H, *J*=10.07 Hz, *J*=3.66 Hz, 4-H), 4.87 (d, 1H, *J*=10.07 Hz, 2-H), 4.95 (d, 1H, *J*=3.67 Hz, 1-H), 5.14–5.19 (m, 1H, 4′-H), 5.21 (d, 1H, *J*=3.36 Hz., 2′-H), 5.43 (dd, 1H, *J*=10.07 Hz, *J*=3.35 Hz, 3′-H), 5.50 (dd, 1H, *J*=10.07 Hz, *J*=9.46 Hz, 3-H); ^{13}C NMR ($CDCl_3$): δ 19.16 (1′-CH_3), 20.58 (CH_3), 20.60 (CH_3), 20.63 (CH_3), 20.68 (two C, CH_3), 20.74 (CH_3), 20.77 (CH_3), 55.34 (OCH_3), 60.66 (6-C), 62.85 (6′-C), 65.87 (4′-H), 68.00 (5-C), 69.42 (5′-C), 69.67 (2-C), 69.72 (3-C), 70.01 (3′-C), 70.96 (4-C), 71.35 (2′-C), 96.20 (1-C), 99.72 (1′-C), 169.83 (C=O), 169.86 (two C, C=O), 169.93 (C=O), 169.98 (C=O), 170.20 (C=O), 170.64 (C=O); HRMS (FAB): cacld for $C_{28}H_{40}O_{18}Na$: 687.2113, found 687.2110.

4.1.26. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-acetyl-α-D-glucopyranosyl)-(*1′→4*)-2,3,6-tri-*O*-acetyl-α-D-glucoside (18). 1′-*C*-methyl-α-disaccharide **15** (17 mg, 0.05 mmol) was acetylated following the **General Procedure 5** to give **18** (22 mg, 66.3%). Colorlessly sticky syrup; $[\alpha]_D^{23}=+87.98°$ (c 2.03, $CHCl_3$); IR (neat): 2963.02, 1749.65, 1435.21, 1371.55, 1226.88, 1126.57, 1037.83, 985.74, 906.65, 736.90 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.46 (s, 3H, CH_3), 1.96 (s, 3H, CH_3CO), 2.02 (s, 3H, CH_3CO), 2.03 (s, 3H, CH_3CO), 2.05 (s, 3H, CH_3CO), 2.08 (s, 3H, CH_3CO), 2.09 (s, 3H, CH_3CO), 2.12 (s, 3H, CH_3CO), 3.45 (s, 3H, CH_3O), 3.90–3.94 (m, 1H, 5-H), 4.02 (t, 1H, *J*=10.07 Hz, 4-H), 4.03 (dd, 1H, *J*=12.21Hz, *J*=2.14 Hz, 6′-H), 4.10–4.14 (m, 1H, 5′-H), 4.24 (dd, 1H, *J*=12.21 Hz. *J*=2.14 Hz, 6′-H), 4.25 (dd, 1H, *J*=11.91 Hz, *J*=1.83 Hz, 6-H), 4.55 (dd, 1H, *J*=11.91 Hz, *J*=1.83 Hz, 6-H), 4.84 (s, 1H, 1-H), 4.85 (dd, 1H, *J*=12.20 Hz, *J*=3.67 Hz, 2-H), 4.97 (d, 1H, *J*=10.37 Hz, 2′-H), 5.06 (t, 1H, *J*=9.77 Hz, 4′-H), 5.38 (t, 1H, *J*=9.77 Hz, 3′-H), 5.48 (t, 1H, *J*=8.24 Hz, 3-H); ^{13}C NMR ($CDCl_3$): δ 20.53 (CH_3), 20.59 (CH_3), 20.61 (CH_3), 20.65 (CH_3), 20.74 (CH_3), 20.79 (CH_3), 21.16 (1′-CH_3), 21. 22 (CH_3), 55.54 (OCH_3), 62.09 (6′-C), 63.15 (6-C), 68.75 (two C, 5-C and 5′-C), 68.85 (4′-C), 70.60 (3′-C), 70.97 (2-C), 71.25 (4-C), 71.68 (3-C), 74.28 (2′-C), 96.39 (1-C), 100.98 (1′-C), 168.92 (C=O), 169.46 (C=O), 169.75 (C=O), 170.10 (C=O), 170.40 (two C, C=O), 170.57 (C=O); HRMS (FAB): cacld for $C_{28}H_{40}O_{18}Na$: 687.2113, found 687.2125.

4.1.27. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-benzoyl-α-D-glucopyranosyl)-(*1′→6*)-2,3,4-tri-*O*-benzoyl-α-D-glucoside (19). 120 μL (1.0 mmol) of Benzoyl chloride was added to a solution of 37 mg (0.1 mmol) of **12a** in 1.0 mL of dry pyridine at 0°C with stirring under the argon atmosphere. The solution was stirred at room temperature for 24 h. To the solution one drop of water was added to quench the reaction, then 20 mL of CH_2Cl_2 were added. The mixture was washed with water (20 mL×2), 3N H_2SO_4 (20 mL), water (20 mL×2) and saturated $NaHCO_3$ (20 mL), successively, and dried over Na_2SO_4. After removing the solvent the residue was applied on a silica gel column chromatography using AcOEt: Hexane (1:2) as the eluent to afford 73.0 mg of the product 19 (yield 66.4%). White solid, mp. 108°C; $[\alpha]_D^{24}=+55.8°$ (*c* 1.0, $CHCl_3$); IR (KBr): 3067.19, 3034.40, 2963.02, 1732.29, 1603.04, 1452.57, 1315.61, 1273.17, 1178.65, 1095.70, 1068.69, 1026.25, 976.10, 709.89 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.46 (s, 3H, CH_3), 3.61 (dd, 1H, *J*= 10.38 Hz, *J*=1.22 Hz, 6-H), 3.74 (s, 3H, CH_3O), 3.85 (t, 1H, *J*=8.85 Hz, 6-H), 4.34 (dd, 1H, *J*=12.21 Hz, *J*= 6.71 Hz, 6′-H), 4.41 (t, *br*, 1H, *J*=8.85 Hz, 5-H), 4.76 (dd, 1H, *J*=11.90 Hz, *J*=1.83 Hz, 6′-H), 4.79–4.84 (m, 1H, 5′-H), 5.00 (dd, 1H, *J*=10.37 Hz, *J*=3.67 Hz, 2-H), 5.13 (t, 1H, *J*=9.77 Hz, 4-H), 5.27 (d, 1H, *J*=3.67 Hz, 1-H), 5.49 (d, 1H, *J*=10.07 Hz, 2′-H), 5.59 (t, 1H, *J*=9.77 Hz, 4′-H), 6.14 (t, 1H, *J*=9.77 Hz, 3-H), 6.20 (t, 1H, *J*= 9.76 Hz, 3′-H), 7.21–7.63 (m, 21H, ArH), 7.75–8.20 (m, 14H, ArH); ^{13}C NMR ($CDCl_3$):δ 20.56 (1′-CH_3), 55.67 (CH_3O), 60.76 (6-C), 63.33 (6′-C), 68.67 (5-C), 69.15 (5′-C), 69.88, 70.04, 70.48, 71.22, 71.98, 74.47 (2-C), 96.65 (1-C), 99.60 (1′-C), 128.16 (Ph), 128.45 (Ph), 128.32 (Ph), 128.39 (Ph), 128.42 (Ph), 128.62 (Ph), 128.74 (Ph), 129.07 (Ph), 129.08 (Ph), 129.15 (Ph), 129.21 (Ph), 129.52 (Ph), 129.58 (Ph), 129.72 (Ph), 128.86 (Ph), 129.89 (Ph), 129.93 (Ph), 130.11 (Ph), 132.93 (Ph), 133.03 (Ph), 133.07 (Ph), 133.30 (Ph), 133.46 (Ph), 165.47 (C=O), 165.50 (C=O), 165.65 (C=O), 165.68 (C=O), 165.80 (C=O), 165.82 (C=O), 166.11 (C=O) (the other sugar carbons could not be determined); HRMS (FAB): cacld for $C_{63}H_{54}O_{18}Na$: 1121.3208, found 1121.3207.

4.1.28. Methyl *O*-(1′-*C*-methyl-2′,3′,4′,6′-tetra-*O*-(*p*-nitrobenzoyl)-α-D-glucopyranosyl)-(*1′→6*)-2,3,4-tri-*O*-(*p*-nitrobenzoyl)-α-D-glucoside (20). To the solution of 37 mg (0.1 mmol) of **12a** and 1.2 mg (0.01 mmol) of 4-dimethylaminopyridine (DMAP) in 1.5 mL of dry pyridine a solution of 390 mg (2.1 mmol) of 4-nitrobenzoyl chloride in 0.5 mL of CH_2Cl_2 was added at 0°C with stirring under the argon atmosphere. The resulting solution was stirred at room temperature for 20 h, then heated at 50°C for 12 h. To the solution 0.2 mL of water, then 30 mL of CH_2Cl_2 were added. The mixture was washed with water (30 mL×3), saturated $NaHCO_3$ (30 mL) and water (30 mL), successively. The organic solution was dried over Na_2SO_4 and concentrated under reduced pressure, the residue was applied on a silica gel column chromatography (AcOEt: Hexane=1:1.5) to afford 114.3 mg of the product 20 (yield 80.8%). Pale yellow solid, mp. 185–186°C; $[\alpha]_D^{24}=+48.40°$ (*c* 1.0, $CHCl_3$); IR (KBr): 3065.26, 3034.40, 2966.88, 2910.94, 1718.78, 1601.11, 1583.75, 1452.57, 1385.06, 1367.70, 1315.61, 1273.17, 1176.71, 1095.70, 989.60, 707.96 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.56 (s, 3H, CH_3), 3.65 (dd, 1H, *J*=10.07 Hz, *J*=1.22 Hz, 6-H), 3.75 (s, 3H, CH_3O), 3.80 (dd, 1H, *J*=10.38 Hz, *J*=2.24 Hz, 6-H), 4.37–4.42 (m, 1H, 6′-H), 4.44 (t, br, 1H, *J*= 8.55 Hz, 5-H), 4.78–4.85 (m, 2H, 5′-H and 6′-H), 5.00 (dd, 1H, *J*=10.07 Hz, *J*=3.66 Hz, 2-H), 5.12 (t, 1H, *J*= 9.47 Hz, 4-H), 5.25 (d, 1H, *J*=3.36 Hz, 1-H), 5.55 (d, 1H, *J*=10.07 Hz, 2′-H), 5.60 (t, 1H, *J*=10.77 Hz, 4′-H), 6.14 (t, 1H, *J*=10.76 Hz, 3-H), 6.17 (t, 1H, *J*=10.08 Hz, 3′-H), 7.95 (d, 2H, *J*=8.85 Hz, ArH), 8.08–8.29 (m, 24H, ArH), 8.37 (d, 1H, *J*=8.85 Hz, ArH), 8.45 (d, 1H, *J*=8.85 Hz, ArH);

^{13}C NMR ($CDCl_3$): δ20.56 (1′-CH_3), 55.88 (CH_3O), 60.54 (6-C), 63.71 (6′-C), 68.12 (5-C), 69.03 (5′-C), 70.33 (two C), 71.13, 71.95, 72.05, 74.69 (2-C), 96.53 (1-C), 99.63 (1′-C), 123.71 (Ph), 123.74 (Ph), 123.78 (Ph), 123.80 (Ph), 123.83 (Ph), 123.93 (Ph), 124.00 (Ph), 130.67 (Ph), 130.71 (Ph), 130.78 (Ph), 130.95 (Ph), 130.98 (Ph), 131.04 (Ph), 131.09 (Ph), 133.26 (Ph), 133.44 (Ph), 133.48 (Ph), 133.71 (Ph), 133.87 (Ph), 150.88 (Ph), 150.94 (Ph), 150.96 (Ph), 150.97 (Ph), 151.03 (Ph), 151.07 (Ph), 163.50 (C=O), 163.62 (C=O), 163.74 (C=O), 163.76 (C=O), 163.85 (C=O), 164.05 (C=O), 164.28 (C=O) (the other sugar carbons could not be determined); HRMS (FAB): cacld for $C_{63}H_{54}O_{18}Na$: 1121.3208, found 1121.3211.

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