CD and ^{1}H NMR Study of the Rotational Population Dependence of the Hydroxymethyl Group in β Glucopyranosides on the Aglycon and Its Absolute Configuration†

Ezequiel Q. Morales, Juan I. Padrón, Mar Trujillo, and Jesús T. Vázquez*

Centro de Productos Naturales Orgánicos Antonio González, Universidad de La Laguna-CSIC, Carretera de La Esperanza 2, 38206 La Laguna, Tenerife, Spain

Received October 19, 1994®

The rotamer population around the C5–C6 bond of chiral and nonchiral alkyl β-D-glucopyranoside derivatives proved to be dependent on the structure of the aglycon; the population of the *gg* and *gt* rotamers decreased and increased, respectively, as the pK_a of the aglycon increased, whereas the *tg* population remained almost constant. In addition, the rotamer populations correlate with the absolute configuration of the aglyconic carbons, namely, higher CD *A* values and smaller $^3J_{H5,H6R}$ coupling constants are obtained for the (*R*)-alkyl glucopyranosides than for their (*S*)-alkyl glucopyranoside counterparts, as the result of increased and decreased *gg* and *gt* populations, respectively. The results show a clear relationship between the rotamer distributions and the stereoelectronic *exo*-anomeric effect. As a consequence of these findings the absolute configuration of secondary alcohols can be determined, a single enantiomer being necessary for this purpose.

Conformational analyses of oligosaccharides in solution are important to rationalize their biological properties,[1] the overall conformation being determined by the torsion angles (ϕ and ψ) about the glycosidic linkages. An additional parameter needs to be considered when (1–6) linkages are involved: the corresponding torsion angle about C5–C6 bonds (ω) (Figure 1).

The conformational analysis of the rotamers *gauche–gauche* (*gg*), *gauche-trans* (*gt*), and *trans-gauche* (*tg*) around the C5–C6 bond (Figure 2) has for a long time been a controversial stereochemical problem due to the discrepancies in the most stable rotamer assigned.[2] The stereospecific syntheses of (6*R*)- and (6*S*)-deuterated D-hexoses[3] and (1-6)-linked disaccharides[4] resolved this problem by differentiating the H6*R* and H6*S* signals in the ^{1}H NMR spectra. For glucose and mannose derivatives the rotamer population of the hydroxymethyl group was shown to be $P_{gg} > P_{gt} \gg P_{tg}$ while for galactose derivatives $P_{tg}, P_{gt} > P_{gg}$.

The circular dichroic exciton chirality method[5] has proved to be extremely sensitive to the conformational changes of chromophorically substituted hydroxymethyl groups in hexopyranosides,[6,7] the preferred rotamers agreeing with those obtained by ^{1}H NMR studies. Moreover, the additivity of the amplitude (*A* value)[8] in the CD exciton curves of multichromophoric systems[6] (one type of chromophore) and the additivity of the CD curves of

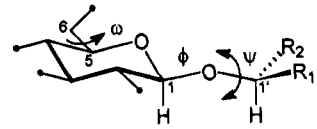


Figure 1. Torsion angles ϕ and ψ, about the glycosidic linkage, and torsion angle ω, around the C5–C6 bond.

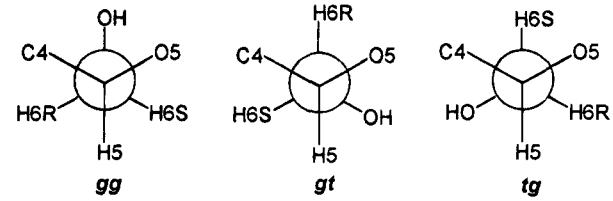


Figure 2. Newman projections of the rotamers around the C5–C6 bond.

bichromophoric systems[7] (two types of chromophores) have been studied in methyl glycopyranosides containing chromophoric esters, thus allowing an easy interpretation of the CD spectra of these types of compounds and establishing an oligosaccharide micromethod by CD spectroscopy.

The rotamer population around the C5–C6 bond has recently been interpreted as a combination of the *gauche* and stereoelectronic effects, since an ^{1}H NMR and MNDO study of different galactopyranosides showed the existence of a correlation between the rotamer population and the pK_a of the substituent at C1, the *tg* population increasing as the pK_a increases.[10] The existent parallelism between this correlation and the well-known relationship between the pK_a of the substituent at the

† Dedicated to Professor Koji Nakanishi on the occasion of his 70th birthday.

® Abstract published in *Advance ACS Abstracts,* March 15, 1995.

(1) For example, see: Lemieux, R. U. *Frontiers of Chemistry*; Laidler, K. J., Ed.; Pergamon: New York, 1982 and references cited therein.

(2) Ohrui, H.; Nishida, Y.; Higuchi, H.; Hori, H.; Meguro, H. *Can. J. Chem.* **1987**, *65*, 1145.

(3) (a) Wu, G. D.; Serianni, A. S.; Barker, R. *J. Org. Chem.* **1983**, *48*, 1750. (b) Nishida, Y.; Ohrui, H.; Meguro, H. *Tetrahedron Lett.* **1984**, *25*, 1575.

(4) Ohrui, H.; Nishida, Y.; Watanabe, M.; Hori, H.; Meguro, H. *Tetrahedron Lett.* **1985**, *26*, 3251.

(5) For a monograph on exciton CD spectroscopy see: Harada, N.; Nakanishi, K. *Circular Dichroic Spectroscopy-Exciton Coupling in Organic Stereochemistry*; University Science Books: Mill Valley, CA, 1983.

(6) Liu, H.-W.; Nakanishi, K. *J. Am. Chem. Soc.* **1982**, *104*, 1178.

(7) (a) Weisler, W. T.; Vázquez, J. T.; Nakanishi, K. *J. Am. Chem. Soc.* **1987**, *109*, 5586. (b) Vázquez, J. T.; Wiesler, W. T.; Nakanishi, K. *Carbohydr. Res.* **1988**, *176*, 175. (c) Meyers, H. V.; Ojika, M.; Wiesler, W. T.; Nakanishi, K. *Carbohydr. Res.* **1990**, *197*, 15.

(8) The amplitude (*A* value) of split CD Cotton effects is defined as $A = \Delta\epsilon_1 - \Delta\epsilon_2$ where $\Delta\epsilon_1$ and $\Delta\epsilon_2$ are intensities of the first and second Cotton effects, respectively. As can be observed in Table 1, most tetra-*O*-benzoyl glucopyranoside derivatives exhibited only the first Cotton effect, the second Cotton effect being masked by a strong background ellipticity.

(9) (a) Chang, M.; Meyers, H. V.; Nakanishi, K.; Ojika, M.; Park, J. H.; Takeda, R.; Vázquez, J. T.; Wiesler, W. T. *Pure Appl. Chem.* **1989**, *61*, 1193. (b) Wiesler, W. T.; Berova, N.; Ojika, M.; Meyers, H. V.; Chang, M.; Zhou, P.; Lo, L.-C.; Niwa, M.; Takeda, R.; Nakanishi, K. *Helv. Chim. Acta* **1990**, *73*, 509.

(10) Vries, N. K.; Buck, H. M. *Carbohydr. Res.* **1987**, *165*, 1.

0022-3263/95/1960-2537$09.00/0

Table 1. CD Data (CH_3CN) and Values of the ^1H NMR Coupling Constant $J_{H5,H6R}$ ($CDCl_3$) for 2,3,4,6-Tetra-*O*-benzoyl-β-glucopyranosides of Secondary Alcohols[13]

entry	alcohol	glucose series	C1′	Δε 233/220 nm	*A* value[a]	$J_{H5,H6R}$ (Hz)
1	(−)-2-octanol	D	*R*	7.3/−0.9	8.2	5.6
2	(+)-2-octanol	D	*S*	6.3/−0.6	6.9	5.8
3	(−)-menthol	D	*R*	5.8	5.8	5.7
4	(+)-menthol	D	*S*	4.2	4.2	6.8
5	(−)-neomenthol	D	*R*	6.6	6.6	5.7
6	(+)-neomenthol	D	*S*	6.2	6.2	5.9
7	(−)-borneol	D	*R*	8.7	8.7	5.7
8	(+)-borneol	D	*S*	7.5/−0.3	7.8	5.8
9	cholesterol	D	*S*	7.4	7.4	5.9
10	cholesterol	L	*S*	−7.8	−7.8	6.1
11	cholestanol	D	*S*	6.2/−0.9	7.1	6.0
12	cholestanol	L	*S*	−7.2	−7.2	6.1
13	testosterone	D	*S*	8.0[a]	8.0	5.6
14	testosterone	L	*S*	−8.1[a]	−8.1	4.7
15	dimethyl D-malate	D	*R*	8.0	8.0	5.6
16	dimethyl L-malate	D	*S*	5.8	5.8	5.0
17	(−)-methyl 3-hydroxybutyrate	D	*R*	10.8	10.8	5.2
18	(+)-methyl 3-hydroxybutyrate	D	*S*	6.2/−0.8	7.0	5.6

[a] Resulting Δε value after subtraction of the overlapping CD contribution at 234 nm (+7.7) of the $\pi \rightarrow \pi^*$ transition of the enone system.

anomeric carbon and the lengths of the *endo*- (O5−C1) and *exo*-cyclic (C1−O1) bonds[11] supports the stereoelectronic origin of the former.

Recently, an X-ray structural analysis of the 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl chloride[12] has shown for first time the occurrence of the *gg* and *gt* rotamers in the crystal. Furthermore, distinctly different bond lengths around the ring oxygen and the anomeric center were observed, the structure of the *gt* rotamer displaying an unusually long C5−O5 distance and that of the *gg* rotamer exhibiting short distances for the C1−Cl and the O5−C1 bonds, confirming the relationship between the ring atomic distances and the orientation of the 6-substituent.

In connection with the study of a new ^1H NMR method for determination of the absolute configuration of secondary alcohols,[13] we found that the intensity of the exciton CD curves of alkyl 2,3,4,6-tetra-*O*-benzoyl-β-glucopyranosides correlates with the absolute configuration of the chiral glycosyl acceptor. Thus, a slightly higher intensity was observed (Table 1) for all β-D-glucosylated derivatives having an *R* absolute configuration at the aglyconic carbon (C1′) than for those with an *S* absolute configuration.

To investigate the origin of these CD spectral differences, nonchiral and chiral alkyl alcohols were coupled to two other chromophorically substituted glucopyranosyl donors of higher molar extinction coefficients (ε) and more characteristic CD patterns than the simpler tetra-*O*-benzoylglucopyranosyl system, and the products were analyzed by CD and NMR spectroscopy.[14]

The present study shows the existence of a rotational population dependence of the hydroxymethyl group in β-D-glucopyranosides on the aglycon (pK_a) and its absolute configuration and reveals a clear correlation between the rotamer distributions and the stereoelectronic *exo*-anomeric effect. In addition, the results allow the absolute configuration of alkyl secondary alcohols to be determined.

Results and Discussion

Synthesis. The model compounds used in the present spectroscopic work contain exciton-coupled chromophores:[5-7,9] the β-D-glucopyranosides **3a−g** and **3m**, as well as the β-L-glucopyranosides **12b−e**, contain *p*-bromobenzoate esters, while the β-D-glucopyranosides **9a−e** and **9h−k** contain those esters and *p*-methoxycinnamate esters also (Chart 1).

A modified Koenigs−Knorr method[15] was chosen for the syntheses of all model compounds. The alkyl β-D-glucopyranosides **3a−g** were synthesized in moderate to good yields by treatment of the 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-α-D-glucopyranosyl bromide (**2**) with the corresponding alcohols of **a−g** in the presence of silver trifluoromethanesulfonate as the catalyst and 1,1,3,3-tetramethylurea (TMU) as the proton acceptor. Similarly, the β-L-glucopyranosides **12b−e** were prepared by coupling the alcohols of **b−e** to 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-α-L-glucopyranosyl bromide (**11**). Compound **3m** was obtained in good yield by treatment of the glucosyl bromide **2** with silver acetate.

The glucosyl bromides **2** and **11** were easily prepared by per-*p*-bromobenzoylation of D- and L-glucose, respectively, and subsequent treatment of the resulting pentakis(*p*-bromobenzoyl) derivatives **1** and **10** (both as a mixture of α- and β-anomers) with HBr/AcOH.

The alkyl 2,3-bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranosides **9a−e** and **9h−k** were obtained by performing the above-modified Koenigs−Knorr reaction.[15] Thus, treatment of the corresponding alcohols with the 2,3-bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-α-D-glucopyranosyl bromide (**8**), silver triflate as catalyst, and TMU as proton acceptor afforded the desired bichromophoric model compounds.

The glucopyranosyl donor **8** was synthesized in good yield from D-glucose in five steps. Benzylidination of D-glucose with benzaldehyde and powdered zinc chloride afforded 4,6-*O*-benzylidene-D-glucopyranose (**4**), which by per-*p*-bromobenzoylation led to 1,2,3-tris-*O*-(*p*-bromobenzoyl)-4,6-*O*-benzylidene-D-glucopyranoside (**5**). Removal of the 4,6-*O*-benzylidene residue in **5** with *p*-toluenesulfonic acid and subsequent per-*p*-methoxycinnamoylation gave 1,2,3-tris-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (**7**). Finally, treatment of **7** in dichloromethane with HBr/AcOH led to the desired 2,3-bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-α-D-glucopyranosyl bromide (**8**).

Characterization. These compounds were characterized on the basis of their one- (^1H and ^{13}C) and two-

(11) (a) Jones, P. G.; Kirby, A. J. *J. Chem. Soc., Chem. Commun.* **1979**, 288. (b) Kirby, A. J. *The Anomeric Effect and Related Stereoelectronic Effects at Oxygen*; Springer-Verlag: Berlin, 1983; pp 58−60 and 90−91.

(12) Lichtenthaler, F. W.; Rönninger, S.; Kreis, U. *Liebigs Ann. Chem.* **1990**, 1001.

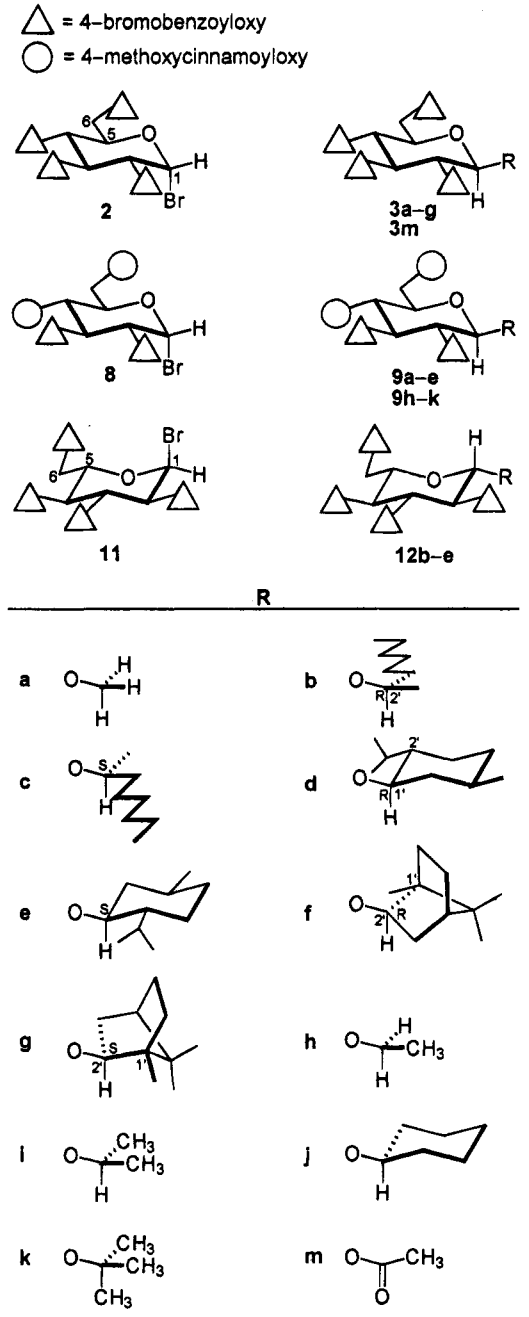
(13) Trujillo, M.; Morales, E. Q.; Vázquez, J. T. *J. Org. Chem.* **1994**, *59*, 6637.

(14) (a) Vázquez, J. T.; Morales, E. Q.; Peña, J. P. 4th Int. Conference on CD; Bochum, FRG, 1991, 181. (b) Vázquez, J. T.; Morales, E. Q.; Padrón, J. I. XIV Reunión Bienal del Grupo de Química Orgánica, Palma de Mallorca, Spain. Symposium communication: *An. Quim.* **1993**, *89*, 123.

(15) (a) Hanessian, S.; Banoub, *J. Carbohydr. Res.* **1977**, *53*, C13. (b) Banoub, J.; Bundle, D. R. *Can. J. Chem.* **1979**, *57*, 2091. (c) Garegg, P. J.; Norberg, T. *Acta Chem. Scand.* **1979**, *B33*, 116.

(16) Lemieux, R. U.; Koto, S. *Tetrahedron* **1974**, *30*, 1933.

Chart 1



dimensional (COSY and HMQC) NMR spectra, as well as UV and CD spectroscopy.

The expected β-configuration at the anomeric carbon for all model compounds was confirmed by measuring the ^{1}H NMR coupling constant between H1 and H2 (doublet 7.7–8.0 Hz). The ^{1}H NMR signals of the prochiral protons at C6, H6*R* and H6*S*, were differentiated on the basis of their chemical shifts and coupling constants;[3b,4] namely, H6*R* signals appear at a higher field than H6*S* signals and $J_{H5,H6R}$ have higher values than $J_{H5,H6S}$.

Similar to the tetra-*O*-benzoyl-β-glucosylated secondary alcohols,[13] the alkyl 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranosides **3b–g** as well as the bichromophoric glucopyranosides **9b–e** exhibited dramatic shifts in the aglycon ^{1}H NMR peaks characteristic of the absolute configuration of the secondary chiral alcohol, the chemical shift of the C1′ protons of the glucosylated *R*-alcohols also appearing at lower field than those of the glucosylated *S*-alcohol counterparts.

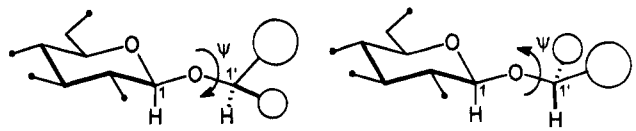


Figure 3. Schematic representation of the rotational dependence of the torsion angle ψ on the structure of the aglycon. Clockwise or counterclockwise rotation along the O1–C1′ bond for glucopyranosides having the main nonbonded interactions between the aglycon and the sugar residue *syn* (left) or *anti* (right) to O5, respectively.

^{13}C NMR data comparison between (*R*)- and (*S*)-alkyl glucopyranosides shows for the former compounds chemical shifts at higher field for C6 (0.0–0.2 ppm), the anomeric carbon (2–4 ppm), and the aglyconic carbon (2–4 ppm). For the glucosylated nonchiral alcohols **9a,h–k**, the following features, confirming the structure of these compounds, were observed: (i) the α-effect on the aglyconic C1′ carbons; (ii) the γ-effect on the anomeric carbons; and (iii) a very small shift to lower field from the glucosylated primary alcohol (methyl, 62.63 ppm) to the tertiary alcohol derivative (*tert*-butyl, 63.04 ppm).

The wavelengths of the split Cotton effects of the exciton CD spectra of compounds **3a–g, m** and **12b–e** (tetra-*p*-bromobenzoates) were at the correct positions, namely around 250 and 232 nm, while those for the bichromophoric compounds **9a–e,h–k** were centered about the *p*-methoxycinnamate λ_{max} 311 nm (322 and 287 nm) and about the *p*-bromobenzoate λ_{max} 245 nm (250 and 232 nm).[7a]

Pyranoside Ring and Glycopyranosidic Conformational Analysis. To ensure a correct CD interpretation of the model compounds, the conformation of the pyranoside rings was studied by analyzing their ^{1}H NMR spectra. The spin–spin coupling constants of the pyranoside ring protons were obtained by first-order analysis. The values of these coupling constants clearly demonstrated that all these compounds adopt the $^4C_1$ chair conformation. The absence of ring distortion was confirmed by comparing the ^{1}H NMR coupling constants of the pyranoside ring protons of these model compounds, which showed almost identical values (±0.1 Hz).

The conformational properties of the glycopyranosidic linkage are well established.[16] While the torsion angle φ (H1–C1–O1–C1′) remains almost constant, due to the *exo*- and *endo*-anomeric effects present in the α-anomers, or to the *exo*-anomeric effect present in the β-anomers, the torsion angle ψ (C1–O1–C1′–H1′) decreases or increases, depending on whether the main nonbonded interactions between the aglycon and the sugar residue are located *syn* or *anti*, respectively, to the oxygen atom of the pyranoside ring (Figure 3). Thus, for example, the more stable conformation for compounds **3b, 3d**, and **3f**, of which the main steric interactions are located *syn* to O5, would be as shown in Figure 3 (left), while for compounds **3c, 3e**, and **3g** these would be as shown in Figure 3 (right), protons H1 and H1′ remaining on the same side. This last arrangement was checked for several model compounds by ROESY experiments. The spectra showed three clear cross peaks of the anomeric proton with C3, C5, and C1′ protons, confirming for these models that the aglyconic C1′ proton is on the same side as the anomeric C1 proton. Furthermore, these model compounds show characteristic shifts in the aglycon ^{1}H NMR peaks, induced by the benzoyl group at C2 and the endocyclic glucopyranoside oxygen (O5) (Figure 4),[13]

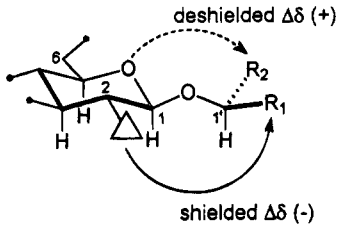


Figure 4. Stereochemical correlation model for alkyl β-D-glucopyranosides.[13]

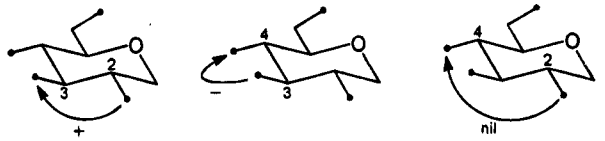


Figure 5. Pairwise interactions having constant intensity and sign.

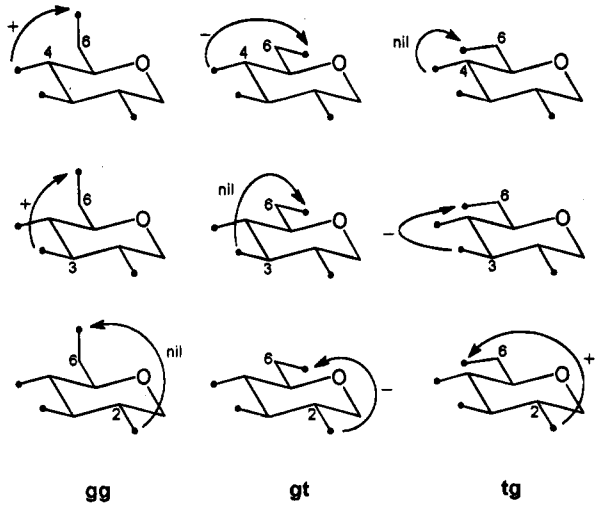


Figure 6. Pairwise interactions involving the chromophore at the 6 position in each of the three stable rotamers.

confirming the *anti* or *syn* arrangement of the alkyl groups R_1 and R_2 with respect to the aforementioned endocyclic oxygen.

Rotational Population Analysis. The CD spectrum of a 2,3,4,6-tetra chromophorically substituted glucopyranosyl system is composed of six pairwise interactions.[5,6] These interactions can be divided into two groups: those having constant intensity and sign, the positive 2/3, the negative 3/4, and the nil 2/4 pairwise interactions (Figure 5) and those interactions involving the chromophore at the 6 position with variable intensity and sign, the 2/6, the 3/6, and the 4/6 pairwise interactions, which depend on the rotamer population of this group (Figure 6).

Since no ring distortion has been observed for these model compounds, any modification in their CD spectra must be due to rotamer population differences of the chromophoric ester at the 6 position, since the contributions of the 2/3, 2/4, and 3/4 interactions remain constant.

Higher intensities of the split Cotton effects and better defined second Cotton effects were obtained by using the *p*-bromobenzoate chromophore instead of the benzoate chromophore. The CD curves of the secondary alkyl 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranosides **3b**–**g** showed a general decrease of the positive first and negative second Cotton effects with respect to those

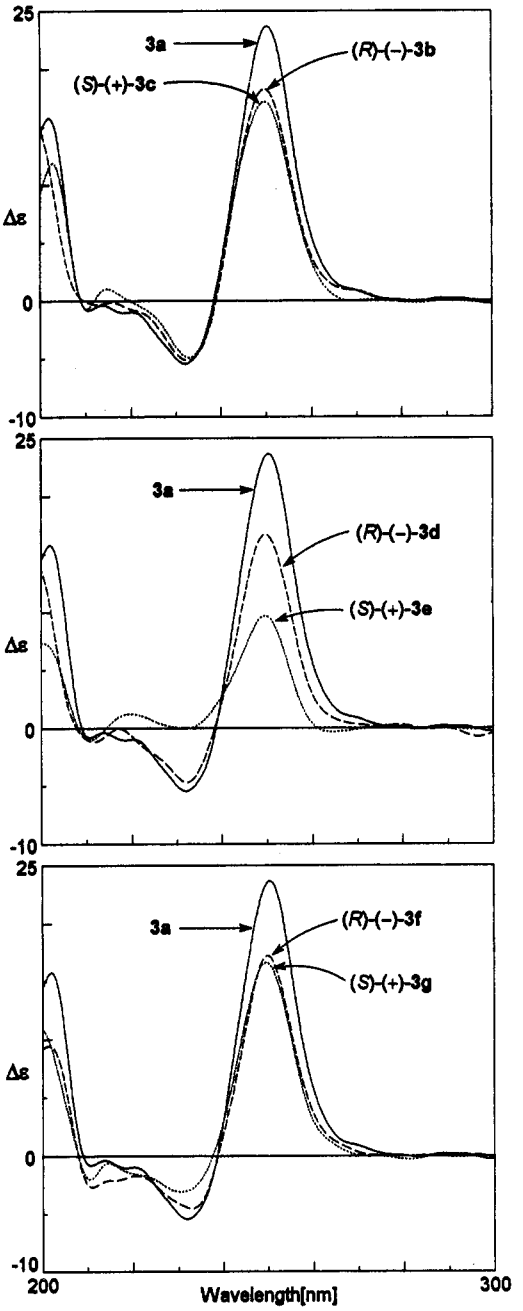


Figure 7. Comparison of methyl glucopyranoside **3a** (solid curves) and (*R*)- (dashed curves) and (*S*)- (dotted curves) alkyl glucopyranosides **3b**–**g** CD spectra (in CH_3CN): (−)- and (+)-2-octyl (top); (−)- and (+)-menthyl (center); and (−)- and (+)-bornyl (bottom).

of the methyl derivative **3a** (Figure 7, Table 2) as occurred with the secondary alkyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosides. In addition, different amplitudes (A values)[8] were also obtained for the two members of each pair of stereoisomers **3b/3c**, **3d/3e**, and **3f/3g**. In every case the glucopyranosides having an *R* absolute configuration at the aglyconic carbon (**3b**, **3d**, **3f**, and those indicated in Table 1) exhibited a higher intensity than their stereoisomers having the opposite absolute configuration (**3c**, **3e**, **3g**, and those in Table 1 with an *S* absolute configuration).

The same behavior was observed by using the polar protic solvent MeOH (Table 2). The secondary alkyl glucopyranoside derivatives **3b**–**g** exhibited a decrease similar to that observed when CH_3CN was used, except

Table 2. CD Data for Model 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)glucopyranosidees 3a–g in CH_3CN and MeOH

			CH_3CN		MeOH	
compd	aglycon	aglyconic config (C1′)	Δε at 250/232 nm	*A* value	Δε at 250/232 nm	*A* value
3a	methyl		23.7/−6.2	29.9	23.4/−4.0	27.4
3b	(−)-2-octyl	*R*	18.6/−5.0	23.6	20.1/−4.9	25.0
3c	(+)-2-octyl	*S*	17.8/−4.6	22.4	17.1/−3.8	20.9
3d	(−)-menthyl	*R*	17.7/−4.1	21.8	17.1/−3.4	20.5
3e	(+)-menthyl	*S*	9.5/−0.5	10.0	16.9/−4.7	21.6
3f	(−)-bornyl	*R*	17.2/−4.8	22.0	15.5/−4.4	19.9
3g	(+)-bornyl	*S*	16.8/−3.3	20.1	15.4/−4.3	19.7

Table 3. $J_{H5,H6}$ Coupling Constants and Calculated Rotameric Populations (%) around the C5–C6 Bond for Model 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranosides 3a–g

compd[a]	aglycon	$J_{H5,H6S}$	$J_{H5,H6R}$	P_{gg}[b]	P_{gt}	P_{tg}
3a	methyl	3.4	4.7	57	26	17
3b	(−)-2-octyl	3.6	5.1	53	29	18
3c	(+)-2-octyl	3.6	5.3	50	32	18
3d	(−)-menthyl	3.6	5.2	51	31	18
3d[c]	(−)-menthyl	3.6	4.9	54	28	18
3e	(+)-menthyl	3.4	6.1	45	40	15
3f	(−)-bornyl	3.7	5.2	51	30	19
3g	(+)-bornyl	3.6	5.4	50	32	18

[a] Proton NMR (400 MHz) spectra were recorded in $CDCl_3$. [b] Calculations use the equations from Nishida et al., ref 17. [c] ^1H NMR spectrum was recorded in CD_3CN.

for the 1(*S*)-menthyl glucopyranoside **3e** which showed a striking change in intensity, increasing its Cotton effects up to the values observed for the other secondary alkyl glucopyranosides.

The general decreases in the CD Cotton effects with respect to those of the methyl glucopyranoside **3a** can be explained by a decrease in the population of the *gg* rotamer, which has a net positive contribution, and an increase in the population of the *gt* rotamer, which contributes negatively (Figure 6).

This explanation was confirmed by analysis of the ^1H NMR coupling constants $J_{H5,H6R}$ and $J_{H5,H6S}$ (Table 3). Higher $J_{H5,H6R}$ values (5.1–6.1 Hz) and slightly higher $J_{H5,H6S}$ values (3.4–3.7 Hz) were obtained for the secondary alkyl glucopyranosides with respect to the methyl derivative **3a** ($J_{H5,H6R}$ = 4.7 and $J_{H5,H6S}$ = 3.4 Hz). Furthermore, and in agreement with CD data, stereoisomers having an *R* absolute configuration at the aglyconic carbon, compounds **3b**, **3d**, and **3f**, showed a smaller $J_{H5,H6R}$ coupling constant than those with the opposite absolute configuration (**3c**, **3e**, **3g**) indicating that stereoisomers with an *R* absolute configuration at the aglyconic carbon have higher *gg* and smaller *gt* populations.

Table 3 shows the rotamer distributions calculated by means of ^1H NMR coupling constants $J_{H5,H6R}$ and $J_{H5,H6S}$.[17] Data comparison of Tables 2 and 3 indicates the existence of an excellent correlation between the magnitudes of these rotamer populations and the CD *A* values.

Note that ^1H NMR spectra were recorded in $CDCl_3$, while CD spectra were taken in CH_3CN. While it is conceivable that the two solvents may show preference for different conformations, and, specifically, different rotamer populations, the ^1H NMR spectra of compound **3d** recorded in either CD_3CN or $CDCl_3$ indicate no appreciable rotational differences (Table 3).

(17) The following set of three equations was used to calculate the ratio of P_{gg}, P_{gt}, and P_{tg}: $1.3P_{gg} + 2.7P_{gt} + 11.7P_{tg} = J_{H5,H6S}$; $1.3P_{gg} + 11.5P_{gt} + 5.8P_{tg} = J_{H5,H6R}$; $P_{gg} + P_{gt} + P_{tg} = 1$. See ref 3.

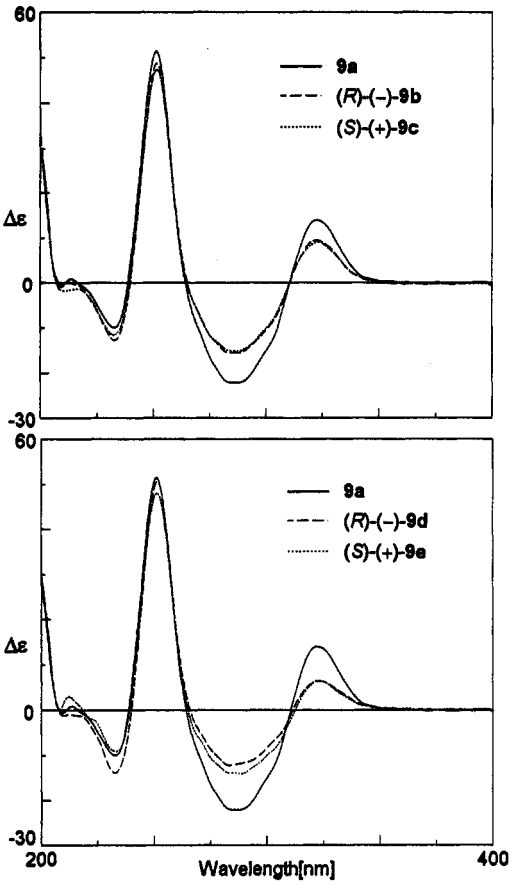


Figure 8. Comparison of methyl glucopyranoside **9a** (solid lines) and (*R*)- (dashed lines) and (*S*)- (dotted lines) alkyl glucopyranosides **9b–e** CD spectra (in CH_3CN): (−)- and (+)-2-octyl (top); (−)- and (+)-menthyl (bottom).

In order to gain a deeper knowledge of the interactions affected by the aglycon, a more informative exciton-coupled system was employed, specifically, the bichromophoric 2,3-bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)glucopyranosyl system.[7] The signs and number of the interactions involved are the same as for the tetrakis-*O*-(*p*-bromobenzoyl)glucopyranosyl system (Figures 5 and 6), but now two types of exciton-coupled interactions are present, the *homo* and the *hetero* interactions. Thus, this system is composed of two *homo* interactions, one benzoate–benzoate (2B/3B), centered about the *p*-bromobenzoate λ_{max} 245 nm, and one cinnamate–cinnamate (4C/6C), centered about the *p*-methoxycinnamate λ_{max} 311 nm, as well as four *hetero* interactions (2B/4C, 2B/6C, 3B/4C, 3B/6C) that cover both the benzoate and cinnamate regions and are weaker in intensity than the *homo* interactions.

The positive first and negative second Cotton effects of the CD spectra of (+)- and (−)-2-octyl and (+)- and (−)-menthyl glucopyranoside derivatives **9b–e** exhibited an important decrease in intensity compared with those of the methyl glucopyranoside **9a** (Figure 8). In addition, the intensities of the first and second Cotton effects of the CD spectra of the glucosylated nonchiral alcohols **9a,h–k** (Figure 9) gradually decreased from methyl (A_C value 36.6),[18] to ethyl (35.4), to isopropyl (31.3), to cyclohexyl (31.3), and to *tert*-butyl glucopyranoside (23.6). For the above model compounds the intensities of the

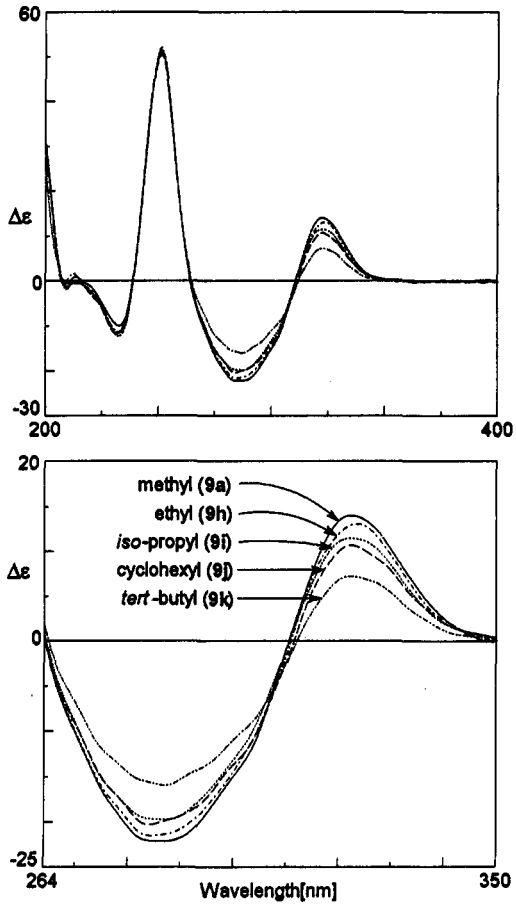


Figure 9. CD spectra (CH_3CN) of the nonchiral 2,3-bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranosides: methyl (**9a**) (solid lines); ethyl (**9h**) (dashed dotted); isopropyl (**9i**) (dotted); cyclohexyl (**9j**) (dashed); and *tert*-butyl (**9k**) (dashed double dotted).

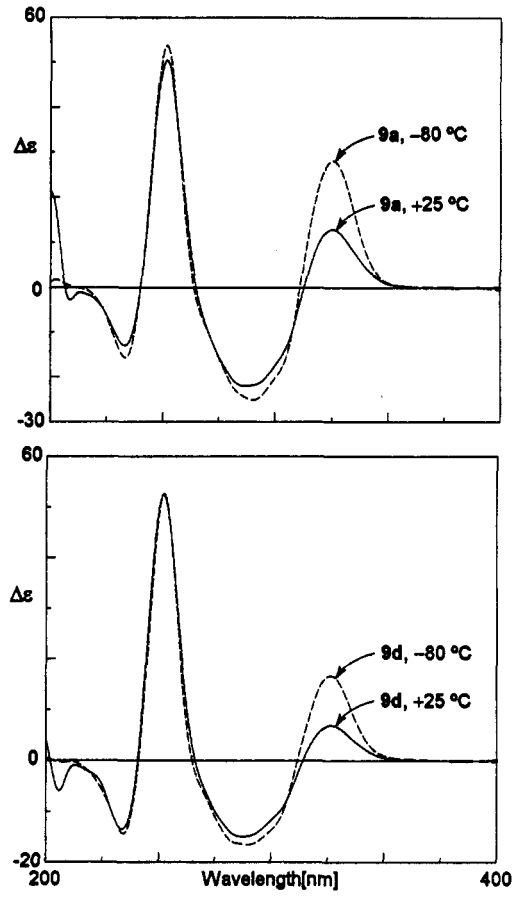


Figure 10. CD spectra of methyl (top) and (−)-menthyl (bottom) glucopyranosides **9a** and **9d**, respectively, at room temperature (solid lines) and at −80 °C (dashed lines), in MeOH.

positive third Cotton effects (around 250 nm) were slightly smaller than that observed for the methyl glucopyranoside **9a**, while the intensities of the negative fourth Cotton effects (near 232 nm) were in general somewhat higher.

The more complex and yet easily interpretable CD curves of these bichromophoric derivatives allowed the modified pairwise interactions to be detected. The main differences were located in the cinnamate−cinnamate coupling region centered about the cinnamate λ_{max} 311 nm. The pairwise interactions making the greatest contributions in this region are the degenerate 4/6 cinnamate/cinnamate (4C/6C) and the nondegenerate 3/4 benzoate/cinnamate (3B/4C). The diminished intensities of the first and second Cotton effects in the CD spectra of these bichromophoric model compounds are only consistent with a smaller contribution of the positively coupled 4C/6C pairwise interaction. The much weaker *hetero* 2B/6C and 3B/6C interactions, covering both cinnamate and benzoate regions, account for the smaller differences observed in the *p*-bromobenzoate coupling region, since a modification of the *homo* 2B/3B pairwise interaction would produce a simultaneous increase or decrease in the couplet centered about the *p*-bromobenzoate λ_{max} 245 nm. These differences in the CD curves clearly indicate that only the interactions involving the chromophore at the six position are significantly affected and, therefore, that the rotamer distributions have changed. Moreover, these spectral differences are only consistent with a decrease and an increase in the proportions of the *gg* and *gt* rotamers, respectively.

Low-temperature CD measurement of compounds **9a** and **9d** (MeOH, −80 °C) confirmed the above results (Figure 10). The striking increase in the first positive and second negative Cotton effects of their CD spectra by lowering the temperature can only be explained by an increase in the positive contribution of the 4C/6C *homo* interaction, namely, to an increase in the rotational population of the *gg* rotamer, and also proves that this rotamer is energetically favored.

The rotamer distributions cannot be calculated for all these bichromophoric compounds by means of ^1H NMR coupling constants since the chemical shifts of protons at C6 are in many cases equivalent, thus providing only a doublet rather than the usual, clearly differentiated doublet of doublets for each proton (Table 4). Furthermore, compounds **9j** and **9e**, which showed the doublet of doublets, display a reversal in the order of H6*R* and H6*S* chemical shifts.[19] On the basis of our CD results the protons at C6 have been assigned as shown in Table 4 and their rotamer distributions calculated. In addition, the coupling constant $J_{H5,H6}$, which gradually increases

(18) We define A_C and A_B values as the amplitudes of split CD Cotton effects in the cinnamate−cinnamate and in the benzoate−benzoate coupling regions centered about the cinnamate λ_{max} 311 nm and about the benzoate λ_{max} 245 nm, respectively.

(19) Other cases of reversal in the order of H6*R* and H6*S* chemical shifts have been observed previously. Rao, V. S.; Perlin, A. S. *Can. J. Chem.* **1983**, *61*, 2688.

Table 4. CD A_C Values,[18] $J_{H5,H6}$ Coupling Constants, and Calculated Rotamer Populations around the C5–C6 Bond for the Bichromophoric β-D-Glucopyranosides 9a–e and 9h–k

compd[a]	aglycon	A_C	$\delta_{H6's}$ or δ_{H6R} and δ_{H6S}	$J_{H5,H6}$ or $J_{H5,H6R}$ and $J_{H5,H6S}$	P_{gg}[b]	P_{gt}	P_{tg}
9a	methyl	36.6	4.44	3.9			
9h	ethyl	35.4	4.42	4.1			
9i	isopropyl	31.3	4.41	4.4			
9j	cyclohexyl	31.3	4.45 and 4.40	5.3 and 3.9	49	30	21
9k	*tert*-butyl	23.6	4.38	4.6			
9b	(−)-2-octyl	25.5	4.40	4.3			
9c	(+)-2-octyl	24.7	4.41	4.7			
9d	(−)-menthyl	19.1	4.42 and 4.45	5.2 and 4.1	49	28	23
9e	(+)-menthyl	20.4	4.42 and 4.39	6.0 and 3.8	43	38	19

[a] CD and NMR (400 MHz) spectra were recorded in CH_3CN and in $CDCl_3$, respectively. [b] Calculations use the equations from Nishida et al., ref 17.

from 3.9 to 4.6 Hz for the glucosylated nonchiral alcohols **9a,h–k**, corroborates the increase in the *gt* population.

The stereoelectronic *exo*-anomeric effect,[20] that increases with increasing ease for charge delocalization from the aglycon to the anomeric carbon,[21] must be responsible for the rotational population dependence of the hydroxymethyl group, since the *gt* population increases as the pK_a of the aglycon increases.

Crystallographic studies of acetoxy β-pyranosides have shown that the length of the O5–C1 and C1–O1 bonds have the same average value,[21,22] and therefore, the *exo*-anomeric effect is nil. To confirm that the observed differences in the CD spectra of the model compounds are due to the *exo*-anomeric effect, the acetyl tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (**3m**) was prepared. As expected, this acetyl glucoside exhibited a CD curve with an intensity (*A* value 31.3) even higher than that of the methyl glucopyranoside **3a** (*A* value 29.9), which can only be explained by an increase in the *gg* population. ^1H NMR data confirmed this result showing a rotational ratio for compound **3m** of 59, 28, and 13 for the *gg*, *gt*, and *tg* rotamers vs 57, 26, and 17 for compound **3a**.

We can conclude from these experiments that the different intensities of the CD spectra and values of the ^1H NMR coupling constants $J_{H5,H6R}$ and $J_{H5,H6S}$ of alkyl glucopyranosides are mainly due to different values of the stereoelectronic *exo*-anomeric effect. The gradual decreases in the CD A_C value and increases in the coupling constant $J_{H5,H6}$ from the methyl to the *tert*-butyl glucopyranoside (compounds **3a,h–k**) can only be satisfactorily explained by an increase in the *exo*-anomeric effect, since this increases as the pK_a of the aglycon increases, and by the fact that for these low molecular size alcohols the existence of nonbonded interactions with the chromophore at C6 cannot be expected. Thus, an increase in the *exo*-anomeric effect leads to a decrease and to an increase in the populations of the *gg* and *gt* rotamers, respectively. Similarly, all glucosylated chiral alcohols showed a higher *gt* population than the corresponding methyl glucopyranosides (**3a** or **9a**), in agreement with an increased *exo*-anomeric effect. In addition, their rotamer distributions proved to be dependent on the absolute configuration of the aglycon, stereoisomers of absolute configuration *R* in the aglyconic carbon (C1′) showing an increased and decreased *gg* and *gt* population, respectively, than stereoisomers having the opposite absolute configuration. These differences were in general much smaller in magnitude than between each of them and the corresponding methyl glucopyranosides (**3a** or **9a**), except for stereoisomers **3d** and **3e** in CH_3CN, meaning that the main factor involved has an electronic origin.

Since the pK_a of the aglycon is the same for a pair of stereoisomers, steric interactions may account for the minor differences between each *R* + *S* aglycon diastereomer pair. The origin of these smaller differences could be explained in two different ways: (i) By nonbonded interactions between the aglycon and the chromophore at C6. Diastereoisomers with an increased *gg* population have an aglycon of absolute configuration *R* in the aglyconic carbon, those with the bulkiest substituent *syn* to O5 (Figure 3, left), and therefore higher nonbonded interactions between these aglycons and the chromophore at C6 in the *gt* conformation could be expected. (ii) By a more favored *antiperiplanar* disposition to the C1–O5 bond of the nonbonding electron pair of the exocyclic oxygen belonging to diastereoisomers with an *S* absolute configuration at the aglyconic carbon than for those with the opposite absolute configuration, namely, a more stabilizing stereoelectronic *exo*-anomeric effect for diastereoisomers with an *S* absolute configuration.

Of these two explanations the first one (i) seems to be nonoperative. Although the above-mentioned relationship applies for each pair of diastereomers studied, in general no relationships exist between the bulkiness of the substituent R_2 of the model compounds (Figure 1), the one *syn* to the endocyclic oxygen, and the rotamer distributions of the hydroxymethyl group. Furthermore, molecular rotations of α-D- and β-D-glucopyranosides[16] support the conclusion that no appreciable nonbonded interaction exists between the aglycon and the C6 hydroxyl group. Therefore, it seems that the stereoelectronic *exo*-anomeric effect is the only one directly affected by the structural nature of the aglycon, both electronically and geometrically, and consequently, different rotamer distributions around C5–C6 are obtained. This dependence is transmitted via the endocyclic oxygen, on the basis of the change in the length of the O5–C1 bond and, therefore, the *gauche* effect (O5–C5–C6–O6).

Absolute Configuration Determination of Chiral Secondary Alcohols. In addition to the conformational analysis described above, the results obtained from the present study allow us to propose a method to determine the absolute configuration of secondary alcohols by simply comparing the intensity of the CD curves of the corresponding diastereoisomeric secondary alkyl 2,3,4,6-tetra-*O*-benzoyl- or 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranosides (Tables 1 and 2). Those compounds exhibiting a higher *A* value, or better, a higher intensity of the first Cotton effect, than their corresponding diastereomers possess an *R* absolute configuration.

Alternatively, stereoisomers with an *S* absolute configuration at the aglyconic carbon (C1′) show higher $J_{H5,H6R}$ (0.2–0.9 Hz) and equal or smaller $J_{H5,H6S}$ (0.0–0.2 Hz) coupling constants ($CDCl_3$) than their corresponding diastereomers (Table 3). However, the 2,3,4,6-tetra-*O*-benzoylglucopyranosides of cholesterol, cholestanol, and dimethyl malate (Table 1) showed a reversal of order

(20) The stereoelectronic *exo*-anomeric effect is the preference for the gauche (sc) conformation about the glycosidic C–OR bond of sugar derivatives. Lemieux, R. U.; Pavia, A. A.; Martin, J. C.; Watanabe, K. A. *Can. J. Chem.* **1969**, *47*, 4427.

(21) Briggs, A. J.; Glenn, R.; Jones, P. G.; Kirby, A. J.; Ramaswamy, P. *J. Am. Chem. Soc.* **1984**, *106*, 6200.

(22) Cossé-Barbi, A.; Watson, D. G.; Dubois, J. E. *Tetrahedron Lett.* **1989**, *30*, 163.

Table 5. CD Data Comparison (CH_3CN) between Model 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D- and β-L-glucopyranosides

compd	$\lambda_{ext}/\Delta\epsilon$	$\lambda_{ext}/\Delta\epsilon$	*A* value
(−)-2-octyl β-D- (**3b**)	232/−5.0	250/18.6	23.6
(+)-2-octyl β-L- (**12c**)	231/5.0	250/−18.8	−23.8
(+)-2-octyl β-D- (**3c**)	233/−4.6	250/17.7	22.3
(−)-2-octyl β-L- (**12b**)	233/4.3	250/−17.4	−21.7
(−)-menthyl β-D- (**3d**)	232/−4.1	249/17.7	21.8
(+)-menthyl β-L- (**12e**)	232/2.6	249/−17.4	−20.0
(+)-menthyl β-D- (**3e**)	232/−0.5	250/9.5	10.0
(−)-menthyl β-L- (**12d**)	234/0.3	249/−10.4	−10.5

in the magnitudes of the $J_{H5,H6R}$ and $J_{H5,H6S}$ coupling constants ($CDCl_3$), probably due to the absence of a substituent at the β- positions in the steroidal aglycons and in the last case to the presence of two carbonyl groups. It is interesting that these three model alcohols gave opposite results in the sign of the chemical shift difference ($\Delta\delta = \delta_D - \delta_L$) of their carbinyl protons as well.[13]

Where only one enantiomer is available, the necessary CD and/or ^1H NMR spectra of the unavailable diastereomer can be obtained by glycoside formation of the available enantiomer with the easily prepared 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-α-L-glucopyranosyl bromide (**11**) to achieve the enantiomer of the unavailable diastereomer. To test the accuracy of this approach the β-L-glucosylated alcohols **12b−e** were prepared and their CD spectra recorded. As expected, the intensities of the CD spectra of the enantiomeric pairs **3b/12c**, **3c/12b**, **3d/12e**, and **3e/12d** were very similar (Table 5), thus allowing the present method to be applied when only one enantiomer is available. Figure 11 shows the CD spectra of (2*R*)-(−)-2-octyl 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-β-D-(**3b**) and β-L-glucopyranoside (**12b**) (positive solid and negative dashed curves, respectively) as well as the CD curve that represents the CD spectrum of the "unavailable" (2*S*)-(+)-2-octyl derivative (**3c**) (positive dotted line), which is obtained by multiplying by minus one the negative CD curve of **12b**.

Conclusions

We have shown, on the basis of the CD spectral differences and values of the ^1H NMR coupling constants, $J_{H5,H6R}$ and $J_{H5,H6S}$, that the rotamer populations of the hydroxymethyl group in esterified alkyl β-D-glucopyranosides depend on the aglycon and the proportions of the *gt* and *gg* rotamers increasing and decreasing, respectively, as the pK_a of the aglycon increases. Moreover, this rotational dependence correlates with the absolute configuration at the aglyconic carbon, namely, higher *gt* populations and diminished *gg* populations are obtained for the glucosylated *S*-alcohols than for the glucosylated *R*-alcohol counterparts. The results clearly point to the *exo*-anomeric effect as being responsible for these rotational differences, and in addition, we tentatively conclude that stereoisomers with an *S* absolute configuration at the aglyconic carbon have higher values of this stereoelectronic effect than their stereoisomers of opposite absolute configuration, likely due to a better *antiperiplanar* disposition of the nonbonding electron pair of the exocyclic oxygen (O1) to the O5−C1 bond.

The absolute configuration of secondary alcohols can therefore be determined by means of the mentioned correlations, namely between the CD and ^1H NMR spectroscopic data and the absolute configurations at the carbinylic (aglyconic) carbon. This approach complements the recently reported method for the determination of the absolute configuration of secondary alcohols, based on the anisotropic effect and glycosidation-induced ^1H NMR shifts, upon tetra-*O*-benzoyl glucosylation of secondary alcohols (Figure 4).[13]

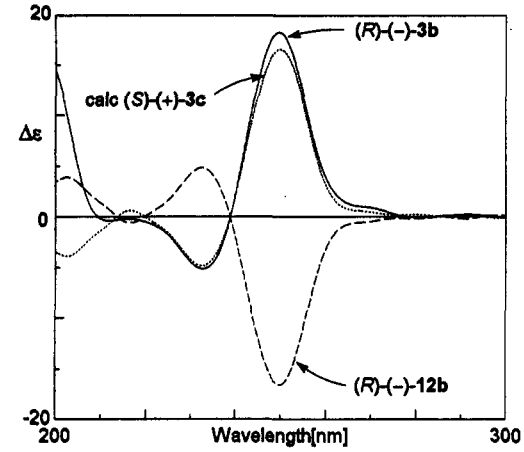


Figure 11. Calculation of the CD curve of the "unavailable" (2*S*)-(+)-2-octyl 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (**3c**) (positive dotted line) from that of (2*R*)-(−)-2-octyl 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-β-L-glucopyranoside (**12b**) (negative dashed line) and comparison with the CD curve of (2*R*)-(−)-2-octyl 2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (**3b**) (positive solid line) (all in CH_3CN).

Experimental Section

General. ^1H NMR spectra were recorded at 400 MHz and ^{13}C NMR at 100 MHz, VTU 300.0 K. Chemical shifts are reported in parts per million. The residual solvent peak ($CDCl_3$) was used as an internal reference. Optical rotations were measured on a digital polarimeter in a 1 dm cell. UV and CD spectra were recorded in the range 400-200 nm and by using 10 mm cells. Prior to measurement of CD spectra, all compounds were purified by HPLC by using a μ-Porasil column, 300 × 7.8 mm i.d., 254 nm, and HPLC grade *n*-hexane/EtOAc solvent systems. The concentrations of the CD samples were ascertained from the UV spectra, using the experimentally determined average tetra-*p*-bromobenzoates ε 38 200 at 245 nm.[6] In the case of di-*p*-bromobenzoates−di-*p*-methoxycinnamates, the standard value of 45 000 at 311 nm for di-*p*-methoxycinnamate (where bromobenzoates are transparent) was used.[7] Density correction was realized in all CD low-temperature measurements.

For analytical and preparative thin-layer chromatography silica gel ready-foils and glass-backed plates (1 mm) were used, respectively, being developed with 254 nm UV light and/or spraying with $AcOH/H_2O/H_2SO_4$ (80:16:4) and heating at 150 °C. Flash column chromatography was performed using silica gel (0.015−0.04 mm). All reagents as well as the chiral alcohols were obtained from commercial sources and used without further purification. Solvents were dried and distilled before use. All reactions were performed under a dry argon atmosphere.

General Procedure for *p*-Bromobenzoylation. The solution of the starting material in dry pyridine with DMAP as catalyst was treated with 1.5 times excess of *p*-bromobenzoyl chloride. The resulting pale yellow solution was heated at 60 °C and stirred overnight. The reaction was quenched with MeOH, diluted with CH_2Cl_2, and extracted with 5% HCl/H_2O and then with saturated NaCl solution. The combined organic layers were concentrated, and the residue obtained was chromatographed to give the purified product. Alternatively, the excess solvent was removed under reduced pressure in the presence of *n*-heptane or toluene and the residue was chromatographed.

General Procedure for Preparation of Glucopyranosyl Bromides. One equiv of the starting material dissolved in dry CH_2Cl_2 (3 mL/mmol) and 4 equiv of 30% (w/w) HBr/AcOH were stirred at room temperature under argon. Once the reaction was finished, one of the following workup procedures was used: (a) CH_2Cl_2 was then added. The mixture was immediately extracted with cold water until the solution was colorless, and then with $NaHCO_3$ and NaCl saturated solutions. The combined organic layers were dried over sodium sulfate, filtered, and concentrated. (b) Toluene was then added, and the solvent was removed under reduced pressure. The residue obtained was purified by crystallization.

General Procedure for β-Glucosylation.[15] To a stirred solution of glycosyl donor (acylglycosyl bromide) in dry CH_2Cl_2 (10 mL/mmol) at room temperature under Ar were added 1−10 equiv of glycosyl acceptor (alcohol) and 1 equiv of 1,1,3,3-tetramethylurea. The reaction mixture was cooled at 0 °C in an ice bath, and 2 equiv of AgOTf was then added in the dark under rigorously anhydrous conditions. The reaction was usually complete within 30 min (TLC). After the reaction was quenched with a few drops of water and filtration through a bed of Celite with CH_2Cl_2, the filtrate was evaporated under diminished pressure, and preparative TLC or flash column chromatography (*n*-hexane/EtOAc solvent systems) led to the purified product, 50−90% yield.

1,2,3,4,6-Pentakis-*O*-(*p*-bromobenzoyl)-D-glucopyranoside (1). This compound was obtained from D-glucopyranose (1.3 g, 7.2 mmol) as a 2:1 mixture of α- and β-anomers (7.2 g, 6.6 mmol) following the standard procedure for *p*-bromobenzoylation described above. TLC $R_{f\alpha}$ 0.60, $R_{f\beta}$ 0.45 (*n*-hexane/EtOAc, 8:2). **α-Anomer**: mp 212.8−213.6 °C; ^{1}H NMR ($CDCl_3$) δ 4.49 (1 H, dd, J = 12.3 and 4.7 Hz), 4.58 (1 H, m), 4.61 (1 H, dd, J = 12.3 and 2.9 Hz), 5.65 (1 H, dd, J = 10.0 and 3.7 Hz), 5.79 (1 H, t, J = 10.0 Hz), 6.20 (1 H, t, J = 10.0 Hz), 6.81 (1 H, d, J = 3.7 Hz), 7.45 and 7.54 (each: 4 H, d, J = 8.5 Hz), 7.55, 7.70, 7.77, 7.78, 7.85, and 7.99 (each: 2 H, d, J = 8.5 Hz); ^{13}C NMR ($CDCl_3$) δ 62.42, 68.81, 70.24, 70.34, 70.49, 90.06, 127.14 − 132.21, 163.58, 164.33, 164.46, 165.10, 165.18. **β-Anomer**: ^{1}H NMR ($CDCl_3$) δ 4.36 (1 H, ddd, J = 9.3, 4.3 and 2.8 Hz), 4.48 (1 H, dd, J = 12.4 and 4.3 Hz), 4.62 (1 H, dd, J = 12.4 and 2.8 Hz), 5.73 (1 H, t, J = 9.3 Hz), 5.77 (1 H, dd, J = 9.3 and 8.0 Hz), 5.95 (1 H, t, J = 9.3 Hz), 6.22 (1 H, d, J = 8.0 Hz), 7.47, 7.50, 7.51, 7.55, 7.57, 7.69, 7.74, 7.75, 7.86 and 7.87 (each: 2 H, d, J = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 62.66, 69.14, 70.94, 72.97, 92.67, 127.15−132.03, 163.83, 164.41, 164.94, 165.30.

2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-α-D-glucopyranosyl Bromide (2). Compound **1** (α- and β-anomers) (3 g, 2.74 mmol) was transformed, according to the general procedure for preparation of glucopyranosyl bromides, with a workup of type a, to the glucopyranosyl bromide **2** (2.4 g, 89% yield): TLC R_f 0.65 (*n*-hexane/EtOAc, 8:2); mp 117−120 °C; $[\alpha]^{25}_D$ +86.4° (*c* 0.5, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 4.50 (1H, dd, J = 12.6 and 4.4 Hz), 4.64 (1 H, dd, J = 12.6 and 2.7 Hz), 4.72 (1 H, ddd, J = 9.9, 4.4 and 2.7 Hz), 5.30 (1H, dd, J = 9.9 and 4.0 Hz), 5.74 (1 H, t, J = 9.9 Hz), 6.17 (1 H, t, J = 9.9 Hz), 6.81 (1 H, d, J = 4.0 Hz), 7.46, 7.52, 7.55, 7.59, 7.71, 7.78, 7.84, and 7.90 (each: 2 H, d, J = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 61.93, 68.10, 70.89, 71.32, 72.42, 86.39, 127.09−132.02, 164.37, 164.49, 164.83, 165.20; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} (Δε) 250 (24.9), 238 (0.0), 231 (−6.0), 208 nm (−10.2). Anal. Calcd for $C_{34}H_{23}O_9Br_5$: C, 41.88; H, 2.38. Found: C, 41.85; H, 2.21.

Methyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (3a). This reaction was performed by using 10 equiv of MeOH as glycosyl acceptor, according to the general procedure for β-glucosylation (92% yield): TLC R_f 0.60 (*n*-hexane/EtOAc, 8:2); mp 82−84 °C; ^{1}H and ^{13}C NMR ($CDCl_3$) in agreement with those already reported;[6] UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} (Δε) 251 (23.7), 239 (0.0), 231 nm (−6.2); UV (MeOH) λ_{max} 245 nm; CD (MeOH) λ_{ext} (Δε) 250 (23.4), 238 (0.0), 231 nm (−4.0). Anal. Calcd for $C_{35}H_{26}O_{10}Br_4$: C, 45.39; H, 2.83. Found: C, 45.56; H, 3.13.

(2*R*)-(−)-2-Octyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (3b). This compound was obtained by using 5 equiv of (−)-2-octanol (100 μL, 0.6 mmol) and according to the general procedure for β-glucosylation (55% yield): TLC R_f 0.65 (*n*-hexane/EtOAc, 8:2); $[\alpha]^{25}_D$ +11.7° (*c* 0.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.83 (3 H, t, J = 6.5 Hz), 1.02 (3 H, d, J = 6.2 Hz), 1.16 −1.29 (10 H, m), 3.79 (1 H, m), 4.10 (1 H, ddd, J = 9.7, 5.2 and 3.5 Hz), 4.46 (1 H, dd, J = 12.0 and 5.2 Hz), 4.58 (1 H, dd, J = 12.0 and 3.5 Hz), 4.85 (1 H, d, J = 7.9 Hz), 5.42 (1 H, d, J = 9.7 and 7.9 Hz), 5.58 (1 H, t, J = 9.7 Hz), 5.80 (1 H, t, J = 9.7 Hz), 7.44, 7.53, 7.69, 7.71, 7.80, 7.81, 7.83 and 7.84 (each: 2 H, d, J = 8.7 Hz); ^{13}C NMR ($CDCl_3$) δ 14.06, 19.76, 22.57, 25.22, 29.12, 31.77, 36.81, 63.37, 70.12, 71.65, 72.17, 73.33, 76.43, 99.39, 127.50 − 131.85, 164.29, 164.48, 165.12, 165.33; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN): λ_{ext} (Δε) 250 (18.6), 239 (0.0), 232 nm (−5.0); UV (MeOH) λ_{max} 245 nm; CD (MeOH) λ_{ext} (Δε) 249 (20.1), 239 (0.0), 234 nm (−4.9).

(2*S*)-(+)-2-Octyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (3c). This compound was prepared in 62% yield from 5 equiv of (+)-2-octanol (100 μL, 0.6 mmol), following the general procedure for β-glucosylation: TLC R_f 0.64 (*n*-hexane/EtOAc, 8:2); mp 64−66 °C; $[\alpha]^{25}_D$ +18.0° (*c* 0.1, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.78 (3 H, t, J = 7.0 Hz), 0.82−1.16 (10 H, m), 1.22 (3 H, d, J = 6.2), 3.69 (1 H, m), 4.12 (1 H, ddd, J = 9.7, 5.3 and 3.5 Hz), 4.46 (1 H, dd, J = 12.0 and 5.3 Hz), 4.60 (1 H, dd, J = 12.0 and 3.5 Hz), 4.85 (1 H, d, J = 7.9 Hz), 5.45 (1 H, dd, J = 9.7 and 7.9 Hz), 5.56 (1 H, t, J = 9.7 Hz), 5.81 (1 H, t, J = 9.7 Hz), 7.44, 7.49, 7.53, 7.54, 7.69, 7.71, 7.80 and 7.84 (each: 2 H, d, J = 8.7 Hz); ^{13}C NMR ($CDCl_3$) δ 14.04, 21.79, 22.54, 25.30, 29.27, 31.64, 36.85, 63.43, 70.10, 71.69, 72.17, 73.23, 79.02, 101.50, 127.44 − 131.87, 164.23, 164.48, 165.13, 165.35; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} (Δε) 250 (17.8), 238 (0.0), 233 nm (−4.6); UV (MeOH) λ_{max} 245 nm; CD (MeOH) λ_{ext} (Δε) 252 (17.1), 239 (0.0), 233 nm (−3.8).

(1R,2S,5*R*)-(−)-1-Menthyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (3d). Following the general procedure for β-glucosylation, 2 equiv of (−)-menthol (70 mg, 0.45 mmol) led to the desired glucopyranoside **3d** in 65% yield: TLC R_f 0.70 (*n*-hexane/EtOAc, 8:2); mp 76−78 °C; $[\alpha]^{25}_D$ −5.3° (*c* 0.4, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.68 (1 H, m), 0.70 (3 H, d, J = 6.9 Hz), 0.78 (1 H, m), 0.79 (3 H, d, J = 6.6 Hz), 0.82 (3 H, d, J = 6.9 Hz), 0.89 (1 H, m), 1.17 (1 H, br t, J = 11.8 Hz), 1.22 (1 H, m), 1.59 (2 H, m), 1.91 (1 H, br t, J = 12.1 Hz), 2.20 (1 H, m), 3.46 (1 H, dt, J = 10.6 and 4.2 Hz), 4.09 (1 H, ddd, J = 9.7, 5.3 and 3.5 Hz), 4.45 (1 H, dd, J = 12.0 and 5.3 Hz), 4.59 (1 H, dd, J = 12.0 and 3.5 Hz), 4.89 (1 H, d, J = 7.9 Hz), 5.42 (1 H, dd, J = 9.7 and 7.9 Hz), 5.57 (1 H, t, J = 9.7 Hz), 5.79 (1 H, t, J = 9.7 Hz), 7.45, 7.48, 7.67, 7.68, 7.71, 7.72, 7.80 and 7.83 (each: 2 H, d, J = 8.6 Hz); ^{1}H NMR (CD_3CN) δ 0.38 (1 H, m), 0.50 (3 H, d, J = 6.9 Hz), 0.55 (3 H, d, J = 6.5 Hz), 0.61 (3 H, d, J = 6.9 Hz), 0.74 (1 H, m), 0.99 (1 H, m), 1.08 (1 H, m), 1.34 (3 H, br d, J = 15.3 Hz), 1.77 − 1.96 (2 H, m), 3.33 (1 H, br dt, J = 10.6 and 4.3 Hz), 4.06 (1 H, ddd, J = 9.6, 4.9 and 3.6 Hz), 4.24 (1 H, dd, J = 12.0 and 4.9 Hz), 4.35 (1 H, dd, J = 12.0 and 3.6 Hz), 4.86 (1 H, d, J = 8.0 Hz), 5.18 (1 H, dd, J = 9.6 and 8.0 Hz), 5.42 (1 H, t, J = 9.6 Hz), 5.68 (1 H, t, J = 9.6 Hz), 7.35, 7.38, 7.44, 7.44, 7.48, 7.55, 7.64 and 7.68 (each: 2 H, d, J = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 15.65, 20.74, 22.06, 23.05, 25.17, 31.39, 34.04, 40.73, 47.31, 63.45, 70.24, 71.62, 72.21, 73.44, 79.02, 98.68, 127.52−131.85, 164.33, 164.52, 165.12, 165.33; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} (Δε) 249 (17.7), 238 (0.0), 232 nm (−4.1); UV (MeOH) λ_{max} 245 nm; CD (MeOH) λ_{ext}(Δε) 250 (17.1), 239 (0.0), 235 nm (−3.4).

(1S,2R,5S)-(+)-1-Menthyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (3e). β-Glucosylation of (+)-menthol (75 mg, 0.48 mmol, 2 equiv) afforded **3e** (143 mg, 57% yield): TLC R_f 0.65 (*n*-hexane/EtOAc, 8:2); mp 96−98 °C; $[\alpha]^{25}_D$ +16.7° (*c* 0.1, $CHCl_3$); ^{1}H NMR ($CDCl_3$) δ 0.42 (3 H, d, J = 6.9 Hz), 0.51 (3 H, d, J = 6.9 Hz), 0.80 (3 H, d, J = 6.5 Hz), 0.84 (2 H, m), 1.10 (1 H, q, J = 11.1 Hz), 1.23 (1 H, m), 1.55 (3 H, m), 1.85 (1 H, m), 2.16 (1 H, br d, J = 12.4 Hz), 3.32 (1 H, dt, J = 10.6 and 4.4 Hz), 4.14 (1 H, ddd, J = 9.7, 6.2 and 3.2 Hz), 4.46 (1 H, dd, J = 12.0 and 6.2 Hz), 4.59 (1 H, dd, J = 12.0 and 3.2 Hz), 4.85 (1 H, d, J = 7.7 Hz), 5.48 (1 H, dd, J = 9.7 and 7.7 Hz), 5.52 (1 H, t, J = 9.7 Hz), 5.81 (1 H, t, J = 9.7 Hz), 7.44, 7.50, 7.53, 7.53, 7.67, 7.73, 7.79 and 7.85 (each: 2 H, d, J = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 15.57, 20.64, 22.11, 22.69,

24.76, 31.65, 34.03, 42.96, 48.00, 63.64, 70.18, 71.70, 72.13, 73.23, 83.40, 102.41, 127.41–131.88, 164.26, 164.53, 165.14, 165.33; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 250 (9.5), 235 (0.0), 232 nm (−0.5); UV (MeOH) λ_{max} 245 nm; CD (MeOH) λ_{ext} ($\Delta\epsilon$) 249 (16.9), 239 (0.0), 234 nm (−4.7).

[(1*S*)-*endo*]-(−)-2-Bornyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (3f). Using 5 equiv of (−)-borneol (158 mg, 1.02 mmol) and following the general procedure, compound **3f** was obtained in 52% yield: TLC R_f 0.68 (*n*-hexane/EtOAc, 8:2); mp 74–76 °C; $[\alpha]^{25}_D$ +9.0° (*c* 1.6, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.67 (1 H, m), 0.77 (3 H, s), 0.79 (3 H, s), 0.81 (1 H, m), 0.82 (3 H, s), 1.11 (1 H, br t, *J* = 10.6 Hz), 1.52 (2 H, m), 1.80 (1 H, br t, *J* = 10.6 Hz), 2.07 (1 H, m), 4.01 (1 H, br d, *J* = 8.2 Hz), 4.14 (1 H, ddd, *J* = 9.7, 5.2 and 3.7 Hz), 4.55 (1 H, dd, *J* = 12.0 and 5.2 Hz), 4.63 (1 H, dd, *J* = 12.0 and 3.7 Hz), 4.82 (1 H, d, *J* = 7.9 Hz), 5.52 (1 H, dd, *J* = 9.7 and 7.9 Hz), 5.65 (1 H, t, *J* = 9.7 Hz), 5.86 (1 H, t, *J* = 9.7 Hz), 7.45, 7.48, 7.50, 7.53, 7.69, 7.71, 7.82 and 7.83 (each: 2 H, d, *J* = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 13.30, 18.76, 19.62, 26.31, 27.95, 35.97, 44.74, 47.89, 49.06, 63.33, 70.21, 71.63, 72.06, 73.08, 83.95, 99.81, 127.47–131.86, 164.24, 164.47, 165.11, 165.33; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 250 (17.2), 239 (0.0), 232 nm (−4.8); UV (MeOH) λ_{max} 245 nm; CD (MeOH) λ_{ext} ($\Delta\epsilon$) 251 (15.5), 240 (0.0), 235 nm (−4.4).

[(1*R*)-*endo*]-(+)-2-Bornyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (3g). Using the general procedure for β-glucosylation, (+)-borneol (158 mg, 1.02 mmol, 5 equiv) was transformed into compound **3g** (136 mg, 63% yield): TLC R_f 0.71 (*n*-hexane/EtOAc, 8:2); mp 95–97 °C; $[\alpha]^{25}_D$ +23.3° (*c* 2.2, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.60 (3 H, s), 0.76 (3 H, s), 0.78 (3 H, s), 1.00 (1 H, m), 1.21 (1 H, m), 1.25 (1 H, m), 1.55 (1 H, m), 1.59 (1 H, m), 1.70 (1 H, m), 2.07 (1 H, m), 3.80 (1 H, br d, *J* = 9.7 Hz), 4.14 (1 H, ddd, *J* = 9.7, 5.3 and 3.6 Hz), 4.54 (1 H, dd, *J* = 12.0 and 5.3 Hz), 4.62 (1 H, dd, *J* = 12.0 and 3.6 Hz), 4.84 (1 H, d, *J* = 7.9 Hz), 5.56 (1 H, dd, *J* = 9.7 and 7.9 Hz), 5.63 (1 H, t, *J* = 9.7 Hz), 5.84 (1 H, t, *J* = 9.7 Hz), 7.45, 7.49, 7.52, 7.53, 7.68, 7.71, 7.80 and 7.84 (each: 2 H, d, *J* = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 13.50, 18.67, 19.53, 26.31, 27.86, 37.09, 44.87, 47.40, 49.35, 63.35, 70.13, 71.59, 72.14, 73.11, 87.82, 102.64, 127.44–131.85, 164.29, 164.47, 165.11, 165.32; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 250 (16.8), 238 (0.0), 231 nm (−3.3); UV (MeOH) λ_{max} 245 nm; CD (MeOH) λ_{ext} ($\Delta\epsilon$) 250 (15.4), 239 (0.0) 233 nm (−4.3).

1-*O*-Acetyl-2,3,4,6-tetrakis-*O*-(*p*-bromobenzoyl)-β-D-glucopyranoside (3m). A stirred solution of **2** (150 mg, 0.15 mmol) in dry CH_2Cl_2 (2 mL) containing 1,1,3,3-tetramethylurea (36 μL) at 0 °C under Ar was treated with silver acetate (50 mg, 0.3 mmol) in the dark. After the reaction was quenched with a few drops of water and filtered through a bed of Celite with CH_2Cl_2, the filtrate was evaporated under diminished pressure. Preparative TLC afforded **3m** (69 mg, 48% yield): TLC R_f 0.40 (*n*-hexane/EtOAc, 8:2); $[\alpha]^{25}_D$ +63.8° (*c* 1.2, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 2.07 (3 H, s), 4.27 (1 H, ddd, *J* = 9.7, 4.7 and 3.0 Hz), 4.46 (1 H, dd, *J* = 12.3 and 4.7 Hz), 4.59 (1 H, dd, *J* = 12.3 and 3.0 Hz), 5.61 (1 H, dd, *J* = 9.7 and 8.3 Hz), 5.66 (1 H, t, *J* = 9.7 Hz), 5.86 (1 H, t, *J* = 9.7 Hz), 6.06 (1 H, d, *J* = 8.3 Hz), 7.47, 7.52, 7.56, 7.59, 7.69, 7.74, 7.80, and 7.89 (each: 2 H, d, *J* = 8.7 Hz); ^{13}C NMR ($CDCl_3$) δ 20.76, 62.70, 69.10, 70.91, 72.87, 73.13, 91.87, 127.22–131.96, 164.27, 164.37, 164.93, 165.30, 168.90; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 250 (26.2), 239 (0.0), 231 nm (−5.1); UV (MeOH) λ_{max} 245 nm; CD (MeOH) λ_{ext} ($\Delta\epsilon$) 251 (22.0), 239 (0.0), 235 nm (−4.8).

4,6-*O*-Benzylidene-D-glucopyranose (4). A mixture of 5 g (27.8 mmol) of D-glucopyranose, 20 g of freshly fused and powdered zinc chloride, and 100 mL of benzaldehyde was shaken for 4 h at room temperature. The reaction was monitored by TLC (R_f 0.46, $CHCl_3$/MeOH, 9:1). The reaction mixture was then cooled in an ice bath, poured into cold *n*-hexane/H_2O (1:1), and kept for 0.5 h at 0 °C. The resulting crystalline mass was filtered through Celite and washed in the funnel with cold water (2 × 25 mL). Column chromatography with $CHCl_3$/MeOH (1:1) as the eluant yielded **4** (3.58 g, 48% yield) as a 2:3 mixture of α- and β-anomers: ^1H NMR (CD_3OD) δ 4.17 (1 H, dd, *J* = 10.7 and 4.9 Hz), 4.25 (1 H, dd, *J* = 10.7 and 4.3 Hz), 4.59 (1 H, d, *J* = 7.7 Hz), 5.13 (1 H, d, *J* = 3.9 Hz), 5.55 (2 H, br s), 7.32 (6 H, m), 7.48 (4 H, m).

4,6-*O*-Benzylidene-1,2,3-tris-*O*-(*p*-bromobenzoyl)-D-glucopyranoside (5). This reaction was carried out according to the general procedure for *p*-bromobenzoylation. Starting from 3 g (11.2 mmol) of **4**, compound **5** (8.3 g, 91% yield) was obtained as a 1:2 mixture of α- and β-anomers after purification, TLC R_f 0.77, *n*-hexane/EtOAc (7:3). **α-Anomer**: mp 201.7–204.1 °C; ^1H NMR ($CDCl_3$) δ 3.87 (1 H, t, *J* = 10.1 Hz), 4.04 (1 H, t, *J* = 9.6 Hz), 4.22 (1 H, dd, *J* = 9.6 and 4.8 Hz), 4.41 (1 H, dd, *J* = 10.1 and 4.8 Hz), 5.56 (1 H, dd, *J* = 9.6 and 3.8 Hz), 5.61 (1 H, s), 6.10 (1 H, t, *J* = 9.6 Hz), 6.73 (1 H, d, *J* = 3.8 Hz), 7.32–7.42 (5 H, m), 7.45, 7.54, 7.66, 7.69, 7.85, and 7.96 (each: 2 H, d, *J* = 8.6 Hz). **β-Anomer**: mp 132.7–134.2 °C; ^1H NMR ($CDCl_3$) δ 3.90 (2 H, m), 4.02 (1 H, t, *J* = 9.1 Hz), 4.49 (1 H, br d, *J* = 5.9 Hz), 5.57 (1 H, s), 5.71 (1 H, dd, *J* = 9.1 and 7.9 Hz), 5.87 (1 H, t, *J* = 9.1 Hz), 6.18 (1 H, d, *J* = 7.9 Hz), 7.31–7.35 (3 H, m), 7.40–7.42 (2 H, m), 7.49, 7.53, 7.57, 7.75, 7.82, and 7.87 (each: 2 H, d, *J* = 8.6 Hz).

1,2,3-Tris-*O*-(*p*-bromobenzoyl)-D-glucopyranose (6). To a solution of compound **5** (8.2 g, 10.0 mmol) in CH_2Cl_2 (the minimum amount to dissolve it) were added MeOH and CH_2Cl_2, avoiding precipitation of compound **5**, up to approximately a total volume of 20 mL. *p*-Toluenesulfonic acid was then added, and the reaction was monitored by TLC (R_f 0.37, $CHCl_3$/^{i}PrOH, 7:3). The reaction mixture was neutralized with Et_3N, the solvent evaporated, and the residue subjected to column chromatography to afford compound **6** (6.5 g, 89% yield) as a 2:3 mixture of α- and β-anomers: ^1H NMR (mixture of anomers) ($CDCl_3$) δ 3.77–4.26 (8 H, m), 5.50 (1 H, dd, *J* = 10.2 and 3.8 Hz), 5.49–5.65 (2 H, m), 5.85 (1 H, dd, *J* = 10.2 and 9.0 Hz), 6.12 (1 H, d, *J* = 7.8 Hz), 6.70 (1 H, d, *J* = 3.8 Hz), 7.45–7.94 (24 H, aromatic-H's).

1,2,3-Tris-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-D-glucopyranoside (7). To a solution of the anomers of **6** (6.4 g, 8.8 mmol) in dry pyridine (40 mL) were added *p*-methoxycinnamoyl chloride (5.3 g, 27 mmol) and DMAP as catalyst. The reaction was then heated at 60 °C and monitored by TLC ($R_{f\alpha}$ 0.67, $R_{f\beta}$ 0.55, *n*-hexane/EtOAc, 7:3). Then, 1 mL of H_2O was added, the mixture was extracted with CH_2Cl_2, dried over sodium sulfate, and filtered, and the solvent was removed in vacuum. Purification by flash column chromatography afforded compound **7** (81% yield). **α-Anomer**: ^1H NMR ($CDCl_3$) δ 3.82 and 3.83 (each: 3 H, s), 4.43 (2 H, br s), 4.49 (1 H, br d, *J* = 2.8 Hz), 5.58 (1 H, dd, *J* = 9.9 and 3.7 Hz), 5.66 (1 H, t, *J* = 9.9 Hz), 6.12 (1 H, t, *J* = 9.9 Hz), 6.20 and 6.33 (each: 1 H, d, *J* = 15.9 Hz), 6.80 (1 H, d, *J* = 3.7 Hz), 6.85 (4 H, d, *J* = 8.7 Hz), 7.39 and 7.43 (each: 2H, d, *J* = 8.7 Hz), 7.46 and 7.49 (each: 2 H, d, *J* = 8.6 Hz), 7.59 and 7.65 (each: 1 H, d, *J* = 15.9 Hz), 7.68, 7.70, 7.78 and 7.98 (each: 2 H, d, *J* = 8.6 Hz). **β-Anomer**: mp 110.5–113.7 °C; ^1H NMR ($CDCl_3$) δ 3.82 and 3.84 (each: 3 H, s), 4.24 (1 H, br d, *J* = 9.8 Hz), 4.44 (2 H, d, *J* = 3.3 Hz), 5.63 (1 H, t, *J* = 9.8 Hz), 5.75 (1 H, br d, *J* = 7.8 Hz), 5.86 (1 H, t, *J* = 9.8 Hz), 6.18 (1 H, d, *J* = 15.9 Hz), 6.20 (1 H, d, *J* = 7.8 Hz), 6.32 (1 H, d, *J* = 15.9 Hz), 6.85 (4 H, d, *J* = 8.7 Hz), 7.39 and 7.48 (each: 2 H, d, *J* = 8.7 Hz), 7.49, 7.51 and 7.56 (each: 2 H, d, *J* = 8.4 Hz), 7.56 and 7.66 (each: 1 H, d, *J* = 15.9 Hz), 7.72, 7.76 and 7.88 (each: 2 H, d, *J* = 8.4 Hz).

2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-α-D-glucopyranosyl Bromide (8). This reaction was performed according to the general procedure for preparation of glucopyranosyl bromides, starting from the mixture of anomers of **7** (7.9 g, 7.5 mmol) and carrying out a workup of type b. The reaction was monitored by TLC using *n*-hexane/EtOAc (7:3) as the eluant: R_f 0.56. Recrystallization in Et_2O/*n*-hexane afforded **8** (5.9 g, 85% yield): mp 98.2–100.9 °C; $[\alpha]^{25}_D$ +113.7° (*c* 1.5, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 3.82 (3 H, s), 3.84 (3 H, s), 4.44 (1 H, dd, *J* = 12.5 and 4.4 Hz), 4.46 (1 H, dd, *J* = 12.5 and 2.8 Hz), 4.57 (1 H, m), 5.26 (1 H, dd, *J* = 9.9 and 4.0 Hz), 5.64 (1 H, t, *J* = 9.9 Hz), 6.10 (1 H, t, *J* = 9.9 Hz), 6.20 and 6.36 (each: 1 H, d, *J* = 15.9 Hz), 6.81 (1 H, d, *J* = 4.0 Hz), 6.86, 6.88, 7.40 and 7.47 (each: 2 H, d, *J* = 8.7 Hz), 7.49 and 7.55 (each: 2 H, d, *J* = 8.6 Hz), 7.59 and 7.69 (each: 2 H, d, *J* = 15.9 Hz), 7.78 and 7.86 (each: 2 H, d, *J* = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 55.29, 61.40, 67.12, 71.10, 71.49, 72.62, 86.65,

96.07, 113.31–114.48, 126.52–131.94, 145.53, 146.61, 161.47, 161.74, 164.46, 164.87, 165.51, 166.56. Anal. Calcd for $C_{40}H_{33}O_{11}Br_3$: C, 51.69; H, 3.58. Found: C, 51.66; H, 3.51.

Methyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9a). Using the general procedure for β-glucosylation and 10 equiv of MeOH, compound **9a** was obtained in 93% yield: TLC R_f 0.48 (*n*-hexane/EtOAc, 7:3); $[\alpha]^{25}_D$ +56.3° (*c* 0.1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 3.55, 3.80, and 3.82 (each: 3 H, s), 4.02 (1 H, m), 4.44 (2 H, d, *J* = 3.9 Hz), 4.71 (1 H, d, *J* = 7.7 Hz), 5.42 (1 H, d, *J* = 9.6 and 7.7 Hz), 5.52 (1 H, t, *J* = 9.6 Hz), 5.74 (1H, t, *J* = 9.6 Hz), 6.16 and 6.32 (each: 1 H, d, *J* = 15.9 Hz), 6.82, 6.83, 7.36, and 7.41 (each: 2 H, d, *J* = 8.7 Hz), 7.44, (2 H, d, *J* = 8.6 Hz), 7.50 (1 H, d, *J* = 16.0 Hz), 7.52 (2 H, d, *J* = 8.6 Hz), 7.60 (1 H, d, *J* = 16.0 Hz), 7.73 and 7.81 (each: 2 H, d, *J* = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 55.31, 57.10, 62.63, 68.97, 71.97, 72.06, 73.40, 101.77, 113.29, 113.68, 114.24, 114.27, 114.75, 126.61–131.73, 145.26, 146.25, 161.44, 161.66, 164.41, 165.12, 165.57, 166.76; UV (CH_3CN) λ_{max} 311, 236 nm; CD (CH_3CN) λ_{ext} (Δε) 322 (14.6), 310 (0.0), 285 (−22.0), 264 (0.0), 251 (51.9), 239 (0.0), 233 nm (−9.7); UV (MeOH) λ_{max} 310, 236 nm; CD (MeOH) λ_{ext} (Δε) 326 (12.3), 313 (0.0), 286 (−22.8), 265 (0.0), 252 (50.1), 240 (0.0), 233 nm (−14.1); CD (MeOH, −80 °C) λ_{ext} (Δε) 326 (26.8), 312 (0.0), 290 (−26.8), 264 (0.0), 253 (53.0), 240 (0.0), 235 nm (−17.1).

(2*R*)-(−)-2-Octyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9b). Glucosylation of (−)-2-octanol (80 μL, 0.5 mmol, 5 equiv) led to **9b** (58 mg, 60% yield): TLC R_f 0.71 (*n*-hexane/EtOAc, 7:3); $[\alpha]^{25}_D$ +2.0° (*c* 3.5, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.83 (3 H, t, *J* = 6.8 Hz), 1.03 (3 H, d, *J* = 6.1 Hz), 1.20–1.42 (10 H, m), 3.80 (1 H, m), 3.82 (3H, s), 3.83 (3H, s), 3.98 (1 H, m), 4.40 (2 H, d, *J* = 4.3 Hz), 4.81 (1 H, d, *J* = 7.9 Hz), 5.38 (1 H, dd, *J* = 9.7 and 7.9 Hz), 5.48 (1 H, t, *J* = 9.7 Hz), 5.70 (1 H, t, *J* = 9.7 Hz), 6.16 and 6.30 (each: 1 H, d, *J* = 15.9 Hz), 6.83 (4 H, d, *J* = 8.6 Hz), 7.36 and 7.40 (each: 2 H, d, *J* = 8.6 Hz), 7.47 and 7.53 (each: 2 H, d, *J* = 8.6 Hz), 7.54 and 7.65 (each: 1 H, d, *J* = 15.9 Hz), 7.74 and 7.80 (each: 2 H, d, *J* = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 14.02, 19.69, 22.52, 25.11, 29.08, 31.71, 36.77, 55.24, 62.86, 69.24, 71.69, 72.31, 73.56, 76.15, 99.22, 113.72, 114.17, 114.21, 114.77, 126.57–131.68, 145.08, 146.12, 161.36, 161.58, 164.24, 165.10, 165.60, 166.69; UV (CH_3CN): λ_{max} 311, 236 nm; CD (CH_3CN) λ_{ext} (Δε) 322 (9.6), 311 (0.0), 288 (−15.9), 265 (0.0), 251 (49.0), 240 (0.0), 233 nm (−13.2).

(2*S*)-(+)-2-Octyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9c). This compound was prepared in 64% yield as described in the general procedure for β-glucosylation by using 5 equiv of (+)-2-octanol (100 μL, 0.6 mmol): TLC R_f 0.68 (*n*-hexane/EtOAc, 7:3); $[\alpha]^{25}_D$ +6.5° (*c* 3.1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.77 (3 H, t, *J* = 7.3 Hz), 0.87 (3 H, m), 1.00–1.09 (7 H, m), 1.25 (3 H, d, *J* = 6.4 Hz), 3.71 (1 H, m), 3.82 (3 H, s), 3.83 (3 H, s), 4.00 (1 H, m), 4.41 (2 H, d, *J* = 4.7 Hz), 4.81 (1 H, d, *J* = 7.9 Hz), 5.41 (1 H, dd, *J* = 9.7 and 7.9 Hz), 5.46 (1 H, t, *J* = 9.7 Hz), 5.71 (1 H, d, *J* = 9.7 Hz), 6.16 and 6.30 (each: 1 H, d, *J* = 16.0 Hz), 6.83, 6.84, 7.37, and 7.40 (each: 2 H, d, *J* = 8.8 Hz), 7.46 and 7.52 (each: 2 H, d, *J* = 8.7 Hz), 7.54 and 7.65 (each: 1 H, d, *J* = 16.0 Hz), 7.73 and 7.81 (each: 2 H, d, *J* = 8.7 Hz); ^{13}C NMR ($CDCl_3$) δ 14.00, 21.78, 22.49, 25.24, 29.25, 31.59, 36.82, 55.27, 62.86, 69.20, 71.74, 72.33, 73.47, 78.82, 101.37, 113.72–114.80, 126.59–131.69, 145.11, 146.16, 161.38, 161.61, 164.19, 165.12, 165.60, 166.69; UV (CH_3CN) λ_{max} 311, 236 nm; CD (CH_3CN) λ_{ext} (Δε) 322 (9.0), 311 (0.0), 288 (−15.7), 265 (0.0), 252 (47.3), 240 (0.0), 232 nm (−12.3).

(1*R*,2*S*,5*R*)-(−)-1-Menthyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9d). This compound was obtained in 47% yield from 5 equiv of (−)-menthol (210 mg, 1.34 mmol) following the general procedure for β-glucosylation: TLC R_f 0.72 (*n*-hexane/EtOAc, 7:3); $[\alpha]^{25}_D$ −21.6° (*c* 2.2, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.67 (1 H, m), 0.75 (3 H, d, *J* = 6.9 Hz), 0.77 (1 H, m), 0.79 (3 H, d, *J* = 6.6 Hz), 0.84 (3 H, d, *J* = 6.9 Hz), 0.97 (1 H, m), 1.22 (1 H, br t, *J* = 12.0 Hz), 1.35 (1 H, m), 1.56 (2 H, m), 1.91 (1 H, m), 2.25 (1 H, m), 3.47 (1 H, m), 3.82 (3 H, s), 3.83 (3 H, s), 3.99 (1 H, m), 4.42 (1 H, dd, *J* = 11.9 and 5.2 Hz), 4.45 (1 H, dd, *J* = 11.9 and 4.1 Hz), 4.84 (1 H, d, *J* = 8.0 Hz), 5.37 (1 H, dd, *J* = 9.7 and 8.0 Hz), 5.46 (1 H, t, *J* = 9.7 Hz), 5.69 (1 H, t, *J* = 9.7 Hz), 6.16 and 6.28 (each: 1 H, d, *J* = 16.0 Hz), 6.83, 6.83, 7.36 and 7.39 (each: 2 H, d, *J* = 8.8 Hz), 7.47 and 7.53 (each: 2 H, d, *J* = 8.6 Hz), 7.54 and 7.63 (each: 1 H, d, *J* = 16.0 Hz), 7.74 and 7.81 (each: 2 H, d, *J* = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 15.58, 20.80, 22.06, 22.97, 25.09, 31.35, 34.04, 40.83, 47.30, 55.30, 63.04, 69.43, 71.64, 72.37, 73.69, 79.09, 98.75, 113.78, 114.23, 114.25, 114.83, 126.64–131.73, 145.09, 146.18, 161.40, 161.63, 164.32, 165.15, 165.70, 166.73; UV (CH_3CN) λ_{max} 311, 236 nm; CD (CH_3CN) λ_{ext} (Δε) 324 (6.6), 311 (0.0), 283 (−12.5), 266 (0.0), 252 (51.0), 240 (0.0), 232 nm (−14.1); UV (MeOH) λ_{max} 310, 236 nm; CD (MeOH) λ_{ext} (Δε) 324 (6.9), 314 (0.0), 291 (−15.5), 266 (0.0), 253 (52.4), 241 (0.0), 234 nm (−13.7); CD (MeOH, −80 °C) λ_{ext} (Δε) 327 (16.2), 312 (0.0), 291 (−17.4), 265 (0.0), 252 (53.0), 241 (0.0), 235 nm (−14.9).

(1*S*,2*R*,5*S*)-(+)-1-Menthyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9e). Following the general procedure, glucosylation of (+)-menthol (200 mg, 1.28 mmol, 5 equiv) led to **9e** (133 mg, 52% yield): TLC R_f 0.71 (*n*-hexane/EtOAc, 7:3); mp 107–109 °C; $[\alpha]^{25}_D$ +10.6° (*c* 2.9, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 0.40 (3 H, d, *J* = 6.9 Hz), 0.51 (3 H, d, *J* = 6.9 Hz), 0.86 (2 H, m), 0.86 (3 H, d, *J* = 6.5 Hz), 1.11 (1 H, q, *J* = 11.0 Hz), 1.24 (1 H, m), 1.52 (3 H, m), 1.84 (1 H, m), 2.20 (1 H, m), 3.32 (1 H, m), 3.82 (3 H s), 3.83 (3 H, s), 4.02 (1 H, ddd, *J* = 9.8, 6.0 and 3.8 Hz), 4.39 (1 H, dd, *J* = 12.0 and 3.8 Hz), 4.42 (1 H, dd, *J* = 12.0 and 6.0 Hz), 4.82 (1 H, d, *J* = 7.8 Hz), 5.44 (1 H, dd, *J* = 9.8 and 7.8 Hz), 5.44 (1 H, t, *J* = 9.8 Hz), 5.72 (1 H, t, *J* = 9.8 Hz), 6.16 and 6.30 (each: 1 H, d, *J* = 16.0 Hz), 6.84 (4 H, d, *J* = 8.8 Hz), 7.37 and 7.40 (each: 2 H, d, *J* = 8.8 Hz), 7.46 and 7.53 (each: 2 H, d, *J* = 8.7 Hz), 7.54 and 7.65 (each: 1 H, d, *J* = 16.0 Hz), 7.73 and 7.79 (each: 2 H, d, *J* = 8.7 Hz); ^{13}C NMR ($CDCl_3$) δ 15.54, 20.62, 22.23, 22.68, 24.72, 31.59, 34.02, 42.93, 47.91, 55.27, 63.03, 69.29, 71.68, 72.28, 73.47, 83.25, 102.30, 113.70, 114.20, 114.24, 114.75, 126.59–131.71, 145.14, 146.21, 161.39, 161.63, 164.23, 165.14, 165.63, 166.70; UV (CH_3CN) λ_{max} 311, 236 nm; CD (CH_3CN) λ_{ext} (Δε) 323 (6.6), 313 (0.0), 287 (−14.2), 265 (0.0), 251 (48.3), 239 (0.0), 234 nm (−9.5); UV (MeOH) λ_{max} 311, 236 nm; CD (MeOH) λ_{ext} (Δε) 329 (5.3), 315 (0.0), 290 (−13.3), 266 (0.0), 252 (50.7), 241 (0.0), 234 nm (−11.0).

Ethyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9h). Using the general procedure for β-glucosylation and 10 equiv of EtOH, compound **9h** was obtained in 97% yield: TLC R_f 0.53 (*n*-hexane/EtOAc, 7:3); $[\alpha]^{25}_D$ +40.3° (*c* 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.17 (3 H, t, *J* = 7.1 Hz), 3.64 (1 H, dd, *J* = 9.8 and 7.1 Hz), 3.81 (3 H, s), 3.83 (3 H, s), 3.96 (1 H, dd, *J* = 9.8 and 7.1 Hz), 4.01 (1 H, m), 4.42 (2 H, d, *J* = 4.1 Hz), 4.79 (1 H, d, *J* = 7.9 Hz), 5.41 (1 H, dd, 9.7 and 7.9 Hz), 5.50 (1 H, t, *J* = 9.7 Hz), 5.71 (1 H, t, *J* = 9.7 Hz), 6.16 and 6.32 (each: 1 H, d, *J* = 16.0 Hz), 6.83, 6.84, 7.36 and 7.41 (each: 2 H, d, *J* = 8.8 Hz), 7.46 and 7.53 (each: 2 H, d, *J* = 8.7 Hz), 7.54 and 7.65 (each: 1 H, d, *J* = 16.0 Hz), 7.73 and 7.81 (each: 2 H, d, *J* = 8.7 Hz); ^{13}C NMR ($CDCl_3$) δ 15.05, 55.31, 62.74, 65.75, 69.03, 71.93, 72.18, 73.47, 100.70, 113.29–114.79, 126.63–132.31, 145.22, 146.22, 161.43, 161.65, 164.36, 165.14, 165.59, 166.78; UV (CH_3CN) λ_{max} 311, 236 nm; CD (CH_3CN) λ_{ext} (Δε) 324 (13.6), 311 (0.0), 285 (−21.8), 264 (0.0), 252 (52.3), 239 (0.0), 233 nm (−11.6).

Isopropyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9i). Using 10 equiv of *i*PrOH and following the general procedure for β-glucosylation, compound **9i** was obtained in 73% yield: TLC R_f 0.4 (*n*-hexane/EtOAc, 7:3); $[\alpha]^{25}_D$ + 24.8° (*c* 0.6, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.07 and 1.23 (each: 3 H, d, *J* = 6.1 Hz), 3.81 and 3.82 (each: 3 H, s), 4.00 (2 H, m), 4.41 (2 H, d, *J* = 4.4 Hz), 4.84 (1 H, d, *J* = 7.9 Hz), 5.39 (1 H, dd, *J* = 9.7 and 7.9 Hz), 5.49 (1 H, t, *J* = 9.7 Hz), 5.72 (1 H, t, *J* = 9.7 Hz), 6.16 and 6.30 (each: 1 H, d, *J* = 16.0 Hz), 6.83, 6.83, 7.36, and 7.40 (each: 2 H, d, *J* = 8.8 Hz), 7.46 and 7.53 (each: 2 H, d, *J* = 8.7 Hz), 7.54 and 7.65 (each: 1 H, d, *J* = 16.0 Hz), 7.74 and 7.80 (each: 2 H, d, *J* = 8.7 Hz); ^{13}C NMR ($CDCl_3$) δ 21.98, 23.25, 55.33, 62.89, 69.20, 71.85, 72.35, 73.17, 73.54, 99.78, 113.31–114.86, 126.66–132.43, 145.18, 146.20, 161.43, 161.66, 164.30, 165.17, 165.63, 166.78; UV (CH_3CN) λ_{max} 310, 236 nm;

CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 322 (11.5), 311 (0.0), 288 (−19.8), 265 (0.0), 251 (50.8), 239 (0.0), 233 nm (−11.9).

Cyclohexyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-*bis*-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9j). Using the general procedure for β-glucosylation and 10 equiv of cyclohexanol, compound **9j** was obtained in 84% yield: TLC R_f 0.62 (*n*-hexane/EtOAc, 7:3); mp 136 °C; $[\alpha]^{25}_D$ +17.6° (*c* 1.3, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.13−1.28 (4 H, m), 1.40−1.60 (4 H, m), 1.65 (1 H, m), 1.93 (1 H, m), 3.67 (1 H, m), 3.82 (3 H, s), 3.83 (3 H, s), 3.99 (1 H, m), 4.40 (1 H, dd, *J* = 12.1 and 3.9 Hz), 4.45 (1 H, dd, *J* = 12.1 and 5.3 Hz), 4.86 (1 H, d, *J* = 7.9 Hz), 5.39 (1 H, dd, *J* = 9.7 and 7.9 Hz), 5.49 (1 H, t, *J* = 9.7 Hz), 5.73 (1 H, t, *J* = 9.7 Hz), 6.16 and 6.30 (each: 1 H, d, *J* = 15.9 Hz), 6.83 (4 H, br d, *J* = 7.2 Hz), 7.36 and 7.40 (each: 2 H, d, *J* = 8.7 Hz), 7.47 and 7.53 (each: 2 H, d, *J* = 8.6 Hz), 7.54 and 7.65 (each: 1 H, d, *J* = 15.9 Hz), 7.74 and 7.80 (each: 2 H, d, *J* = 8.6 Hz); ^{13}C NMR ($CDCl_3$) δ 23.40, 23.58, 25.30, 31.49, 33.12, 55.24, 62.83, 69.20, 71.70, 72.29, 73.49, 78.08, 99.44, 113.72, 114.17, 114.20, 114.79, 126.56−131.68, 145.08, 146.10, 161.35, 161.58, 164.23, 165.10, 165.57, 166.69; UV (CH_3CN) λ_{max} 311, 236 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 323 (10.9), 312 (0.0), 285 (−20.4), 264 (0.0), 251 (50.5), 239 (0.0), 232 nm (−12.0).

***tert*-Butyl 2,3-Bis-*O*-(*p*-bromobenzoyl)-4,6-bis-*O*-(*p*-methoxycinnamoyl)-β-D-glucopyranoside (9k).** Glucosylation of ^{t}BuOH (100 μL, 1.06 mmol, 10 equiv) was carried out as described in the general procedure to afford **9k** (49 mg, 50% yield): TLC R_f 0.5 (*n*-hexane/EtOAc, 7:3); $[\alpha]^{25}_D$ +13.1° (*c* 1.5, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.20 (9 H, s), 3.82 (3 H, s), 3.83 (3 H, s), 4.01 (1 H, m), 4.38 (2 H, d, *J* = 4.6 Hz), 4.92 (1 H, d, *J* = 7.9 Hz), 5.38 (1 H, dd, *J* = 9.7 and 7.9 Hz), 5.43 (1 H, t, *J* = 9.7 Hz), 5.73 (1 H, t, *J* = 9.7 Hz), 6.16 and 6.28 (each: 1 H, d, *J* = 16.0 Hz), 6.84, 6.85, 7.37 and 7.40 (each: 2 H, d, *J* = 8.8 Hz), 7.46 and 7.53 (each: 2 H, d, *J* = 8.5 Hz), 7.54 and 7.64 (each: 1 H, d, *J* = 16.0 Hz), 7.74 and 7.80 (each: 2 H, d, *J* = 8.5 Hz); ^{13}C NMR ($CDCl_3$) δ 28.42, 55.31, 63.04, 69.32, 71.78, 72.32, 73.66, 76.72, 95.67, 113.74, 114.25, 114.86, 126.63−131.77, 145.06, 146.19, 161.41, 161.64, 164.13, 165.15, 165.65, 166.68; UV (CH_3CN) λ_{max} 311, 236 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 321 (7.4), 312 (0.0), 287 (−16.2), 265 (0.0), 251 (51.4), 239 (0.0), 232 nm (−12.4).

1,2,3,4,6-Pentakis-*O*-(*p*-bromobenzoyl)-L-glucopyranoside (10). A stirred solution of L-glucopyranose (500 mg, 2.8 mmol) in dry pyridine (20 mL) was treated as described in the general procedure for *p*-bromobenzoylation, affording compound **10** (2.14 g, 70% yield) as a 2:1 mixture of α- and β-anomers. TLC $R_{f\beta}$ 0.62, $R_{f\alpha}$ 0.45 (*n*-hexane/EtOAc, 8:2). ^1H and ^{13}C NMR ($CDCl_3$) for α- and β-anomers: see compound **1**.

2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-α-L-glucopyranosyl Bromide (11). Following the general procedure for glucosyl bromides, **10** (α- and β-anomers) (1 g, 0.91 mmol) was transformed to the desired product **11** (683 mg, 77% yield). A workup of type a was used: TLC R_f 0.65 (*n*-hexane/EtOAc, 8:2); $[\alpha]^{25}_D$ −83.7° (*c* 2.1, $CHCl_3$); ^1H and ^{13}C NMR ($CDCl_3$) see compound **2**. Anal. Calcd for $C_{34}H_{23}O_9Br_5$: C, 41.88; H, 2.38. Found: C, 41.85; H, 2.19.

(2*R*)-(−)-2-Octyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-L-glucopyranoside (12b). Using the general procedure for β-glucosylation, (−)-2-octanol (80 μL, 0.5 mmol, 5 equiv) was transformed to **12b** (58 mg, 57% yield): TLC R_f 0.64 (*n*-hexane/EtOAc, 8:2); $[\alpha]^{25}_D$ −20.2° (*c* 0.5, $CHCl_3$); ^1H and ^{13}C NMR ($CDCl_3$) see compound **3c**; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} 250 (−17.4), 238 (0.0), 233 nm (4.3).

(2*S*)-(+)-2-Octyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-L-glucopyranoside (12c). Standard β-glucosylation using 5 equiv of (+)-2-octanol (80 μL, 0.5 mmol) led to **12c** (53 mg, 52% yield): TLC R_f 0.65 (*n*-hexane/EtOAc, 8:2); $[\alpha]^{25}_D$ −10.3° (*c* 1.1, $CHCl_3$); ^1H and ^{13}C NMR ($CDCl_3$) see compound **3b**; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 250 (−18.8), 239 (0.0), 231 nm (5.0).

(1*R*,2*S*,5*R*)-(−)-1-Menthyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-L-glucopyranoside (12d). Using the general procedure, glucosylation of (−)-menthol (70 mg, 0.45 mmol, 5 equiv) afforded compound **12d** (45 mg, 48% yield): TLC R_f 0.65 (*n*-hexane/EtOAc, 8:2); $[\alpha]^{25}_D$ −18.3° (*c* 0.6, $CHCl_3$); ^1H and ^{13}C NMR ($CDCl_3$) see compound **3e**; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 263 (0.5), 249 (−10.4), 236 (0.0), 234 nm (0.3).

(1*S*,2*R*,5*S*)-(+)-1-Menthyl 2,3,4,6-Tetrakis-*O*-(*p*-bromobenzoyl)-β-L-glucopyranoside (12e). (+)-Menthol (78 mg, 0.5 mmol, 5 equiv) was glucosylated to compound **12e** (53 mg, 51% yield) following the general procedure: TLC R_f 0.71 (*n*-hexane/EtOAc, 8:2); $[\alpha]^{25}_D$ +6.3° (*c* 0.2, $CHCl_3$); ^1H and ^{13}C NMR ($CDCl_3$) see compound **3d**; UV (CH_3CN) λ_{max} 245 nm; CD (CH_3CN) λ_{ext} ($\Delta\epsilon$) 249 (−17.4), 236 (0.0), 232 nm (2.6).

Acknowledgment. Support of this work by the Dirección General de Investigación Científica y Técnica (DGICYT), Ministerio de Educación y Ciencia (Spain), through Grant PB93-0559 is gratefully acknowledged. We thank Prof. Julio D. Martin (University of La Laguna) for his valuable support and interest in this work. E.Q.M. and J.I.P. thank the Ministerio de Educación y Ciencia for a fellowship.

Supplementary Material Available: Copies of ^1H NMR spectra for all model glucopyranosides and glucosyl bromides (23 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

JO941762D