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A Difference CD Method for Determining Absolute Stereochemistry of Acyclic 1,2,4-Triols

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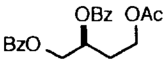
Abstract: A general method based on difference circular dichroic (DIF CD) spectroscopy for assigning the absolute configuration of 1,2,4-triol is presented. Four possible stereoisomers of 6-heptene-1,2,4-triol were prepared and served as models to develop the procedure. The sign of the DIF CD Cotton effect is correlated to the absolute configuration of the C2 position.

The 1,3-polyol systems are widely distributed in nature and attract a great deal of attention from chemists because they form the basic structure of polyene and polyol macrolides which are important antifungal and antiviral agents.[1] A wide variety of synthetic methods for creating skipped polyols have been developed,[2] and several of these polyene macrolide antibiotics have been synthesized in the past few years.[3] On the other hand, the stereochemical assignment of natural macrolide has been carried out in only a handful of cases. The structures of amphotericin B[4] and roxaticin[5] have been determined by crystallography, the structures of mycoticin,[6] roflamycoin,[7] and nystatin[8] have been identified by a combination of NMR analysis, chemical degradation, and partial synthesis, and the partial structure of lienomycin[9] has been identified by the NMR and CD spectroscopic analysis of the degradation products. Most of these studies involves many steps of chemical manipulation. Therefore, development of a simple spectroscopic method for both the synthetic and natural products in this area is clearly demanded.

The CD exciton chirality method[10] has been extensively utilized for the determination of the absolute stereochemistry of numerous natural products. The extension of this method to acyclic polyol systems with a high degree of conformational complexity has recently emerged. The most comprehensive CD studies on 1,3-diols were accomplished by Harada and co-workers,[11] and the absolute stereochemistry of optically active *anti*-1,3-diols was determined from the 1,3-dibenzoate exciton couplet. Recently, a bichromophoric exciton chirality method has been demonstrated to be useful for assigning the stereochemistry of 1,2,3-triols[12] and 1,2,4,6-tetrols.[13] We have reported the first attempt at using a difference CD (DIF CD) method to obtain the stereochemical information of 1,3-polyols, which gave the absolute configuration at C-3 based on the sign of acyclic allylic benzoate CD.[14] We now report that this DIF CD method is extendible to a terminal 1,2-diol system where the conformations are dynamic.[15]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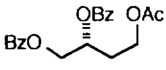
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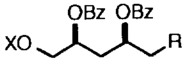
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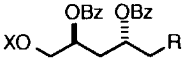
3b X=Piv, R=$CH=CH_2$
4a X=Bz, R=CH_2OH
4b X=Piv, R=CH_2OH
5a X=Bz, R=CH_2OAc
5b X=Piv, R=CH_2OAc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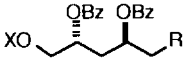
6b X=Piv, R=$CH=CH_2$
7a X=Bz, R=CH_2OH
7b X=Piv, R=CH_2OH
8a X=Bz, R=CH_2OAc
8b X=Piv, R=CH_2OAc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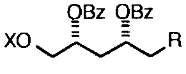
9b X=Piv, R=$CH=CH_2$
10a X=Bz, R=CH_2OH
10b X=Piv, R=CH_2OH
11a X=Bz, R=CH_2OAc
11b X=Piv, R=CH_2OAc

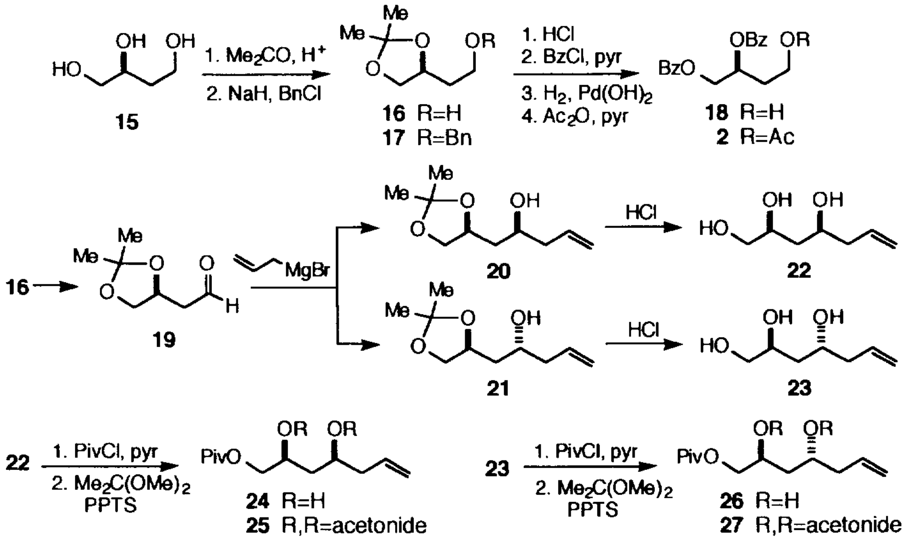

12a X=Bz, R=$CH=CH_2$
12b X=Piv, R=$CH=CH_2$
13a X=Bz, R=CH_2OH
13b X=Piv, R=CH_2OH
14a X=Bz, R=CH_2OAc
14b X=Piv, R=CH_2OAc

Bz=benzoyl
Piv=pivaloyl

Synthesis of Optically Active 1,2,4-Triol Derivatives

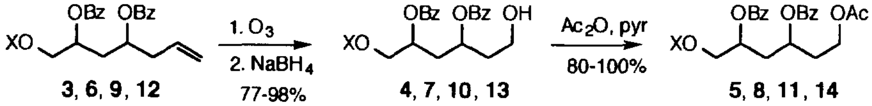
Two enantiomeric benzoates **1** and **2** and the stereoisomeric di- and tribenzoate derivatives **3**-**14** with established configurations were prepared from (*S*)- and (*R*)-butane-1,2,4-triols. (*S*)-Butane-1,2,4-triol (**15**) (99% ee) was regioselectively converted to acetonide **17** by reaction with acetone and *p*-toluenesulfonic acid followed by the benzylation of the remaining primary hydroxyl group. Deprotection of the acetonide and the subsequent benzoylation and hydrogenolysis of the benzyl group gave **18**. Dibenzoate **18** was acetylatd to give compound **1**.

6-Heptene-1,2,4-triols **22** and **23** with two chiral centers were synthesized from **16**. Thus, oxidation of **16** with pyridinium chlorochromate gave aldehyde **19** which was treated with allylmagnesium bromide to afford a mixture of homoallylic alcohols. Separation of the mixture by careful flash chromatography gave pure **20** and **21** in 43 and 38% yields, respectively.



Removal of the acetonide of **20** and **21** provided 6-heptene-1,2,4-triols **22** and **23**, respectively.

The stereochemistry of the triols was determined by ^{13}C NMR acetonide analysis developed by Rychnovsky.[16] In general, it has been observed that *syn*-1,3-diol acetonides have acetal methyl chemical shifts at 19 and 30 ppm, while *anti*-1,3-diol acetonides have methyl chemical shifts at approximately 25 ppm. The ^{13}C NMR of acetonide **25**, prepared from **22** *via* **24** by treatment with pivaloyl chloride in pyridine followed by 2,2-dimethoxypropane and pyridinium *p*-toluenesulfonate, revealed methyl signals at 19.67 and 30.00 ppm, indicating the presence of a *syn*-acetonide ring. The other isomer **23** was also transformed into the acetonide derivative **27**, and the configuration was confirmed to be *anti* from the ^{13}C chemical shifts (24.64, 24.69 ppm). Derivatizations of 6-heptene-1,2,4-triols for difference CD spectroscopic analysis are very simple. Thus, benzoylation of **22** and **23** gave tribenzoates **3a** and **6a** and that of **24** and **26** afforded 1-*O*-pivaloyl-2,4-dibenzoates **3b** and **6b**, respectively. Other enantiomeric benzoate derivatives **2**, **9**, and **12** were synthesized in the same manner starting from (*R*)-butane-1,2,4-triol. Hexane-1,2,4,6-tetrol derivatives were prepared from the acylated 6-heptene-1,2,4-triols. Thus, ozonolysis of **3**, **6**, **9**, and **12** followed by the sodium borohydride reduction gave the hydroxy derivatives **4**, **7**, **10**, and **13**, which were acetylated to give **5**, **8**, **11**, and **14**.



a series, X=Bz; b series, X=Piv

Conformational Analysis, Difference CD Spectra, and Absolute Configuration

The difference CD (DIF CD) method was originally utilized for 1,3-polyols having a terminal allylic benzoate system.[14] Extension of this method to 1,2,4,...polyols to determine the absolute stereochemistry would be very important, because such polyol systems are typically derived from various natural products by either periodate or ozonolysis degradation, as was the case for lienomycin[9]. In the present study, the pair of tribenzoate **II** and 1-*O*-pivaloyl-2,4-dibenzoate **III** was required, which could be easily prepared from the acyclic triol **I** by acylations. The CD Cotton effect of **II** reflects the overall interactions of the exciton chiralities between three benzoates, while that of **III** is caused only by the 2,4-dibenzoate exciton coupling. Because **II** and **III** have the same structure except for their terminal acyl groups, their conformations are considered to be the same. Subtraction of the CD spectrum of **III** from that of **II** provides a DIF CD spectrum, where the benzoate exciton interaction between C2 and C4 is canceled, and the Cotton effect of the DIF CD spectrum must therefore reflect the exciton interaction of the terminal 1,2-dibenzoate system (Fig. 1).

Studies have shown the sensitivity of exciton interaction to conformational changes; it is theoretically predicted and experimentally demonstrated that the coupling magnitude depends upon both the dihedral angle and the interchromophoric distance between transitions.[10] Interaction of the acyclic 1,2-dibenzoates in **IV** is particularly sensitive because **IV** is an equilibrated mixture of three limiting rotamers, **gt**, **gg**, and **tg**, about the C1-C2 bond, wherein the first letter indicates the relative orientation between O_1 and O_2 (gauche or trans), while the

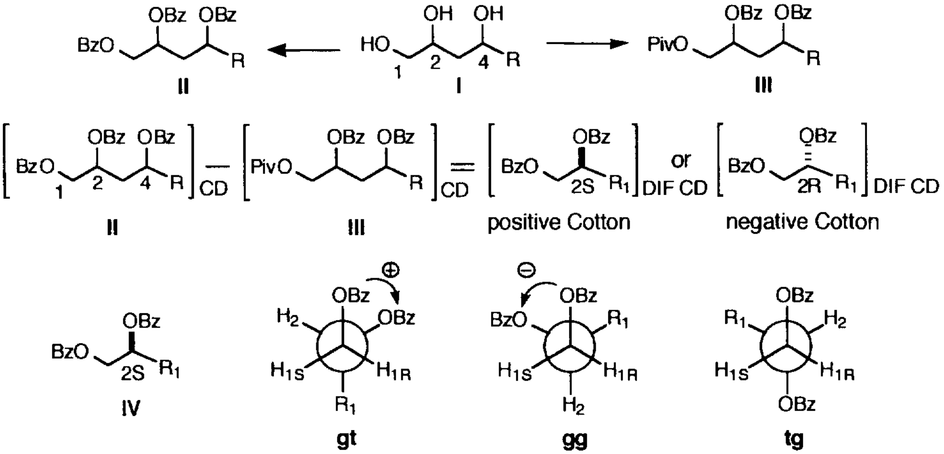


Fig. 1. Correlations of the DIF CD Cotton effects with the absolute configuration of the C2 position and the Newman projections of the three possible rotamers about the C1-C2 bond.

second letter indicates the orientation between O_1 and the alkyl group R_1. It is generally assumed that these staggered rotamers represent stable conformations of minimum free energy. Inspection of the three rotamers reveals that **gt** and **gg** have opposite exciton chiralities, while **tg** exhibits no chirality between benzoate chromophores. The rotamer **gt** would be more favored than **gg** because of the presence of a gauche interaction between the C1 benzoyloxy and R_1 groups in **gg**. The major rotamer **gt** exhibiting a positive chirality is expected to make the most significant contribution to the CD spectrum and produce a positive first Cotton effect (longer wavelength) and a negative second Cotton effect (shorter wavelength). The CD spectra of the enantiomeric **1** and **2**, measured in methanol, clearly indicated the exciton split Cotton effects around 230 nm due to the interchromophoric transition of the terminal 1,2-dibenzoate chromophores (Fig. 2). As already discussed, the Cotton effect signs of **1** and **2** are mainly governed by the exciton chirality of the preferred conformer **gt**.

To better understand the contributions of rotamers **gt** and **gg** to the CD spectra, the distribution of rotamers was calculated using the equations[17] employed in sugar chemistry that describe the observed coupling constants as averages of the population-weighted coupling constants for the three rotamers. Calculation of the rotameric distribution about the C1-C2 bond was carried out using the procedure reported by Nakanishi et al.[18] The ^{1}H NMR assignments of the prochiral C1 methylene protons of the model compounds are based on the comparison with the reported data; H_{1S} has a smaller $J_{1S\text{-}2}$ coupling constant (2.6-4.3 Hz) and appears at a lower field than H_{1R} having a larger $J_{1R\text{-}2}$ (5.1-6.9Hz).[18] The observed coupling constants measured in methanol-d_4 and the calculated populations of the three C1-C2 rotamers of the six derivatives are summarized in Table I. The calculations indicate that **gt** and **gg** are the major rotamers in all cases and the population of the **gt** rotamer (47-51%) having a large $J_{1R\text{-}2}$ is greater than that of the **gg** rotamer (36-41%). These results also supported the fact that rotamer **gt** contributes to the positive first Cotton effect of **1**.

Table I. ^{1}H NMR Data of C1-H of 1,2,4-Triols and Calculated Populations of C1-C2 Rotamers

compound	H_{1S}	H_{1R}	$J_{1S\text{-}2}$	$J_{1R\text{-}2}$	P_{gt}	P_{gg}	P_{tg}
18	4.68	4.49	3.2	6.6	0.47	0.41	0.12
1	4.67	4.49	3.4	6.7	0.47	0.40	0.13
3a	4.64	4.48	3.4	6.6	0.46	0.40	0.14
3b	4.40	4.25	3.4	6.8	0.48	0.38	0.14
6a	4.66	4.46	3.4	6.8	0.48	0.38	0.14
6b	4.40	4.22	3.4	7.1	0.51	0.36	0.13

Populations were calculated using the following equations[17];
$1.3P_{gg}+2.7P_{gt}+11.7P_{tg}=J_{1S\text{-}2}$, $1.3P_{gg}+11.5P_{gt}+5.8P_{tg}=J_{1R\text{-}2}$, $P_{gg}+P_{gt}+P_{tg}=1$.

Table II. CD Data of Tri- and Dibenzoates of 1,2,4-Triols and Their DIF CD Data

entry	tribenzoate	nm (Δε)	dibenzoate	nm (Δε)	DIF CD nm (Δε)	abs config of C2
1			**1**	236 (+5.31) 220 (-2.84)		*S*
2			**2**	236 (-5.07) 222 (+3.61)		*R*
3	**3a**	236 (+6.19) 221 (-4.25)	**3b**	no Cotton	236 (+6.52) 221 (-4.02)	*S*
4	**4a**	236 (+6.42) 219 (-2.58)	**4b**	243 (-0.70) 225 (+1.69)	237 (+6.35) 220 (-4.08)	*S*
5	**5a**	236 (+7.02) 221 (-3.56)	**5b**	243 (-0.41) 222 (+0.99)	237 (+6.91) 221 (-4.54)	*S*
6	**6a**	235 (-11.13) 219 (+3.11)	**6b**	236 (-16.54) 219 (+6.11)	237 (+5.56) 222 (-3.38)	*S*
7	**7a**	236 (-11.15) 218 (+2.46)	**7b**	236 (-15.89) 219 (+5.50)	237 (+4.82) 222 (-3.59)	*S*
8	**8a**	236 (-10.58) 217 (+2.28)	**8b**	236 (-16.31) 220 (+5.79)	237 (+5.77) 222 (-4.03)	*S*
9	**9a**	235 (+11.17) 218 (-2.80)	**9b**	236 (+15.69) 220 (-5.49)	237 (-4.71) 222 (+3.12)	*R*
10	**10a**	235 (+11.53) 218 (-2.12)	**10b**	236 (+16.94) 220 (-5.57)	237 (-5.66) 221 (+3.89)	*R*
11	**11a**	235 (+11.34) 218 (-2.03)	**11b**	236 (+16.80) 219 (-5.32)	236 (-5.73) 222 (+3.59)	*R*
12	**12a**	236 (-6.20) 221 (+4.43)	**12b**	no Cotton	236 (-6.61) 220 (+4.01)	*R*
13	**13a**	236 (-6.73) 221 (+2.72)	**13b**	244 (+0.65) 221 (-1.62)	236 (-6.81) 221 (+4.34)	*R*
14	**14a**	236 (-6.67) 221 (+3.30)	**14b**	244 (+0.66) 224 (-0.62)	236 (-6.92) 221 (+3.74)	*R*

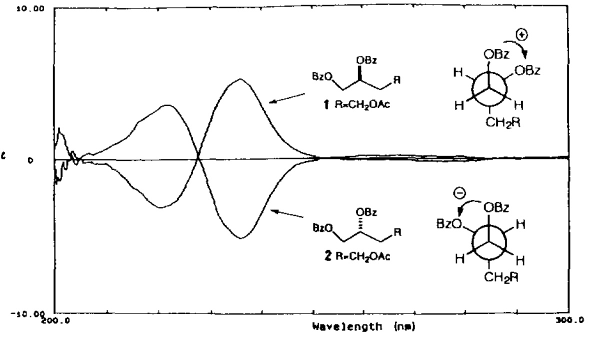


Fig. 2. CD spectra of **1** and **2**.

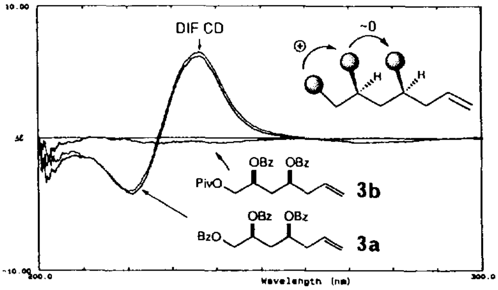


Fig. 3. CD and DIF CD spectra of **3a** and **3b**.

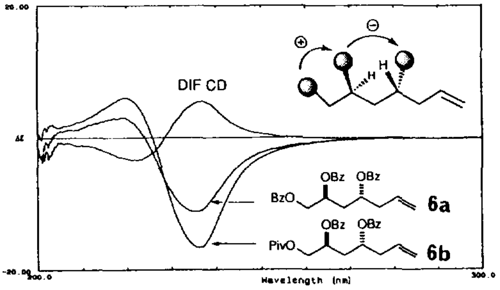


Fig. 4. CD and DIF CD spectra of **6a** and **6b**.

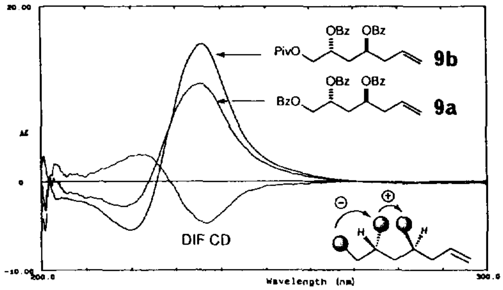


Fig. 5. CD and DIF CD spectra of **9a** and **9b**.

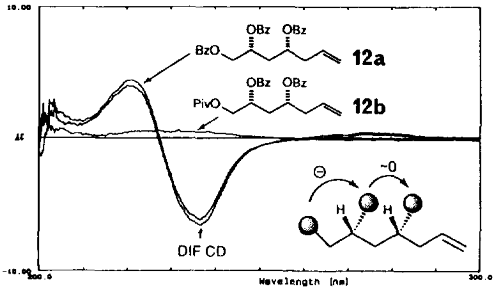


Fig. 6. CD and DIF CD spectra of **12a** and **12b**.

There are uncertainties in the calculated mole fractions due to uncertain coupling constant values for each rotamer and other factors. However, such uncertainties are inconsequential to this study as we are interested in using these values only to indicate general trends in the distribution of three rotamers.

In order to evaluate whether such prediction is possible in the case of DIF CD analysis, the CD spectra of four pairs of tribenzoates and the corresponding 1-*O*-pivaloyl-2,4-dibenzoates were measured. The CD and DIF CD data of **1-14** are listed in Table II. Figs. 3-6 show the CD spectra of the paired tri- and dibenzoates of four stereoisomeric 6-heptene-1,2,4-triols. In all cases, DIF CD curves were nicely extracted from the CD spectra, and it was found that the observed DIF CD Cotton effects were consistent with the Cotton effects of the reference spectra shown in Fig. 2. The (2*S*)-absolute configuration at C2 of **3a** and **6a** is correlated with a positive DIF CD (Fig. 3 and 4), while the (2*R*)-configuration of **9a** and **12a** is correlated with a negative DIF CD (Fig. 5 and 6). The DIF CD spectra of other pairs of (2*S*)- and (2*R*)-hexane-1,2,4,6-tetrol derivatives showed similar Cotton curves, the data of which are summarized in Table II. These results demonstrate that applications of the DIF CD method to terminal 1,2-diol systems have proven successful. The small differences of the DIF CD intensities between *syn*- and *anti*-2,4-isomers indicate the presence of a weak 1,4-dibenzoate coupling. Stereochemistry at the C4 position of 1,2,4-triols is characterized by the intensity of the Cotton effects of **3b**, **6b**, **9b**, and **12b**. The CD spectra of the dibenzoates with a 2,4-*anti* relationship showed strong Cotton effects (Fig. 4 and 5) in contrast to the case of the 2,4-*syn* relationship which showed no exciton Cotton effect (Fig. 3 and 6). These general trends were observed in the case of hexane-1,2,4,6-tetrol derivatives, because the skeletal chains of acyclic *anti* and *syn*-1,3-benzoates adopt an extended zigzag form in the most stable conformer as described by Harada and co-workers.[11] In the case of *anti*-1,3-dibenzoates, the angle between two chromophores is ca. 120°, while it is almost zero in the case of *syn*-1,3-dibenzoates. Therefore, only *anti*-isomers exhibit a strong exciton coupling CD reflecting the absolute configuration. The configurational assignment of *syn*-1,3-isomers cannot be directly achieved for this reason. In the present case of 1,2,4-triol systems, the absolute stereochemistry of C2 can be unambiguously determined from the sign of the DIF CD of 1,2,4-tribenzoates and that of C4 can therefore be assigned from the CD spectrum of the corresponding 1-*O*-pivaloyl-2,4-dibenzoates.

It is worthwhile to emphasize that derivatizations of polyols employed in this study are simple acylations, i.e., benzoylation and pivaloylation, which make the DIF CD method useful and practical. Applications of this DIF CD method to longer 1,2,4,6...polyols are in progress.

Experimental

General. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ or CD_3OD on JEOL JNM-GX 270 and 400 spectrometers. IR spectra were measured on a JASCO IR-810 spectrometer. Mass spectra were obtained with a JEOL HX-110 spectrometer. UV measurements were performed on a Shimadzu UV-2100 spectrophotometer using methanol as a solvent. Optical rotations were determined on a JASCO DIP-370 digital polarimeter. CD spectra were recorded in methanol (1-cm quartz cell) using a JASCO J-600 spectropolarimeter driven by a JASCO DP-600 data processor. The concentrations of methanol solutions were determined on the basis of the experimentally determined average benzoate UV ε's at 229nm (dibenzoate, ε 26300; tribenzoate, ε 36400).

Optically active (R) and (S)-butane-1,2,4-triols were purchased from Aldrich Chemical Company, Inc. Flash chromatography was carried out with E. Merck silica gel 60 (230-400 mesh). The term "dried" refers to drying of an organic solution over $MgSO_4$.

(*S*)-1,2-*O*-Isopropylidene-4-benzyloxybutane-1,2-diol (17). To a stirred solution of **16**[19] (5.15g, 35.27mmol) in dry DMF (40ml) at 0°C was added 50% NaH in mineral oil (4.2g, 88.2mmol). After being stirred for 10 min, benzyl bromide (8.4ml, 54mmol) was added and the suspension was stirred for 1.5h. The reaction was quenched with water and the mixture was extracted with ether.

The extract was washed with water and brine, dried, and concentrated. Purification by flash chromatography (10% EtOAc/hexane) gave **17** (14.7g, 88%). $[\alpha]_D^{25}$ +3.10° (c=1.0, $CHCl_3$). IR ($CHCl_3$): 1380, 1365, 1160, 1090cm^{-1}. ^1H NMR (270MHz, $CDCl_3$) δ: 1.36 (3H, s), 1.41 (3H, s), 1.90 (2H, m), 3.56 (2H, m), 3.58 (1H, dd, J=8.1, 5.0Hz), 4.07 (1H, dd, J=8.1, 6.1Hz), 4.22 (1H, quint, J=6.1Hz), 4.51 (2H, s), 7.33 (5H, m). Anal. Calcd for $C_{14}H_{20}O_3$: C, 71.14; H, 8.54. Found: C, 70.91; H, 8.85.

(*S*)-4-*O*-Acetyl-1,2-di-*O*-(benzoyl)butane-1,2,4-triol (1). A solution of **17** (691mg, 2.72mmol) in MeOH (9ml) was treated with 5%HCl-MeOH (7ml) and the solution was stirred for 3.5h. The mixture was concentrated and the residue was purified by flash chromatography (EtOAc) to give (*S*)-4-benzyloxybutane-1,2-diol (483mg, 91%), $[\alpha]_D^{25}$ +5.82° (c=1.0, $CHCl_3$). The diol (470mg, 2.47mmol) was dissolved in pyridine (7ml) and benzoyl chloride (0.78ml, 6.73mmol) was added. After being stirred for 3h at room temperature, the reaction was quenched with MeOH (0.5ml) and the mixture was extracted with ether. The extract was washed with saturated aqueous $NaHCO_3$, water, and brine, dried, and concentrated. Purification by flash chromatography (20% EtOAc/hexane) gave a dibenzoate (932mg, 93%), $[\alpha]_D^{25}$ +26.9° (c=0.96, $CHCl_3$). A suspension of the dibenzoate (882mg, 2.17mmol) and 10% $Pd(OH)_2$/C (40mg) in EtOAc (15ml) was flushed with hydrogen and then stirred vigorously under ballon pressure. After being stirred for 3h, the mixture was filtered through a short column of Celite and the filtrate was concentrated. Purification by flash chromatography (50% EtOAc/hexane) gave **18** (643mg, 94%) as a colorless oil. $[\alpha]_D^{25}$ -9.05° (c=1.0, $CHCl_3$). IR ($CHCl_3$): 3500, 1720, 1600, 1580, 1345, 1280, 1260, 1110, 1065cm^{-1}. ^1H NMR (400MHz, CD_3OD) δ: 2.06 (2H, m), 3.72 (2H, m), 4.49 (1H, dd, J=12.0, 6.6Hz), 4.68 (1H, dd, J=12.0, 3.2Hz), 5.64 (1H, m), 7.44 (4H, m), 7.56 (2H, m), 7.99 (4H, m). UV (MeOH) λ_{max} : 229.1 nm (ε 26300). CD (MeOH) λ_{ext} (Δε): 235.4 (+6.53), 220.4 (-2.84). Anal. Calcd for $C_{18}H_{18}O_5$: C, 68.76; H, 5.78. Found: C, 68.52; H, 6.04.

A solution of **18** (7.8mg, 0.025mmol) in pyridine (0.5ml) was treated with acetic anhydride (24μl) and the solution was stirred at room temperature for 14h. After removal of the solvent *in vacuo*, the residue was purified by flash chromatography (10% acetone/hexane) to give **1** (8.2mg, 93%) as a colorless oil. $[\alpha]_D^{25}$ -30.9° (c=0.36, $CHCl_3$). IR ($CHCl_3$): 1725, 1600, 1580, 1450, 1315, 1270, 1210, 1115, 1070, 1025cm^{-1}. ^1H NMR (270MHz, CD_3OD) δ: 1.96 (3H, s), 2.19 (2H, q, J=6.1Hz), 4.24 (2H, t, J=6.1Hz), 4.49 (1H, dd, J=12.1, 6.7Hz), 4.67 (1H, dd, J=12.1, 3.4Hz), 5.61 (1H, m), 7.45 (4H, m), 7.58 (2H, m), 7.99 (4H, m). UV (MeOH) λ_{max} (ε): 229.3 nm (26300). HREIMS *m/z*: calcd for $C_{20}H_{20}O_6$ (M^+): 356.1259; found: 356.1273.

(*R*)-4-*O*-Acetyl-1,2-di-*O*-(benzoyl)butane-1,2,4-triol (2) was prepared in the same manner starting from (*R*)-butane-1,2,4-triol. $[\alpha]_D^{25}$ +28.4° (c=0.68, $CHCl_3$).

(2*S*,4*S*)- and (2*S*,4*R*)-1,2-*O*-Isopropylidene-6-heptene-1,2,4-triols (20 and 21). A cloudy solution of 1M allylmagnesium bromide in ether (100ml, 100mmol) was cooled to -15°C under argon and **19**[19b] (13.4g, 93mmol) was added dropwise. After being stirred for 30 min, the reaction was quenched with saturated aqueous NH_4Cl and the mixture was extracted with ether. The extract was washed with water and brine, dried, and concentrated. Purification by flash chromatography (3% acetone/CH_2Cl_2) gave **20** (7.37g, 43%) and **21** (6.58g, 38%).

(2*S*,4*S*)-Isomer (20): R_f=0.78 (8% acetone/CH_2Cl_2). $[\alpha]_D^{25}$ +13.3° (c=0.72, $CHCl_3$). IR ($CHCl_3$): 3510, 1635, 1380, 1370, 1230, 1150, 1080, 990, 920, 820cm^{-1}. ^1H NMR (270MHz, C_6D_6) δ: 1.24 (3H, s), 1.28 (1H, ddd, *J*=14.1, 4.0, 4.0Hz), 1.49 (1H, ddd, *J*=14.1, 9.1, 4.1Hz), 2.19 (2H, m), 2.77 (1H, d, *J*=1.7Hz, OH), 3.26 (1H, t, *J*=7.7Hz), 3.70 (1H, m), 3.71 (1H, dd, *J*=7.7, 3.7Hz), 3.93 (1H, m), 5.03 (1H, d, *J*=11.8Hz), 5.40 (1H, d, *J*=15.5Hz), 5.84 (1H, m). Anal. Calcd for $C_{10}H_{18}O_3$: C, 64.47; H, 9.75. Found: C, 64.59; H, 9.97.

(2*S*,4*R*)-Isomer (21): R_f=0.70 (8% acetone/CH_2Cl_2). $[\alpha]_D^{25}$ -7.70° (c=0.98, $CHCl_3$). IR ($CHCl_3$): 3500, 1630, 1375, 1365, 1230, 1150, 1050, 990, 915, 815cm^{-1}. ^1H NMR (270MHz, C_6D_6) δ: 1.33 (3H, s), 1.39 (3H, s), 1.39 (1H, ddd, *J*=14.1, 14.1, 5.0Hz), 1.55 (1H, ddd, *J*=14.1, 7.4, 2.7Hz), 1.70 (1H, d, *J*=4.4Hz, OH), 2.20 (2H, t, *J*=6.7Hz), 3.40 (1H, t, *J*=7.7Hz), 3.69 (1H, m), 3.85 (1H, dd, *J*=8.1, 6.1Hz), 4.18 (1H, m), 4.98 (2H, m), 5.66 (1H, m). Anal. Calcd for $C_{10}H_{18}O_3$: C, 64.47; H, 9.75. Found: C, 64.31; H, 10.07.

(2*S*,4*S*)-6-Heptene-1,2,4-triol (22). A solution of **20** (1.05g, 5.65mmol) in MeOH (30ml) was treated with 5% HCl-MeOH (0.5ml) and the solution was stirred at room temperature for 20h. After removal of the solvent, the residue was purified by flash chromatography (1% MeOH/EtOAc) to give **22** (766mg, 93%) as a colorless oil. $[\alpha]_D^{25}$ +15.9° (c=0.79, $CHCl_3$). IR ($CHCl_3$): 3400, 1660, 1635, 1420, 1100, 990, 915cm^{-1}. ^1H NMR (270MHz, $CDCl_3$) δ: 1.59 (2H, m), 2.26 (2H, m), 3.12 (3H, br, OH), 3.48 (1H, dd, *J*=11.1, 6.4Hz), 3.64 (1H, dd, *J*=11.1, 3.4Hz), 3.96 (2H, m), 5.13 (1H, d, *J*=14.5Hz), 5.14 (1H, d, *J*=11.4Hz), 5.63 (1H, m). HREIMS *m/z*: calcd for $C_7H_{14}O_3$ (M^+): 146.0942; found: 146.0967.

(2*S*,4*R*)-6-Heptene-1,2,4-triol (23). The procedure for the preparation of **22** was employed with **21** (1.05g, 5.65mmol) to give **23** (796mg, 97%) as a colorless oil. $[\alpha]_D^{25}$ -18.3° (c=0.93, $CHCl_3$). IR ($CHCl_3$): 3350, 1665, 1635, 1410, 1060, 1010, 915cm^{-1}. ^1H NMR (270MHz, $CDCl_3$) δ: 1.50 (1H, ddd, *J*=14.1, 9.1, 3.4Hz), 1.62 (1H, ddd, *J*=14.1, 9.1, 3.0Hz), 2.26 (2H, t, *J*=6.7Hz), 2.72 (1H, br, OH), 3.44 (1H, br, OH), 3.49 (1H, dd, *J*=11.4, 7.4Hz), 3.61 (1H, dd, *J*=11.4, 3.4Hz), 3.84 (1H, br, OH), 3.98 (2H, m), 5.12 (1H, d, *J*=11.1Hz), 5.13 (1H, d, *J*=15.1Hz), 5.81 (1H, m). HREIMS *m/z*: calcd for $C_7H_{14}O_3$ (M^+): 146.0942; found: 146.0953.

(2*S*,4*S*)-1-*O*-Pivaloyl-6-heptene-1,2,4-triol (24). To a stirred solution of **22** (36.3mg, 0.249mmol) in pyridine (1ml) at 0°C was added pivaloyl chloride (33.7μl, 0.274mmol). After being stirred for 1h, the reaction was quenched with MeOH (0.1ml) and the mixture was extracted with EtOAc. The extract was washed with water and brine, dried, and concentrated. Purification by flash chromatography (40% EtOAc/hexane) gave **24** (41.2mg, 72%) as a colorless oil. $[\alpha]_D^{25}$ +7.67° (c=0.81, $CHCl_3$). IR ($CHCl_3$): 3600, 3450, 1725, 1600, 1480, 1395, 1285, 1160, 1045, 875cm^{-1}. ^1H NMR (270MHz, $CDCl_3$) δ: 1.22 (9H, s), 1.64 (2H, m), 2.26 (2H, m), 2.92 (1H, br s, OH), 3.32 (1H, br s, OH), 3.94 (1H, m), 4.04 (1H, dd, *J*=12.1, 4.7Hz), 4.08 (1H, t, *J*=8.4Hz), 4.10 (1H, m), 5.14 (1H, d, *J*=17.1Hz), 5.15 (1H, d, *J*=11.1Hz), 5.81 (1H, m). HREIMS *m/z*: calcd for $C_{12}H_{22}O_4$ (M^+): 230.1517; found: 230.1523.

(2*S*,4*S*)-2,4-*O*-Isopropylidene-1-*O*-pivaloyl-6-heptene-1,2,4-triol (25). A mixture of **24** (2.2mg) and pyridinium *p*-toluenesulfonate (1mg) in CH_2Cl_2 (0.5ml) and 2,2-dimethoxypropane (0.1ml) was stirred at room temperature for 15min. After addition of Et_3N (0.05ml), the reaction mixture was concentrated. Purification by flash chromatography (8% EtOAc/hexane) gave **25** (2.5mg, 97%) as a colorless oil. $[\alpha]_D^{25}$ +7.36° (c=0.21, $CHCl_3$). IR ($CHCl_3$): 1725, 1480, 1380, 1220, 1160, 995, 790cm^{-1}. ^1H NMR (400MHz, $CDCl_3$) δ: 1.21 (9H, s), 1.23 (1H, ddd, *J*=12.5, 11.0, 11.0Hz), 1.40 (3H, s), 1.43 (3H, s), 1.51 (1H, ddd, *J*=12.5, 2.2, 2.2Hz), 2.17 (1H, ddd, *J*=14.7, 6.6, 6.6Hz), 2.32 (1H, ddd, *J*=14.7, 5.9, 5.9Hz), 3.90 (1H, m), 4.02-4.08 (3H, m), 5.07 (1H, d, *J*=10.3Hz), 5.09 (1H, d, *J*=17.5Hz), 5.80 (1H, ddd, *J*=17.5, 10.3, 6.6Hz). ^{13}C NMR (100MHz, $CDCl_3$) δ: 19.67, 27.14 (3C), 30.00, 32.66, 38.81, 40.75, 98.69, 117.28, 133.92, 178.34. HREIMS *m/z*: calcd for $C_{15}H_{26}O_4$ (M^+): 270.1830; found: 270.1821.

(2*S*,4*R*)-1-*O*-Pivaloyl-6-heptene-1,2,4-triol (26). The procedure for the preparation of **24** was employed with **23** (38.7mg, 0.265mmol) to give **26** (39.8mg, 65%) as a colorless oil. $[\alpha]_D^{25}$ -12.5° (c=0.85, $CHCl_3$). IR ($CHCl_3$): 3500, 1720, 1480, 1285, 1165, 995, 920cm^{-1}. ^1H NMR (270MHz, $CDCl_3$) δ: 1.22 (9H, s), 1.64 (2H, m), 2.28 (2H, m), 2.74 (1H, br, OH), 3.99 (1H, br, OH), 4.05 (1H, dd, *J*=11.1, 7.1Hz), 4.15 (1H, dd, *J*=11.1, 3.0Hz), 5.15 (1H, d, *J*=10.8Hz), 5.16 (1H, d, *J*=17.5Hz), 5.82 (1H, ddd, *J*=17.5, 10.8, 6.7Hz). HREIMS *m/z*: calcd for $C_{12}H_{22}O_4$ (M^+): 230.1517; found: 230.1508.

(2*S*,4*S*)-2,4-*O*-Isopropylidene-1-*O*-pivaloyl-6-heptene-1,2,4-triol (27). The procedure for the preparation of **25** was employed with **26** (2.0mg) to give **27** (2.2mg, 94%) as a colorless oil. $[\alpha]_D^{25}$ -16.5° (c=0.13, $CHCl_3$). IR ($CHCl_3$): 1725, 1480, 1380, 1290, 1220, 1160, 1000, 740cm^{-1}. ^1H NMR (400MHz, $CDCl_3$) δ: 1.21 (9H, s), 1.35 (3H, s), 1.36 (3H, s), 1.62 (2H, m), 2.21 (1H, ddd, *J*=13.9, 6.6, 6.6Hz), 2.32 (1H, ddd, *J*=13.9, 7.7, 7.7Hz), 3.88 (1H, m), 4.00 (1H, dd, *J*=11.0, 6.6Hz), 4.03 (1H, m), 4.13 (1H, dd, *J*=11.0, 2.9Hz), 5.06 (1H, d, *J*=10.3Hz), 5.10 (1H, d, *J*=17.6Hz), 5.80 (1H, ddd, *J*=17.6, 10.3, 7.3Hz). ^{13}C NMR (100MHz, $CDCl_3$) δ: 24.64, 24.69, 27.14 (3C), 38.79, 40.01, 100.48, 117.10, 134.15, 178.36. HREIMS *m/z*: calcd for $C_{15}H_{26}O_4$ (M^+): 270.1830; found: 270.1838.

Preparation of 3a, 3b, 6a, and 6b. Compounds **22**, **23**, **24**, and **26** were benzoylated as follows. To a stirred solution of a triol or diol (0.10mmol) in pyridine (1ml) at 0°C was added benzoyl chloride (0.5mmol for a triol; 0.3mmol for a diol). After being stirred at room temperature for 1h, the reaction was quenched with MeOH (0.05ml) and the mixture was extracted with ether. The extract was washed with water and brine, dried, and concentrated. The crude product was purified by flash chromatography (10% EtOAc/hexane for a tribenzoate; 5% EtOAc/hexane for a dibenzoate). The enantiomers of **22, 23, 24, 26**, prepared from (*R*)-butane-1,2,4-triol in the same manner as previously described, were also benzoylated to give **12a**, **9a**, **12b**, and **9b**, respectively.

(2*S*,4*S*)-1,2,4-Tri-*O*-benzoyl-6-heptene-1,2,4-triol (3a). $[\alpha]_D^{25}$ +3.74° (c=1.0, $CHCl_3$). IR ($CHCl_3$): 1720, 1600, 1450, 1325, 1270, 1115, 1070, 1025cm^{-1}. ^1H NMR (400MHz, CD_3OD) δ: 2.23 (1H, ddd, *J*=14.9, 4.6, 4.6Hz), 2.32 (1H, ddd, *J*=14.9, 7.8, 7.8Hz), 2.52 (2H, m), 4.48 (1H, dd, *J*=12.0, 6.6Hz), 4.64 (1H, dd, *J*=12.0, 3.4Hz), 5.05 (1H, d, *J*=10.0Hz), 5.12 (1H, d, *J*=17.1Hz), 5.34 (1H, m), 5.66 (1H, m), 5.83 (1H, dddd, *J*=17.1, 10.0, 7.1, 7.1Hz), 7.28-7.55 (9H, m), 7.86-7.92 (6H, m). UV (MeOH) λ_{max}: 229.3nm (ε 36400). HREIMS *m/z*: calcd for $C_{28}H_{26}O_6$ (M^+): 458.1728; found: 458.1735.

(2*R*,4*R*)-1,2,4-Tri-*O*-benzoyl-6-heptene-1,2,4-triol (12a). $[\alpha]_D^{25}$ -4.05° (c=1.0, $CHCl_3$).

(2*S*,4*S*)-2,4-Di-*O*-benzoyl-1-*O*-pivaloyl-6-heptene-1,2,4-triol (3b). $[\alpha]_D^{25}$ +9.58° (c=0.83, $CHCl_3$). IR ($CHCl_3$): 1720, 1600, 1445, 1315, 1275, 1160, 1110, 1020cm^{-1}. ^1H NMR (400MHz, CD_3OD) δ: 1.09 (9H, s), 2.15 (1H, ddd, *J*=14.6, 4.6, 4.6Hz), 2.25 (1H, ddd, *J*=14.6, 8.1, 8.1Hz), 2.52 (2H, m), 4.25 (1H, dd, *J*=12.0, 6.8Hz), 4.40 (1H, dd *J*=12.0, 3.4Hz), 5.07 (1H, d, *J*=10.0Hz), 5.13 (1H, d, *J*=17.1Hz), 5.35 (1H, m), 5.54 (1H, m), 5.84 (1H, dddd, *J*=17.1, 10.0, 7.1, 7.1Hz), 7.33 (4H, m), 7.52 (2H, m), 7.88 (4H, m). UV (MeOH) λ_{max}: 229.0nm (ε 26300). HREIMS *m/z*: calcd for $C_{26}H_{30}O_6$ (M^+): 438.2041; found: 438.2052.

(2*R*,4*R*)-2,4-Di-*O*-benzoyl-1-*O*-pivaloyl-6-heptene-1,2,4-triol (12b). $[\alpha]_D^{25}$-10.1°(c=1.0, $CHCl_3$).

(2*S*,4*R*)-1,2,4-Tri-*O*-benzoyl-6-heptene-1,2,4-triol (6a). $[\alpha]_D^{25}$ -68.9° (c=1.0, $CHCl_3$). IR ($CHCl_3$): 1720, 1600, 1450, 1315, 1270, 1110, 1070, 1020cm^{-1}. ^1H NMR (400MHz, CD_3OD) δ: 2.28 (2H, m), 2.56 (2H, t, *J*=6.4Hz), 4.46 (1H, dd, *J*=12.0, 6.8Hz), 4.66 (1H, dd, *J*=12.0, 3.4Hz), 5.07 (1H, d, *J*=10.3Hz), 5.14 (1H, d, *J*=17.1Hz), 5.36 (1H, m), 5.64 (1H, m), 5.85 (1H, dddd, *J*=17.1, 10.3, 6.8, 6.8Hz), 7.39 (6H, m), 7.57 (3H, m), 7.93 (6H, m). UV (MeOH) λ_{max}: 229.7nm (ε 36400). HREIMS *m/z*: calcd for $C_{28}H_{26}O_6$ (M^+): 458.1728; found: 458.1737.

(2*R*,4*S*)-1,2,4-Tri-*O*-benzoyl-6-heptene-1,2,4-triol (9a). $[\alpha]_D^{25}$ +64.9° (c=1.0, $CHCl_3$).

(2*S*,4*R*)-2,4-Di-*O*-benzoyl-1-*O*-pivaloyl-6-heptene-1,2,4-triol (6b). $[\alpha]_D^{25}$ -64.9° (c=1.0, $CHCl_3$). IR ($CHCl_3$): 1720, 1600, 1445, 1310, 1270, 1160, 1110, 1065, 1020cm^{-1}. ^1H NMR (400MHz, CD_3OD) δ: 1.09 (9H, s), 2.15 (1H, ddd, *J*=14.9, 9.3, 3.7Hz), 2.23 (1H, ddd, *J*=14.9, 9.5, 3.4Hz), 4.22 (1H, dd, *J*=12.0, 7.1Hz), 4.40 (1H, dd, *J*=12.0, 3.4Hz), 5.07 (1H, d, *J*=10.0Hz), 5.13 (1H, d, *J*=17.1Hz), 5.30 (1H, m), 5.53 (1H, m), 5.83 (1H, dddd, *J*=17.1, 10.0, 7.1, 7.1Hz), 7.40 (4H, m), 7.54 (2H, m), 7.92 (4H, m). UV (MeOH) λ_{max}: 229.6nm (ε 26300). HREIMS *m/z*: calcd for $C_{26}H_{30}O_6$ (M^+): 438.2041; found: 438.2049.

(2*R*,4*S*)-2,4-Di-*O*-benzoyl-1-*O*-pivaloyl-6-heptene-1,2,4-triol (9b). $[\alpha]_D^{25}$ +69.8° (c=1.0, $CHCl_3$).

Preparation of 4, 7, 10, and 13. An acylated 6-heptene-1,2,4-triol (0.2mmol) was dissolved in MeOH (8ml) and cooled to -78°C. Ozone was bubbled through the solution until a blue color persisted. Nitrogen was then bubbled through the solution until it was colorless, then $NaBH_4$ (2.0mmol) was added and the reaction mixture was allowed to slowly warm to room temperature. After 30min, the solution was neutralized by careful addition of 1% HCl and extracted with EtOAc. The extract was washed with water and brine, dried, and concentrated. The crude product was purified by flash chromatography (30% EtOAc/hexane for **a** series; 35% EtOAc/hexane for **b** series) to give the desired product.

(2*S*,4*S*)-1,2,4-Tri-*O*-(benzoyl)hexane-1,2,4,6-tetrol (4a). $[\alpha]_D^{25}$ -11.6° (c=1.0, $CHCl_3$). IR ($CHCl_3$): 3500, 1720, 1600, 1445, 1265, 1110cm^{-1}. ^1H NMR (400MHz, CD_3OD) δ: 2.01 (2H, m), 2.30 (1H, ddd, *J*=15.1, 4.6, 4.6Hz), 2.38 (1H, ddd, *J*=15.1, 7.6, 7.6Hz), 3.63 (2H, m), 4.48 (1H, dd, *J*=12.0, 6.4Hz), 4.67 (1H, dd, *J*=12.0, 3.2Hz), 5.52 (1H, m), 5.67 (1H, m), 7.30-7.56 (9H, m), 7.87-7.95 (6H, m). HREIMS *m/z*: calcd for $C_{27}H_{26}O_7$ (M^+): 462.1677; found: 462.1653.

(2*R*,4*R*)-1,2,4-Tri-*O*-(benzoyl)hexane-1,2,4,6-tetrol (13a). $[\alpha]_D^{25}$ +10.1° (c=0.8, $CHCl_3$).

(2*S*,4*S*)-2,4-Di-*O*-benzoyl-1-*O*-(pivaloyl)hexane-1,2,4,6-tetrol (4b). $[\alpha]_D^{25}$ -7.62° (c=0.8, CHCl$_3$). IR (CHCl$_3$): 3500, 1720, 1600, 1280, 1160cm^{-1}. ^{1}H NMR (270MHz, CD$_3$OD) δ: 1.09 (9H, s), 1.99 (2H, m), 2.18 (1H, ddd, *J*=15.1, 4.7, 4.7Hz), 2.30 (1H, ddd, *J*=15.1, 7.7, 7.7Hz), 3.64 (2H, m), 4.25 (1H, dd, *J*=11.8, 6.7Hz), 4.43 (1H, dd, *J*=11.8, 3.4Hz), 5.46 (1H, m), 5.54 (1H, m), 7.33-7.38 (4H, m), 7.50-7.56 (2H, m), 7.87-7.93 (4H, m). HREIMS *m/z*: calcd for $C_{25}H_{30}O_7$ (M$^+$): 442.1990; found: 442.1972.

(2*R*,4*R*)-2,4-Di-*O*-benzoyl-1-*O*-(pivaloyl)hexane-1,2,4,6-tetrol (13b). $[\alpha]_D^{25}$+7.0°(c=0.6, CHCl$_3$).

(2*S*,4*R*)-1,2,4-Tri-*O*-(benzoyl)hexane-1,2,4,6-tetrol (7a). $[\alpha]_D^{25}$ -67.0° (c=0.8, CHCl$_3$). IR (CHCl$_3$): 3500, 1720, 1600, 1270, 1110cm^{-1}. ^{1}H NMR (400MHz, CD$_3$OD) δ: 1.99 (1H, m), 2.06 (1H, m), 2.27 (1H, ddd, *J*=15.1, 8.8, 3.2Hz), 2.40 (1H, ddd, *J*=15.1, 9.5, 3.4Hz), 3.66 (2H, m), 4.46 (1H, dd, *J*=12.0, 6.7Hz), 4.67 (1H, dd, *J*=12.0, 3.4Hz), 5.48 (1H, m), 5.67 (1H, dddd, *J*=9.8, 6.7, 3.4, 3.4Hz), 7.35-7.58 (9H, m), 7.89-7.97 (6H, m). HREIMS *m/z*: calcd for $C_{27}H_{26}O_7$ (M$^+$): 462.1677; found: 462.1685.

(2*R*,4*S*)-1,2,4-Tri-*O*-(benzoyl)hexane-1,2,4,6-tetrol (10a). $[\alpha]_D^{25}$ -70.8° (c=1.0, CHCl$_3$).

(2*S*,4*R*)-2,4-Di-*O*-benzoyl-1-*O*-(pivaloyl)hexane-1,2,4,6-tetrol (7b). $[\alpha]_D^{25}$ -80.5° (c=0.43, CHCl$_3$). IR (CHCl$_3$): 3450, 1720, 1600, 1270, 1150cm^{-1}. ^{1}H NMR (270MHz, CD$_3$OD) δ: 2.01 (2H, m), 2.17 (1H, ddd, *J*=15.1, 8.7, 3.4Hz), 2.30 (1H, ddd, *J*=15.1, 9.4, 3.4Hz), 3.64 (2H, m), 4.23 (1H, dd, *J*=11.8, 6.7Hz), 4.41 (1H, dd, *J*=11.8, 3.4Hz), 5.42 (1H, m), 5.55 (1H, dddd, *J*=10.4, 7.1, 3.4, 3.4Hz), 7.35-7.45 (4H, m), 5.50-7.58 (2H, m), 7.89-7.94 (4H, m). HREIMS *m/z*: calcd for $C_{25}H_{30}O_7$ (M$^+$): 442.1990; found: 442.1978.

(2*R*,4*S*)-2,4-Di-*O*-benzoyl-1-*O*-(pivaloyl)hexane-1,2,4,6-tetrol (10b). $[\alpha]_D^{25}$ +78.2° (c=0.67, CHCl$_3$).

Preparation of 5, 8, 11, and 14. A solution of a hydroxyl derivative (0.02mmol) obtained above in pyridine (0.4ml) was treated with acetic anhydride (50μl). After being stirred for 12h, the solvents were removed *in vacuo*. The product was purified by flash chromatography (25% EtOAc/hexane for **a** series; 20% EtOAc/hexane for **b** series).

(2*S*,4*S*)-6-*O*-Acetyl-1,2,4-tri-*O*-(benzoyl)hexane-1,2,4,6-tetrol (5a). $[\alpha]_D^{25}$ -19.8° (c=1.0, CHCl$_3$). IR (CHCl$_3$): 1720, 1600, 1450, 1270, 1210, 1010cm^{-1}. ^{1}H NMR (270MHz, CD$_3$OD) δ: 1.85 (3H, s), 2.13 (2H, m), 2.27 (1H, ddd, *J*=14.8, 4.7, 4.7Hz), 2.40 (1H, ddd, *J*=14.8, 7.7, 7.7Hz), 4.16 (2H, t, *J*=6.1Hz), 4.50 (1H, dd, *J*=12.1, 6.4Hz), 4.67 (1H, dd, *J*=12.1, 3.4Hz), 5.49 (1H, m), 5.67 (1H, m), 7.32-7.59 (9H, m), 7.88-7.94 (6H, m). HREIMS *m/z*: calcd for $C_{29}H_{28}O_8$ (M$^+$): 504.1782; found: 504.1767.

(2*R*,4*R*)-6-*O*-Acetyl-1,2,4-tri-*O*-(benzoyl)hexane-1,2,4,6-tetrol (14a). $[\alpha]_D^{25}$ +15.3° (c=0.8, CHCl$_3$).

(2*S*,4*S*)-6-*O*-Acetyl-2,4-di-*O*-benzoyl-1-*O*-(pivaloyl)hexane-1,2,4,6-tetrol (5b). $[\alpha]_D^{25}$ -17.6° (c=0.36, CHCl$_3$). IR (CHCl$_3$): 1720, 1600, 1460, 1265, 1210, 1010cm^{-1}. ^{1}H NMR (270MHz, CD$_3$OD) δ: 1.09 (9H, s), 1.86 (3H, s), 2.11 (2H, m), 2.16 (1H, ddd, *J*=14.8, 5.0, 5.0Hz), 2.31 (1H, ddd, *J*=14.8, 8.1, 8.1Hz), 4.16 (2H, t, J=6.1Hz), 4.26 (1H, dd, J=11.8, 6.7Hz), 4.42 (1H, dd, J=11.8, 3.4Hz), 5.43 (1H, m), 5.55 (1H, m), 7.34-7.40 (4H, m), 7.50-7.57 (2H, m), 7.88-7.94 (4H, m). HREIMS *m/z*: calcd for $C_{27}H_{32}O_8$ (M^+): 484.2095; found: 484.2107.

(2*R*,4*R*)-6-*O*-Acetyl-2,4-di-*O*-benzoyl-1-*O*-(pivaloyl)hexane-1,2,4,6-tetrol (14b). $[\alpha]_D^{25}$ +17.2° (c=0.27, $CHCl_3$).

(2*S*,4*R*)-6-*O*-Acetyl-1,2,4-tri-*O*-(benzoyl)hexane-1,2,4,6-tetrol (8a). $[\alpha]_D^{25}$ -48.5° (c=1.3, $CHCl_3$). IR ($CHCl_3$): 1720, 1600, 1450, 1270, 1210, 1015cm^{-1}. ^{1}H NMR (270MHz, CD_3OD) δ: 1.86 (3H, s), 2.14 (2H, m), 2.29 (1H, ddd, J=15.1, 8.4, 3.7Hz), 2.37 (1H, ddd, J=15.1, 9.1, 3.7Hz), 4.16 (2H, t, J=6.1Hz), 4.47 (1H, dd, J=11.8, 6.7Hz), 4.67 (1H, dd, J=11.8, 3.7Hz), 5.46 (1H, m), 5.65 (1H, dddd, J=9.1, 6.7, 3.7, 3.7Hz), 7.36-7.45 (6H, m), 7.51-7.60 (3H, m), 7.89-7.96 (6H, m). HREIMS *m/z*: calcd for $C_{29}H_{28}O_8$ (M^+): 504.1782; found: 504.1764.

(2*R*,4*S*)-6-*O*-Acetyl-1,2,4-tri-*O*-(benzoyl)hexane-1,2,4,6-tetrol (11a). $[\alpha]_D^{25}$ +52.4° (c=0.48, $CHCl_3$).

(2*S*,4*R*)-6-*O*-Acetyl-2,4-di-*O*-benzoyl-1-*O*-(pivaloyl)hexane-1,2,4,6-tetrol (8b). $[\alpha]_D^{25}$ -41.3° (c=0.24, $CHCl_3$). IR ($CHCl_3$): 1720, 1600, 1460, 1260, 1210, 1110cm^{-1}. ^{1}H NMR (270MHz, CD_3OD) δ: 1.10 (9H, s), 1.87 (3H, s), 2.11 (2H, m), 2.18 (1H, ddd, J=15.1, 8.4, 3.7Hz), 2.27 (1H, ddd, J=15.1, 9.1, 3.7Hz), 4.15 (2H, t, J=6.1Hz), 4.23 (1H, dd, J=11.8, 7.1Hz), 4.42 (1H, dd, J=11.8, 3.4Hz), 5.40 (1H, m), 5.53 (1H, dddd, J=9.4, 7.1, 3.4, 3.4Hz), 7.37-7.43 (4H, m), 7.52-7.59 (2H, m), 7.90-7.95 (4H, m). HREIMS *m/z*: calcd for $C_{27}H_{32}O_8$ (M^+): 484.2095; found: 484.2069.

(2*R*,4*S*)-6-*O*-Acetyl-2,4-di-*O*-benzoyl-1-*O*-(pivaloyl)hexane-1,2,4,6-tetrol (11b). $[\alpha]_D^{25}$ +46.3° (c=0.67, $CHCl_3$).

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