Diastereoselective Addition of Grignard Reagents to 3,4-*O*-Isopropylidene-1-*O*-triphenylmethyl-L-*glycero*-2-tetrulose and 1-*O*-Benzoyl-3,4-*O*-isopropylidene-L-*glycero*-2-tetrulose[1)]

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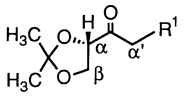
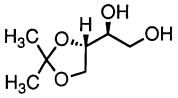
Diastereoselectivity in the addition of Grignard reagents (RMgX) to 3,4-*O*-isopropylidene-1-*O*-triphenylmethyl-L-*glycero*-2-tetrulose (**1**) and 1-*O*-benzoyl-3,4-*O*-isopropylidene-L-*glycero*-2-tetrulose (**2**) depended remarkably on R, X, the solvent, and the reaction temperature. In the reaction of **1** in diethyl ether at 0°C and **2** in tetrahydrofuran were obtained (2*R*,3*S*)-adducts with moderate to high diastereoselectivity, while in the reaction of **2** in diethyl ether at −78 °C (2*S*,3*S*)-adducts were the major products. (2*R*)-2-Hydroxymethyl-2-nonyloxirane and (2*S*)-2-hydroxymethyl-2-tetradecyloxirane were synthesized.

Chiral tertiary alcohols are quite frequent in nature and a number of methods for their synthesis have been developed. In particular highly diastereoselective chelation controlled nucleophilic addition of simple organometallic reagents such as Grignard reagents to α-chiral α-alkoxy ketones is an efficient method for the synthesis of chiral tertiary alcohols.[2)] The usefulness of this methods would be enhanced if diastereoselectivity could be controlled even in the presence of an additional α′-oxygen containing function. To our knowledge, however, very few investigations on the diastereoselectivity in the nucleophilic addition to α-chiral α,α′-dialkoxy ketones have been reported.[3,4)] We now report the diastereoselectivity in the addition of organometallics to 3,4-*O*-isopropylidene-1-*O*-triphenylmethyl-L-*glycero*-2-tetrulose (**1**)[5)] and 1-*O*-benzoyl-3,4-*O*-isopropylidene-L-*glycero*-2-tetruloses **2**, **3**, and **4**, i.e., ketones having an α-asymmetric center and α, β, and α′-oxygen substituents, and applications of this reaction to natural product synthesis.



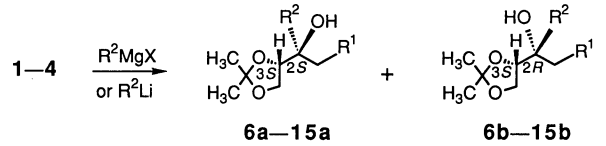


5

1 R^1 = $OCPh_3$
2 R^1 = OCOPh
3 R^1 = $OCOC_6H_4OMe$-*p*
4 R^1 = $OCOC_6H_4NO_2$-*p*
21 R^1 = alkyl or aryl

Compounds **2**, **3**, and **4** were prepared from 1,2-*O*-isopropylidene-L-threitol (**5**)[6)] by the protection of the primary hydroxyl group with benzoyl chlorides followed by the oxidation of the secondary hydroxyl group with chromium(VI) oxide–pyridine complex.

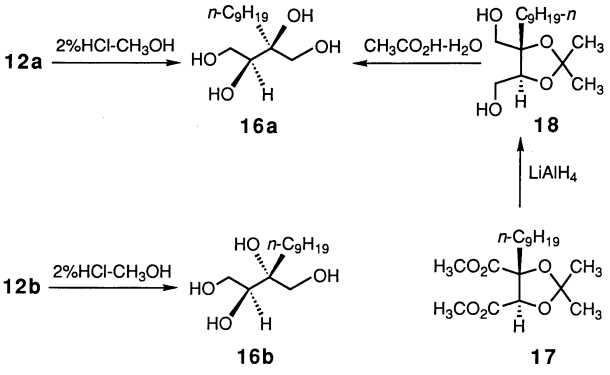
The results of the addition of Grignard reagents to the ketones **1**—**4** are summarized in Table 1 (see Scheme 1).



6a—15a **6b—15b**

6a, 6b	R^1= $OCPh_3$,	R^2= CH_3
7a, 7b	R^1= $OCPh_3$,	R^2= CH_2CH_3
8a, 8b	R^1= $OCPh_3$,	R^2= $CH(CH_3)_2$
9a, 9b	R^1= $OCPh_3$,	R^2= $(CH_2)_3CH_3$
10a, 10b	R^1= OCOPh,	R^2= CH_3
11a, 11b	R^1= OCOPh,	R^2= CH_2CH_3
12a, 12b	R^1= OH,	R^2= *n*-C_9H_{19}
13a, 13b	R^1= OH,	R^2= *n*-$C_{14}H_{29}$
14a, 14b	R^1= OCOPh,	R^2= C≡CH
15a, 15b	R^1= OH,	R^2= CH_3

Scheme 1.



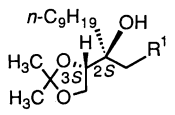
Scheme 2.

Assignment of stereochemistry of the tertiary alcohols **6**—**15** was performed as follows. Nucleophilic addition of nonylmagnesium bromide to the ketone **2** gave the diols **12a** and **12b** in 55 and 26% yields, respectively (Entry 17). These diols were then hydrolyzed separately to give the tetrols **16a** and **16b** (Scheme 2). On

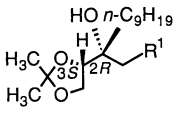
Table 1. Nucleophilic Addition of R^2MgX and R^2Li to the Ketones **1**—**4**

Entry	Ketone	R^2MgX or R^2Li	Solvent	Temp[a] °C	Product	Yield %	Diastereomer ratio(2*S*:2*R*)
1	**1**	MeMgBr	THF	−78	**6**	99	20:80
2	**1**	MeMgBr	THF	0	**6**	99	29:71
3	**1**	EtMgI	Ether	−78	**7**	89	53:47
4	**1**	EtMgI	Ether	0	**7**	100	12:88
5	**1**	EtMgBr	Ether	−78	**7**	86	11:89
6	**1**	EtMgBr	Ether	0	**7**	94	3:97
7	**1**	*i*-PrMgI	Ether	−78	**8**	75	2:98
8	**1**	*i*-PrMgI	Ether	0	**8**	82	2:98
9	**1**	*i*-PrMgBr	Ether	0	**8**	74	1:99
10	**1**	*n*-BuMgI	Ether	−78	**9**	84	10:90
11	**1**	*n*-BuMgBr	Ether	−78	**9**	94	13:87
12	**1**	*n*-BuMgCl	Ether	−78	**9**	82	5:95
13	**1**	*n*-BuMgCl	Ether	0	**9**	96	2:98
14	**2**	MeMgI	Ether	−78	**10**	89	62:38
15	**2**	EtMgI	Ether	−78	**11**	61	77:23
16	**2**	EtMgBr	Ether	−25	**11**	89	40:60
17	**2**	*n*-$C_9H_{19}MgBr$	Ether	−78→0	**12**	81	68:32
18	**2**	*n*-$C_{14}H_{29}MgBr$	Ether	−50	**13**	84	80:20
19	**2**	*n*-$C_{14}H_{29}MgBr$	Ether	0	**13**	81	32:68
20	**2**	MeMgBr	THF	−78	**10**	85	18:82
21	**2**	HC≡MgCl	THF	0	**14**	79	31:69[b]
22	**2**	HC≡CMgBr	THF	0	**14**	76	36:64[b]
23	**2**	*n*-$C_9H_{19}MgBr$	THF	−78	**12**	89	17:83
24	**2**	*n*-$C_{14}H_{29}MgBr$	THF	−50	**13**	82	8:92
25	**2**	*n*-$C_{14}H_{29}MgBr$	THF	0	**13**	70	9:91
26	**3**	*n*-$C_{14}H_{29}MgBr$	THF	0	**13**	83	7:93
27	**4**	*n*-$C_{14}H_{29}MgBr$	THF	−50	**13**	78	13:87
28	**1**	MeLi	THF	−78	**6**	100	63:37
29	**1**	*n*-BuLi	THF	−78	**9**	100	45:55
30	**2**	MeLi	THF	−100	**15**	74	79:21

a) The reaction mixture (Entries 18, 19, and 23—27) was heated under reflux before work-up.
b) Opposite diastereoselectivity in the addition of lithium trimethylsilylacetylide to 3,4-*O*-isopropylidene-1-*O*-pivaloyl-D-*glycero*-tetrulose has recently been reported (see Ref. 4).



19a R^1= $OCPh_3$
20a R^1= OCOPh

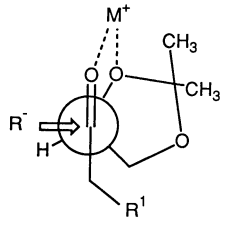


19b R^1= $OCPh_3$
20b R^1= OCOPh

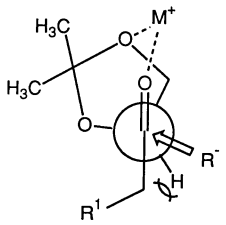
the other hand reduction of dimethyl (2*R*,3*R*)-2,3-*O*-isopropylidene-2-nonyltartrate (**17**)[7] with lithium aluminium hydride gave the diol **18**. The diol was then hydrolyzed to give (2*S*,3*S*)-2-nonyl-1,2,3,4-butanetetrol, $[\alpha]_D$ −8.7°, which was identical with the major tetrol **16a**, $[\alpha]_D$ −8.9°. This shows, furthermore, that the racemization of the ketone **2** during its preparation and the nucleophilic addition did not occur. The stereochemistry of the diastereomeric pairs **6**—**11**, **13**, and **15** was determined in comparing their Δδ values [=δ(2*S*,3*S*)−δ(2*R*,3*S*)] in ^{13}C NMR spectra with those of **12**, **19**, and **20**, i.e., compounds **6**—**9** and **19**: Δδ(-O-*C*(Me)$_2$-O-)>0, Δδ(O*C*Ph$_3$)<0, Δδ(C_3)<0, Δδ(C_2)<0, Δδ(C_1)>0, and Δδ(C_4)<0; compounds **10**, **11**, and **20**: Δδ(-O-*C*(Me)$_2$-O-)>0, Δδ(C_3)<0, Δδ(C_2)<0, Δδ(C_1)>0, and Δδ(C_4)<0; compounds **12**, **13**, and **15**: Δδ(-O-*C*(Me)$_2$-O-)>0, Δδ(C_3)>0, Δδ(C_2)<0, Δδ(C_1)>0, and Δδ(C_4)<0. The stereochemistry of the ethynyl alcohols **14** (Entries 21 and 22) was assigned by transforming them to the corresponding saturated alcohols **11** by catalytic hydrogenation over 10% Pd-C in ethanol. Furthermore, the assignment of the stereochemistry of **12a** and **13b** was confirmed by transforming them to the known compounds **24** and **28**, respectively (vide infra). The diastereomer ratios were deduced by HPLC analysis (Entries 1—16), ^1H NMR spectra (Entries 1, 2, 14, 20—22, 28, and 30), and proton broadband-decoupled ^{13}C NMR spectra (Entries 10, 11, 14—16, 20—22, and 28—30; integration ratios of the five diastereomeric pairs of 1-C, 2-C, 3-C, 4-C, and -O-*C*(CH_3)$_2$-O- were used for the determination of the diastereomer ratios. The ratios were well in accord with those obtained by HPLC and ^1H NMR spectra). The diastereomers of **12** and **13** (Entries 17—19 and 23—27) were separated by flash chromatography and their diastereomer ratios were determined.

The addition of Grignard reagents to the ketone **21** occurs stereoselectively via chelation of α-oxygen (**A**).[2,8] Chelation of β-oxygen (**B**) is not preferable because of

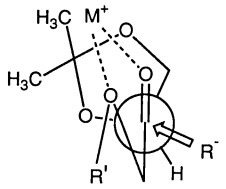
the steric repulsion between CH_2R^1 and 3-H.[8b] The diastereoselectivity in the reaction of **1**—**4** where their oxygen functions compete chelation depended remarkably on the bulk of alkyl groups (R^2), the halides (Cl, Br, and I), the solvents (diethyl ether and tetrahydrofuran (THF)), and the reaction temperature. In the addition of Grignard reagents to the ketone **1** were yielded (2*R*,3*S*)-diastereomers as the major products except for Entry 3. The α'-oxygen carrying a bulky triphenylmethyl group may be prevented to participate in chelations **C** (a variant of Felkin–Ahn model) and **D**,[3] and the nucleophilic addition may proceed via chelation **A** to give (2*R*,3*S*)-diastereomers. The proportion of the (2*R*,3*S*)-diastereomers increased in the order of R^2MgI, R^2MgBr, and R^2MgCl. Furthermore, it was revealed that the reaction in diethyl ether at 0 °C gave rise to higher selectivity than did the reaction at −78 °C (Entries 3 versus 4, 5 versus 6, and 12 versus 13). In THF, however, higher diastereoselectivity was obtained at −78 °C (Entries 1 versus 2).



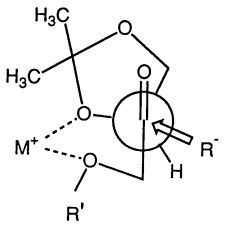
A



B

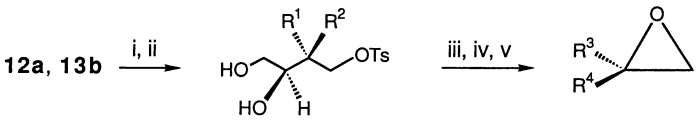


C



D

In order to apply this reaction to natural product synthesis, selective hydrolysis of the acetonide and the triphenylmethyl ether in **8** was attempted under various acidic conditions, but to no avail. Diastereoselective addition of Grignard reagents to the ketones **2**—**4** which possess an acid stable benzoyl ester group instead of the triphenylmethyl ether group was then examined. Addition of R^2MgX to the ketone **2** in diethyl ether at −78 or −50 °C gave (2*S*, 3*S*)-adducts as the major products (Entries 14, 15, 17, and 18), while at a higher temperature the diastereoselectivity was reversed (Entries 16 and 19). (2*S*, 3*S*)-Adducts may be yielded through the chelations **C** and/or **D**, but the dependence of diastereoselectivity on the reaction temperature shows the lack of tight chelation structure.[9] When the reaction was performed in THF were obtained (2*R*,3*S*)-adducts with moderate to high diastereoselectivities and the diastereomer ratio [(2*R*,3*S*)/(2*S*,3*S*)] tends to increase with increasing size of R^2 (C≡CH<CH_3<*n*-C_9H_{19}<*n*-$C_{14}H_{29}$) (Entries 20—25). The diastereoselectivity of the reaction performed in THF was not affected by the reaction temperature (Entries 24 and 25). *p*-Methoxybenzoate **3** and *p*-nitrobenzoate **4** showed a similar diastereoselectivity and the *p*-substituents did not affect the selectivity (Entries 26 and 27).



22 R^1= *n*-C_9H_{19}
R^2= OH

26 R^1= OH
R^2= *n*-$C_{14}H_{29}$

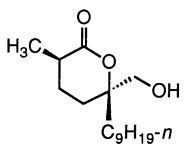
23 R^3= *n*-C_9H_{19}
R^4= $CH(OH)CH_2OH$

24 R^3= *n*-C_9H_{19}
R^4= CH_2OH

27 R^3= $CH(OH)CH_2OH$
R^4= *n*-$C_{14}H_{29}$

28 R^3= CH_2OH
R^4= *n*-$C_{14}H_{29}$

29 R^3= $CO_2CH_2CH_3$
R^4= *n*-$C_{14}H_{29}$



25

Scheme 3. Reagents: 1, TsCl/pyridine; ii, 3%HCl–CH_3OH; iii, NaOH; iv, $NaIO_4$; v, $NaBH_4$.

Addition of methyllithium to the ketones **1** and **2** (Entries 28 and 30) and butyllithium (Entry 29) did not show useful diastereoselectivity.[4,9]

Finally, the reaction was applied to natural product synthesis (Scheme 3). Compound **12a** was transformed to (2*R*)-2-hydroxymethyl-2-nonyloxirane (**24**) in five steps and in 58% overall yield. Selective tosylation of the primary hydroxyl group of **12a** followed by acid-catalyzed hydrolysis gave the triol **22**. The triol **22** was then treated with sodium hydroxide to give the epoxy diol **23**. Oxidative cleavage of the epoxy diol **23** with sodium periodate followed by reduction with sodium borohydride gave **24**, $[\alpha]_D$ +15.4°. Transformation of the epoxy alcohol **24** to (−)-malyngolide (**25**), an antibiotic isolated from marine blue-green alga *Lyngbya majuscula* Gomont, has been reported.[10] Compound **13b** was also transformed to (2*S*)-2-hydroxymethyl-2-tetradecyloxirane (**28**), $[\alpha]_D$ −11.3°, an intermediate for the synthesis of *R*-palmoxirate (**29**) (a hypoglycemic agent)[11] by use of the same procedures in 31% overall yield (**13b**→**26**→**27**→**28**).

Experimental

Melting points were determined on a Yanaco micro melting point apparatus and are uncorrected. IR spectra were taken on a JASCO A-3 spectrometer. ^{1}H NMR spectra were recorded on a JEOL GX-270 (270 MHz) spectrometer with chloroform-*d* (unless otherwise stated) as solvent and tetramethylsilane as internal standard. ^{13}C NMR were recorded on the instrument (67.8 MHz) with chloroform-*d* (unless otherwise stated) as solvent and internal standard (δ=77.00). Mass spectra were obtained on a JEOL DX-300 mass spectrometer using electron impact mode (70 eV). Optical rotations were determined on a JASCO DIP-181 digital polarimeter. High performance liquid chromatography (HPLC) was carried out with a JASCO TRI ROTAR-IV apparatus. Silica gel (Wakogel C-300) was used for flash chromatography.

1-*O*-Benzoyl-3,4-*O*-isopropylidene-L-*glycero*-2-tetrulose (2). To a solution of 1,2-*O*-isopropylidene-L-threitol (**5**) (4.07 g) in dry pyridine (20 ml) cooled to 0 °C was added dropwise a solution of benzoyl chloride (4.0 g) in dry diethyl ether (50 ml). The mixture was stirred at 0 °C for 1.5 h and then allowed to stand at 5 °C overnight. Water and then dilute hydrochloric acid were added. The ethereal layer was washed successively with aqueous sodium hydrogencarbonate, water, and saturated brine, and dried over anhydrous sodium sulfate. The crude oily product was purified by flash chromatography (silica gel 200 g; eluent: hexane–ethyl acetate 5:1) to give 4-*O*-benzoyl-1,2-*O*-isopropylidene-L-threitol (5.42 g, 81%), an oil; $[\alpha]_D$ +1.9° (*c* 3.0, $CHCl_3$), IR (neat) 3480, 1725, 1605, 1587, 1275, 1115, 1070, 850, and 713 cm^{-1}; ^{1}H NMR δ=8.04 (2H, d, *J*=7.1 Hz, Ph), 7.6—7.4 (3H, m, Ph), 4.43 (1H, dd, *J*=11.7 and 6.4 Hz, 1-H), 4.37 (1H, dd, *J*=11.7 and 4.9 Hz, 1-H), 4.23 (1H, ddd, *J*=6.4, 6.4, and 4.6 Hz, 2-H), 4.10 (1H, dd, *J*=8.3 and 6.6 Hz, 3-H), 3.93 (2H, m, 4-H), 1.47 (3H, s, CH_3), and 1.38 (3H, s, CH_3); MS *m*/*z* 251 (M^+-CH_3, rel intensity 21%), 105 (PhCO, 100), and 101 (84). Found: *m*/*z* 251.0903. Calcd for $C_{13}H_{15}O_5$: $M-CH_3$, 251.0919.

To a suspension of chromium(VI) oxide (6.64 g) in dry dichloromethane (160 ml) cooled to 0 °C was added pyridine (10.5 ml) and the mixture was stirred for 15 min. A solution of 4-*O*-benzoyl-1,2-*O*-isopropylidene-L-threitol (3.00 g) in dry dichloromethane (30 ml) was then added and the mixture was stirred at room temperature overnight. The mixture was loaded on a silica-gel column (SiO_2, 150 g) and eluted with hexane–ethyl acetate (5:1). The crude oily product was crystallized from hexane–diethyl ether to give the ketone **2** (2.25 g, 76%), colorless plates, mp 58.5—59.0 °C; $[\alpha]_D^{26}$ −83.2° (*c* 0.99, $CHCl_3$); IR (KBr) 1745, 1720, 1602, 1583, 1273, 1120, 1105, 1073, 840, 730, and 710 cm^{-1}; ^{1}H NMR δ=8.09 (2H, d, *J*=7.1 Hz, Ph), 7.58 (1H, t, *J*=7.3 Hz, Ph), 7.46 (2H, dd, *J*=7.8 and 7.8 Hz, Ph), 5.24 (1H, d, *J*=17.5 Hz, 1-H), 5.16 (1H, d, *J*=17.5 Hz, 1-H), 4.61 (1H, dd, *J*=7.8 and 5.6 Hz, 3-H), 4.22 (2H, m, 4-H), 1.55 (3H, s, CH_3), and 1.42 (3H, s, CH_3); ^{13}C NMR δ=203.25, 165.84, 133.36, 129.86, 129.22, 128.43, 111.37, 79.19, 66.79, 66.53, 25.93, and 24.72; MS *m*/*z* 249 (M^+-CH_3, 4), 163 (10), 105 (48), and 101 (100). Found: *m*/*z* 249.0776. Calcd for $C_{13}H_{13}O_5$: $M-CH_3$, 249.0763.

3: Colorless plates, mp 60.8—61.8 °C (recrystallized from diethyl ether–hexane), $[\alpha]_D^{26}$ −83.8° (*c* 0.92, $CHCl_3$); IR (KBr) 1743, 1713, 1610, 1510, 843, and 775 cm^{-1}; ^{1}H NMR δ=8.04 (2H, d, *J*=9.0 Hz, Ph), 6.94 (2H, d, *J*=9.0 Hz, Ph), 5.20 (1H, d, *J*=17.8 Hz, 1-H), 5.14 (1H, d, *J*=17.8 Hz, 1-H), 4.61 (1H, dd, *J*=7.7 and 5.5 Hz, 3-H), 4.25 (2H, m, 4-H), 3.87 (3H, s, OCH_3), 1.55 (3H, s, CH_3), and 1.41 (3H, s, CH_3); ^{13}C NMR δ=203.42, 165.46, 163.66, 131.89, 121.52, 113.66, 111.27, 79.13, 66.52, 66.43, 55.36, 25.86, and 24.68; MS *m*/*z* 279 (M^+-CH_3, 3.5), 193 (35), 135 (81), and 101 (100). Found: *m*/*z* 279.0872. Calcd for $C_{14}H_{15}O_6$: $M-CH_3$, 279.0869.

4: Colorless needles, mp 65.9—66.8 °C (recrystallized from diethyl ether–hexane): $[\alpha]_D^{26}$ −80.0° (*c* 0.69, $CHCl_3$); IR (KBr) 1745, 1730, 1610, 1535, 1355, 1275, 1113, 1090, 860, and 725 cm^{-1}; ^{1}H NMR δ=8.29 (2H, d, *J*=9.0 Hz, Ph), 8.25 (2H, d, *J*=9.0 Hz, Ph), 5.30 (1H, d, *J*=17.7 Hz, 1-H), 5.22 (1H, d, *J*=17.7 Hz, 1-H), 4.62 (1H, dd, *J*=7.8 and 5.1 Hz, 3-H), 4.28 (1H, dd, *J*=8.9 and 7.8 Hz, 4-H), 4.18 (1H, dd, *J*=8.9 and 5.2 Hz, 4-H), 1.57 (3H, s, CH_3), and 1.42 (3H, s, CH_3); ^{13}C NMR δ=202.67, 163.92, 150.69, 134.55, 130.91, 123.51, 111.41, 79.05, 67.37, 66.46, 25.84, and 24.52; MS *m*/*z* 294 (M^+-CH_3, 4), 150 (28), and 101 (100). Found: *m*/*z* 294.0611. Calcd for $C_{13}H_{12}O_7N$: $M-CH_3$, 294.0614.

(2*S*,3*S*)- and (2*R*,3*S*)-3,4-*O*-Isopropylidene-2-methyl-1-*O*-triphenylmethyl-1,2,3,4-butanetetrols (6). To a solution of the ketone **1** (51 mg, 0.13 mmol) in dry THF (3 ml) cooled to −78 °C was added a solution of methylmagnesium bromide in THF (0.82 mol dm^{-3}; 0.90 ml, 0.74 mmol) and the mixture was stirred at −78 °C for 4 h under argon. Saturated aqueous ammonium chloride was added and the mixture was warmed to room temperature. The product was then extracted with diethyl ether. Purification by flash chromatography gave the alcohol **6** (52 mg, 99% yield), colorless oil, as a diastereomeric mixture. Compound **6** was also obtained similarly by the addition of a solution of methyllithium in THF (1.0 mol dm^{-3}; 1.2 ml, 1.2 mmol) to a solution of the ketone **1** (56 mg, 0.14 mmol) in THF (3 ml) at −78 °C under argon. Analytical HPLC of **6** was performed on a Finpak Sil column (4.6×250 mm) with a solvent system (hexane–ethyl acetate 94:6 v/v) at a flow rate of 1.5 ml min^{-1}. The peaks were detected by the absorption at 260 nm. Retention times: **6a**, 40.2 min and **6b**, 43.8 min.

6a: ^{1}H NMR δ=7.46—7.20 (15H, m, Ph), 4.34 (1H, dd, *J*=8.1 and 6.3 Hz, 3-H), 3.99—3.79 (2H, m, 4-H), 3.19 (1H, d, *J*=8.5 Hz, 1-H), and 2.92 (1H, d, *J*=8.5 Hz, 1-H); ^{13}C NMR

δ=143.82, 128.72, 127.74, 127.01, 109.11 (-O-*C*(CH_3)$_2$-O-), 86.66 (*C*Ph_3), 78.74 (3-C), 71.47 (2-C), 68.33 (1-C), 64.79 (4-C), 26.33, 25.48, and 20.50.

6b: ^{1}H NMR δ=7.46—7.20 (15H, m, Ph), 4.23 (1H, dd, *J*=6.8 and 6.8 Hz, 3-H), 3.85 (2H, m, 4-H), 3.23 (1H, d, *J*=9.0 Hz, 1-H), and 2.95 (1H, d, *J*=9.0 Hz, 1-H); ^{13}C NMR δ= 143.62, 128.66, 127.84, 127.09, 108.95 (-O-*C*(CH_3)$_2$-O-), 86.81 (*C*Ph_3), 78.80 (3-C), 72.18 (2-C), 67.84 (1-C), 64.86 (4-C), 26.29, 25.11, and 21.24.

(2*S*,3*S*)- and (2*R*,3*S*)-2-Ethyl-3,4-*O*-isopropylidene-1-*O*-triphenylmethyl-1,2,3,4-butanetetrols (7). Colorless oil. Retention times in HPLC under the conditions described for **6**: **7a**, 26.4 min and **7b**, 27.7 min.

7a: ^{1}H NMR δ=7.5—7.2 (15H, m, Ph), 4.44 (1H, dd, *J*=8.6 and 6.2 Hz, 3-H), 4.00 (1H, dd, *J*=8.6 and 6.2 Hz, 4-H), 3.89 (1H, dd, *J*=8.6 and 8.6 Hz, 4-H), 3.19 (1H, d, *J*=9.3 Hz, 1-H), 2.95 (1H, d, *J*=9.3 Hz, 1-H), 1.43 (3H, s, CH_3), 1.37 (3H, s, CH_3), and 0.68 (3H, t, *J*=7.6 Hz, CH_3); ^{13}C NMR δ=143.79, 128.68, 127.71, 126.99, 108.75 (-O-*C*(CH_3)$_2$-O-), 86.59 (*C*Ph_3), 78.34 (3-C), 73.00 (2-C), 64.46 (1-C or 4-C), 64.11 (4-C or 1-C), 26.38, 25.94, 25.64, and 6.68.

7b: ^{1}H NMR δ=7.45—7.20 (15H, m, Ph), 4.22 (1H, dd, *J*= 7.1 and 7.1 Hz, 3-H), 3.75 (2H, d, *J*=7.1 Hz, 4-H), 3.21 (1H, d, *J*=9.3 Hz, 1-H), 2.91 (1H, d, *J*=9.3 Hz, 1-H), 1.77 (2H, q, *J*=7.6 Hz, CH_2), 1.36 (6H, s, CH_3), and 0.80 (3H, t, *J*=7.6 Hz, CH_3); ^{13}C NMR δ=143.48, 128.42, 127.81, 127.11, 108.62 (-O-*C*(CH_3)$_2$-O-), 86.81 (*C*Ph_3), 79.06 (3-C), 73.37 (2-C), 64.56 (1-C or 4-C), 64.20 (4-C or 1-C), 28.02, 26.29, 25.32, and 7.24.

(2*S*,3*S*)- and (2*R*,3*S*)-2-Isopropyl-3,4-*O*-isopropylidene-1-*O*-triphenylmethyl-1,2,3,4-butanetetrols (8). Retention times in HPLC under the conditions described for **6**: **8a**, 17.1 min and **8b**, 18.7 min.

8a: ^{13}C NMR δ=108.49 (-O-*C*(CH_3)$_2$-O-), 77.72 (3-C), 74.78 (2-C), 64.55 (1-C or 4-C), and 64.06 (4-C or 1-C).

8b: ^{1}H NMR δ=7.45—7.2 (15H, m, Ph), 4.25 (1H, dd, *J*=7.3 and 7.3 Hz, 3-H), 3.81 (2H, m, 4-H), 3.17 (1H, d, *J*=9.8 Hz, 1-H), 3.06 (1H, d, *J*=9.8 Hz, 1-H), 2.09 (1H, m), 1.37 (3H, s, CH_3), 1.35 (3H, s, CH_3), 0.91 (3H, d, *J*=6.8 Hz, CH_3), and 0.87 (3H, d, *J*=6.8 Hz, CH_3); ^{13}C NMR δ=143.42, 128.78, 127.81, 127.11, 108.16 (-O-*C*(CH_3)$_2$-O-), 87.37 (*C*Ph_3), 78.01 (3-C), 74.78 (2-C), 65.22 (4-C), 63.65 (1-C), 34.22, 26.36, 25.51, 17.54, and 17.00. Assignment of the ^{13}C NMR spectrum of **8b** was performed by off-resonance and selective decoupling experiments.

(2*S*,3*S*)- and (2*R*,3*S*)-2-Butyl-3,4-*O*-isopropylidene-1-*O*-triphenylmethyl-1,2,3,4-butanetetrols (9). Retention times in HPLC under the conditions described for **6**: **9a**, 18.5 min and **9b**, 20.5 min.

9a: ^{1}H NMR δ=7.45—7.2 (15H, m, Ph), 4.44 (1H, dd, *J*=8.3 and 6.4 Hz, 3-H), 4.01 (1H, dd, *J*=7.8 and 6.4 Hz, 4-H), 3.89 (1H, dd, *J*=8.3 and 7.8 Hz, 4-H), 3.20 (1H, d, *J*=8.6 Hz, 1-H), 2.96 (1H, d, *J*=8.8 Hz, 1-H), 1.43 (3H, s, CH_3), 1.38 (3H, s, CH_3), 1.8—1.0 (6H, m, CH_2), and 0.80 (3H, t, *J*=7.1 Hz, CH_3); ^{13}C NMR δ=143.81, 128.74, 127.87, 127.01, 108.79 (-O-*C*(CH_3)$_2$-O-), 86.59 (*C*Ph_3), 78.48 (3-C), 72.97 (2-C), 64.56 (1-C or 4-C), 64.52 (4-C or 1-C), 32.98, 26.40, 25.66, 24.35, 23.19, and 13.95.

9b: ^{1}H NMR δ=7.46—7.21 (15H, m, Ph), 4.23 (1H, dd, *J*=7.1 and 7.1 Hz, 3-H), 3.76 (2H, d, *J*=7.1 Hz, 4-H), 3.22 (1H, d, *J*=9.3 Hz, 1-H), 2.90 (1H, d, *J*=9.3 Hz, 1-H), 1.36 (6H, s, CH_3), 1.8—1.0 (6H, m, CH_2), and 0.87 (3H, t, *J*=7.1 Hz, CH_3); ^{13}C NMR δ=143.49, 128.69, 127.83, 127.12, 108.68 (-O-*C*-(CH_3)$_2$-O-), 86.82 (*C*Ph_3), 79.32 (3-C), 73.30 (2-C), 64.56 (1-C or 4-C), 64.52 (4-C or 1-C), 35.20, 26.32, 25.35, 24.89, 23.28, and 14.07.

(2*S*,3*S*)- and (2*R*,3*S*)-1-*O*-Benzoyl-3,4-*O*-isopropylidene-2-methyl-1,2,3,4-butanetetrols (10). Colorless oil; IR (neat) 3480, 1720, 1602, 1585, 1272, 1210, 1110, 1067, 850, and 710 cm^{-1}; MS *m*/*z* 265 (M^+ −CH_3, 12), 105 (100), and 101 (72). Analytical HPLC of **10** was performed on a Finpak Sil C_{18}S column (4.6×150 mm) with a solvent system (water–methanol 4:6 v/v) at a flow rate of 1.0 ml min^{-1}. The peaks were detected by the absorption at 230 nm. Retention times: **10a**, 27.3 min and **10b**, 30.0 min. Found: *m*/*z* 265.1097. Calcd for $C_{14}H_{17}O_5$: M −CH_3, 265.1076.

10a: ^{1}H NMR δ=8.07—8.03 (2H, m, Ph), 7.61—7.54 (1H, m, Ph), 7.48—7.27 (2H, m, Ph), 4.45—3.93 (5H, m, 1-H, 3-H, and 4-H), 1.44 (3H, s, CH_3), 1.36 (3H, s, CH_3), and 1.23 (3H, s, 2-CH_3); ^{13}C NMR δ=166.57, 133.08, 129.60, 128.45, 109.63 (-O-*C*(CH_3)$_2$-O-), 78.61 (3-C), 70.90 (2-C), 69.40 (1-C), 64.60 (4-C), 26.29, 25.24, and 20.06.

10b: ^{1}H NMR δ=8.07—8.03 (2H, m, Ph), 7.61—7.54 (1H, m, Ph), 7.50—7.20 (2H, m, Ph), 4.45—3.93 (5H, m, 1-H, 3-H, and 4-H), 1.45 (3H, s, CH_3), 1.37 (3H, s, CH_3), and 1.33 (3H, s, 2-CH_3); ^{13}C NMR δ=166.34, 133.23, 129.63, 128.37, 109.34 (-O-*C*(CH_3)$_2$-O-), 78.71 (3-C), 71.95 (2-C), 69.05 (1-C), 64.82 (4-C), 26.23, 24.88, and 20.82. Assignment of the ^{13}C NMR spectra of **10a** and **10b** was performed by off-resonance experiment.

(2*S*,3*S*)- and (2*R*,3*S*)-1-*O*-Benzoyl-2-ethyl-3,4-*O*-isopropylidene-1,2,3,4-butanetetrols (11). Retention times in HPLC under the conditions described for **10**: **11a**, 43.3 min and **11b**, 45.3 min.

11a: ^{1}H NMR δ=8.06—8.01 (2H, m, Ph), 7.60—7.42 (3H, m, Ph), 4.50—3.90 (5H, m, 1-H, 3-H, and 4-H), 1.60 (2H, m, C$H_2$$CH_3$), 1.43 (3H, s, CH_3), 1.36 (3H, s, CH_3), and 1.00 (3H, t, *J*=7.5 Hz, CH_2CH_3); ^{13}C NMR δ=166.31, 133.07, 129.60, 128.40, 109.28 (-O-*C*(CH_3)$_2$-O-), 77.98 (3-C), 72.59 (2-C), 66.30 (1-C), 64.34 (4-C), 26.32, 26.26, 25.35, and 7.33.

11b: ^{1}H NMR δ=8.06—8.01 (2H, m, Ph), 7.60—7.42 (3H, m, Ph), 4.50—3.90 (5H, m, 1-H, 3-H, and 4-H), 1.77 (2H, m, C$H_2$$CH_3$), 1.45 (3H, s, CH_3), 1.38 (3H, s, CH_3), and 1.02 (3H, t, *J*=7.5 Hz, CH_2CH_3); ^{13}C NMR δ=166.31, 133.23, 130.04, 128.47, 108.99 (-O-*C*(CH_3)$_2$-O-), 78.61 (3-C), 73.01 (2-C), 66.03 (1-C), 64.76 (4-C), 28.12, 25.21, and 7.47.

(2*S*,3*S*)- and (2*R*,3*S*)-3,4-*O*-Isopropylidene-2-nonyl-1,2,3,4-butanetetrols (12). To a solution of nonylmagnesium bromide, prepared from 1-bromononane (2.07 g) and magnesium (243 mg), in diethyl ether (13 ml) cooled to −78 °C was added a solution of the ketone **2** (541 mg) in diethyl ether (6 ml) under argon. The mixture was stirred at −78 °C for 2 h, and at room temperature for 1 h, and then heated under reflux for 20 min. Work-up as usual followed by flash chromatography (silica gel, 50 g; eluent: hexane–ethyl acetate 4:1) gave **12a** (326 mg, 55% yield) and **12b** (155 mg, 26% yield).

12a: Colorless oil; IR (neat) 3475, 1070, and 860 cm^{-1}; ^{1}H NMR δ=4.12 (1H, dd, *J*=8.1 and 6.3 Hz, 3-H), 4.00 (1H, d, *J*=6.3 Hz, 4-H), 3.99 (1H, d, *J*=8.1 Hz, 4-H), 3.74 (1H, dd, *J*=11.5 and 2.0 Hz, 1-H), 3.53 (1H, dd, *J*=11.5 and 9.9 Hz, 1-H), 2.70 (1H, s, OH), 2.56 (1H, dd, *J*=9.9 and 2.0 Hz, OH), 1.43 (3H, s, CH_3), 1.38 (3H, s, CH_3), 1.26 (16H, br s, CH_2), and 0.88 (3H, t, *J*=6.6 Hz, CH_3); ^{13}C NMR δ=109.38 (-O-*C*(CH_3)$_2$-O-), 80.80 (3-C), 72.08 (2-C), 67.51 (1-C), 64.76 (4-C), 34.15, 31.85, 30.29, 29.50, 29.46, 29.27, 26.23, 25.54, 22.98, 22.65, and 14.08; MS *m*/*z* 273 (M^+−CH_3, 3), 101 (60), and 43

(100). Found: m/z 273.2045. Calcd for $C_{15}H_{29}O_4$: M−CH_3, 273.2066.

12b: Colorless oil; IR (neat) 3470, 1065, and 863 cm^{-1}; ^1H NMR δ=4.15 (1H, dd, J=7.6 and 6.6 Hz, 3-H), 4.00 (1H, dd, J=8.4 and 6.6 Hz, 4-H), 3.87 (1H, dd, J=8.4 and 7.6 Hz, 4-H), 3.59 (1H, dd, J=11.5 and 4.6 Hz, 1-H), 3.51 (1H, dd, J=11.5 and 6.1 Hz, 1-H), 2.58 (1H, s, OH), 2.53 (1H, br s, OH), 1.43 (3H, s, CH_3), 1.36 (3H, s, CH_3), 1.26 (16H, br s, CH_2), and 0.88 (3H, t, J=6.6 Hz, CH_3); ^{13}C NMR δ=108.66 (-O-$C(CH_3)_2$-O-), 79.79 (3-C), 73.47 (2-C), 65.04 (1-C or 4-C), 64.95 (4-C or 1-C), 34.90, 31.83, 30.23, 29.50, 29.24, 26.30, 25.07, 23.06, 22.62, and 14.04 (Assignment of the ^{13}C NMR spectra of **12a** and **12b** was performed by INEPT experiment); MS m/z 273 (M^+−CH_3, 2), 101 (57), and 43 (100). Found: m/z 273.2070. Calcd for $C_{15}H_{29}O_4$: M−CH_3, 273.2066.

(2*S*,3*S*)-3,4-*O*-Isopropylidene-2-tetradecyl-1,2,3,4-butanetetrol (13a). Mp 37.5—39.5 °C (recrystallized from hexane); IR (neat) 3325, 1260, 1210, 1155, 1112, 1065, 860, and 720 cm^{-1}; ^1H NMR δ=4.12 (1H, dd, J=8.1 and 6.6 Hz, 3-H), 4.00 (2H, m, 4-H), 3.71 (1H, d, J=11.4 Hz, 1-H), 3.53 (1H, d, J=11.4 Hz, 1-H), 1.43 (3H, s, CH_3), 1.37 (3H, s, CH_3), 1.25 (26H, br s, CH_2), and 0.88 (3H, t-like, J=6.8 Hz, CH_3); ^{13}C NMR δ=109.24 (-O-$C(CH_3)_2$-O-), 80.38 (3-C), 72.22 (2-C), 67.02 (1-C), 64.65 (4-C), 34.04, 31.83, 30.25, 29.60, 29.57, 29.50, 29.41, 29.27, 26.13, 25.38, 22.91, 22.60, and 14.01.

(2*R*,3*S*)-3,4-*O*-Isopropylidene-2-tetradecyl-1,2,3,4-butanetetrol (13b). Mp 47.5—49.0 °C (recrystallized from hexane); IR (neat) 3480, 3375, 1210, 1160, 1065, 1040, 895, 860, and 718 cm^{-1}; ^1H NMR δ=4.14 (1H, dd, J=7.6 and 6.6 Hz, 3-H), 4.00 (1H, dd, J=8.3 and 6.6 Hz, 4-H), 3.87 (1H, dd, J=8.3 and 7.6 Hz, 4-H), 3.60 (1H, dd, J=11.5 and 4.6 Hz, 1-H), 3.52 (1H, dd, J=11.5 and 4.6 Hz, 1-H), 1.44 (3H, s, CH_3), 1.37 (3H, s, CH_3), 1.25 (26H, br s, CH_2), and 0.88 (3H, t-like, J=6.5 Hz, CH_3); ^{13}C NMR δ=108.69 (-O-$C(CH_3)_2$-O-), 79.92 (3-C), 73.44 (2-C), 65.08 (1-C or 4-C), 64.98 (4-C or 1-C), 34.97, 34.12, 31.89, 30.25, 29.62, 29.56, 29.51, 29.33, 26.33, 25.09, 23.08, 22.65, and 14.07; MS m/z 343 (M^+−CH_3, 18), 257 (100), and 101 (92). Found: m/z 343.2819. Calcd for $C_{20}H_{39}O_4$: M−CH_3, 343.2848.

(2*S*,3*S*)- and (2*R*,3*S*)-1-*O*-Benzoyl-2-ethynyl-3,4-*O*-isopropylidene-1,2,3,4-butanetetrols (14). Colorless oil; IR (neat) 3430, 3290, 2120, 1725, 1602, 1588, 1270, 1070, 855, and 715 cm^{-1}.

14a: ^1H NMR δ=8.08 (2H, d, J=7.2 Hz, Ph), 7.59—7.42 (3H, m, Ph), 4.68—4.16 (5H, m, 1-H, 3-H, and 4-H), 2.52 (1H, s, ≡CH), 1.49 (3H, s, CH_3), and 1.38 (3H, s, CH_3); ^{13}C NMR δ=166.19, 133.29, 129.81, 128.47, 110.71, 81.00, 78.03, 75.03, 70.11, 67.85, 65.72, 26.18, and 25.17.

14b: ^1H NMR δ=8.08 (2H, d, J=7 Hz, Ph), 7.59—7.42 (3H, m, Ph), 4.68—4.16 (5H, m, 1-H, 3-H, and 4-H), 2.55 (1H, s, ≡CH), 1.50 (3H, s, CH_3), and 1.39 (3H, s, CH_3); ^{13}C NMR δ=166.78, 133.42, 129.85, 128.51, 110.48, 81.36, 77.67, 75.03, 71.45, 68.33, 65.83, 26.30, and 25.17.

The propargyl alcohols **14** (36 mg) was hydrogenated over 10% Pd-C (10 mg) in ethanol (2 ml) to give the saturated alcohols **11** (28 mg, 76% yield).

(2*S*,3*S*)- and (2*R*,3*S*)-3,4-*O*-Isopropylidene-2-methyl-1,2,3,4-butanetetrols (15). 15a: ^1H NMR δ=4.10—3.90 (3H, m, 3-H and 4-H), 3.67 (1H, d, J=11.2 Hz, 1-H), 3.44 (1H, d, J=11.2 Hz, 1-H), 1.42 (3H, s, CH_3), 1.36 (3H, s, CH_3), and 1.05 (3H, s, CH_3); ^{13}C NMR δ=109.66 (-O-$C(CH_3)_2$-O-), 80.63 (3-C), 70.81 (2-C), 69.51 (1-C), 64.88 (4-C), 26.20, 25.37, and 19.87.

15b: ^1H NMR δ=4.10—3.91 (3H, m, 3-H and 4-H), 3.63 (1H, d, J=11 Hz, 1-H), 3.47 (1H, d, J=11 Hz, 1-H), 1.42 (3H, s, CH_3), 1.34 (3H, s, CH_3), and 1.14 (3H, s, CH_3); ^{13}C NMR δ=109.02 (-O-$C(CH_3)_2$-O-), 79.33 (3-C), 72.35 (2-C), 67.31 (1-C), 65.01 (4-C), 26.26, 24.88, and 20.20.

(2*S*,3*S*)-2-Nonyl-1,2,3,4-butanetetrol (16a). The diol **12a** (85 mg) was hydrolyzed with 2% methanolic hydrochloric acid (4 ml) at room temperature for 1.5 h to give the tetrol **16a** (52 mg, 76% yield), colorless plates, mp 62.5—63.5 °C (recrystallized from hexane-ethyl acetate), $[\alpha]_D^{24}$ −8.9° (c 1.6, methanol); IR (Nujol) 3300, 1050, and 723 cm^{-1}; ^1H NMR (acetone-d_6) δ=4.0—3.45 (5H, m, 1-H, 3-H, and 4-H), 1.65—1.4 (2H, m, CH_2), 1.30 (14H, br s, CH_2), and 0.88 (3H, t-like, CH_3); ^{13}C NMR (acetone-d_6) δ=75.45 (2-C), 75.42 (3-C), 65.70 (1-C or 4-C), 63.30 (4-C or 1-C), 35.22, 32.63, 31.26, 30.44, 30.37, 30.08, 23.47, 23.31, and 14.36; MS m/z 217 (M^+−CH_2OH, 10), 199 (M^+−CH_2OH−H_2O, 2), 187 (M^+−$CH(OH)CH_2OH$, 38), 155 (12), and 43 (100). Found: m/z 217.1833. Calcd for $C_{12}H_{25}O_3$: M−CH_2OH, 217.1803.

Dimethyl (2*R*,3*R*)-2,3-*O*-isopropylidene-2-nonyltartrate (**17**) was transformed to the tetrol **16a** as follows. To a suspension of lithium aluminium hydride (69 mg) in dry diethyl ether (3 ml) was added a solution of **17** (155 mg) in dry diethyl ether (5 ml) and the mixture was stirred at room temperature for 1.5 h under nitrogen. Work-up as usual gave the diol **18** (102 mg, 79% yield), which was hydrolyzed in acetic acid (4.5 ml) and water (0.5 ml) under reflux. After neutralization of the mixture with aqueous sodium hydrogencarbonate, the product was extracted with diethyl ether and was then chromatographed (silica gel, 5 g; eluent: ethyl acetate) to give **16a** (54 mg, 61% yield), mp 63.0—63.5 °C, $[\alpha]_D^{24}$ −8.7° (c 1.1, methanol).

(2*R*,3*S*)-2-Nonyl-1,2,3,4-butanetetrol (16b). The diol **12b** (70 mg) was hydrolyzed with 2% methanolic hydrochloric acid (4 ml) to give the tetrol **16b** (44 mg, 73% yield), colorless plates, mp 63.0—63.5 °C (recrystallized from hexane-ethyl acetate); $[\alpha]_D^{30}$ −6.8° (c 1.1, methanol); IR (Nujol) 3420, 3300, 1150, 1090, 1035, 1005, 890, and 722 cm^{-1}; ^1H NMR (acetone-d_6) δ=3.95—3.45 (5H, m, 1-H, 3-H, and 4-H), 1.7—1.4 (2H, m, CH_2), 1.30 (14H, br s, CH_2), and 0.88 (3H, t-like, CH_3); ^{13}C NMR (acetone-d_6) δ=76.30 (3-C), 75.56 (2-C), 65.69 (1-C or 4-C), 63.43 (4-C or 1-C), 34.46, 32.63, 31.30, 23.54, 23.30, and 14.36; MS m/z 217 (M^+−CH_2OH, 13), 199 (M^+−CH_2OH−H_2O, 3), 187 (M^+−$CH(OH)CH_2OH$, 46), 155 (18), 95 (56), and 43 (100). Found: m/z 217.1827. Calcd for $C_{12}H_{25}O_3$: M−CH_2OH, 217.1803.

(2*S*,3*S*)- and (2*R*,3*S*)-3,4-*O*-Isopropylidene-2-nonyl-1-*O*-triphenylmethyl-1,2,3,4-butanetetrols (19). Treatment of **12a** and **12b** with chlorotriphenylmethane, 4-dimethylaminopyridine, and triethylamine in dichloromethane gave **19a** and **19b**, respectively.

19a: ^{13}C NMR δ=143.84, 128.76, 127.74, 127.02, 108.82 (-O-$C(CH_3)_2$-O-), 86.60 (CPh_3), 78.48 (3-C), 73.00 (2-C), 64.56 (1-C or 4-C), 64.53 (4-C or 1-C), 33.34, 31.88, 30.12, 29.49, 29.46, 29.33, 26.42, 25.68, 22.68, 22.16, and 14.11.

19b: ^{13}C NMR δ=143.48, 128.69, 127.90, 127.81, 127.11, 108.66 (-O-$C(CH_3)_2$-O-), 86.81 (CPh_3), 79.29 (3-C), 73.31 (2-C), 64.53 (1-C and 4-C), 35.50, 31.86, 30.21, 29.62, 29.54, 29.31, 26.30, 25.34, 22.72, 22.65, and 14.09.

(2*S*,3*S*)- and (2*R*,3*S*)-1-*O*-Benzoyl-3,4-*O*-isopropylidene-2-nonyl-1,2,3,4-butanetetrols (20). Benzoylation **12a** and **12b** with benzoyl chloride in pyridine gave **20a** and **20b**, respectively.

20a: ^{13}C NMR δ=166.28, 133.04, 130.53, 129.57, 128.39, 109.28 (-O-*C*(CH$_3$)$_2$-O-), 78.08 (3-C), 72.48 (2-C), 66.75 (1-C), 64.36 (4-C), 33.56, 31.80, 30.12, 29.41, 29.36, 29.23, 26.32, 25.37, 22.79, 22.62, and 14.05.

20b: ^{13}C NMR δ=166.36, 133.23, 130.55, 129.63, 128.47, 109.01 (-O-*C*(CH$_3$)$_2$-O-), 78.83 (3-C), 72.97 (2-C), 66.37 (1-C), 64.76 (4-C), 35.50, 31.84, 30.16, 29.69, 29.49, 29.27, 26.27, 25.20, 22.96, 22.65, and 14.08.

(2*S*)-2-[(1*S*)-1,2-Dihydroxyethyl]-2-nonyloxirane (23). A solution of the diol **12a** (176 mg) and *p*-toluenesulfonyl chloride (500 mg) in pyridine (1 ml) was allowed to stand at room temperature overnight. The mixture was poured into water and the product was extracted with diethyl ether. Flash chromatography (silica gel, 5 g; eluent: hexane–ethyl acetate 6 : 1) of the extract gave the monotosylate (244 mg, 91% yield), colorless solid, mp 51—52 °C; IR (neat) 3550, 1604, 1190, 1180, 1070, 985, 850, 818, and 670 cm^{-1}; ^{1}H NMR δ=7.80 (2H, d, *J*=8.4 Hz, Ph), 7.35 (2H, d, *J*=8.4 Hz, Ph), 4.1—3.8 (5H, m, 1-H, 3-H, and 4-H), 2.45 (3H, s, CH$_3$), 1.35 (3H, s, CH$_3$), 1.29 (3H, s, CH$_3$), 1.26 (14H, br s, CH$_2$), and 0.89 (3H, t-like, CH$_3$).

A solution of the tosylate (203 mg) in 3% methanolic hydrochloric acid (7 ml) was stirred at room temperature for 1 h to give **22**. A 2% solution of sodium hydroxide in methanol (15 ml) was then added and the mixture was stirred at room temperature for 30 min. After neutralization with 4% hydrochloric acid the mixture was concentrated under reduced pressure. Water was added and the product was extracted with diethyl ether. Flash chromatography (silica gel, 15 g; eluent: hexane–ethyl acetate 4 : 1 and then 1 : 1) of the crude product gave the epoxide **23** (94 mg, 89% yield), colorless oil; IR (neat) 3400 and 1040 cm^{-1}; ^{1}H NMR δ=3.75 (3H, m, C*H*-OH and C*H*$_2$OH), 2.92 (1H, d, *J*=4.7 Hz, oxirane proton), 2.64 (1H, d, *J*=4.7 Hz, oxirane proton), 2.30 (1H, d, *J*=7.0 Hz, OH), 2.14 (1H, dd, *J*=7.5 and 4.3 Hz, OH), 1.77 (1H, m, CH), 1.55 (1H, m, CH), 1.26 (14H, br s, CH$_2$), and 0.88 (3H, t-like, *J*=6.5 Hz, CH$_3$); MS *m/z* 199 (M$^+$−CH$_2$OH, 3), 95 (56), 82 (100), and 55 (74). Found: *m/z* 199.1647. Calcd for C$_{12}$H$_{23}$O$_2$: M−CH$_2$OH, 199.1698.

(2*R*)-2-Hydroxymethyl-2-nonyloxirane (24). To a solution of the diol **23** (87 mg) in THF (3 ml) cooled to 0 °C was added a solution of sodium periodate (210 mg) in water (2 ml). The mixture was stirred at 0 °C for 50 min. A solution of sodium borohydride (69 mg) in water (1 ml) was then added and the mixture was stirred at 0 °C for 30 min. Water was added and the product was extracted with diethyl ether. Flash chromatography (silica gel, 3.5 g; eluent: hexane–ethyl acetate 7 : 1) of the crude product gave the epoxy alcohol **24** (54 mg, 72% yield), colorless oil, $[\alpha]_D^{30}$ +15.4° (*c* 3.6, CHCl$_3$) (lit, [10a] $[\alpha]_D$ +11.0° (*c* 13.0, CHCl$_3$) and lit,[10b] $[\alpha]_D$ −13.2° (*c* 11.0, CHCl$_3$) for the enantiomer of **24**). IR, ^{1}H NMR, ^{13}C NMR, and MS spectral data of **24** were identical with those reported.[10a]

(2*R*)-2-[(1*S*)-1,2-Dihydroxyethyl]-2-tetradecyloxirane (27). Treatment of the diol **13b** (149 mg) with *p*-toluenesulfonyl chloride (502 mg) in pyridine (1 ml) gave the monotosylate (140 mg, 66% yield), mp 38.0—39.0 °C (recrystallized from hexane); IR (neat) 3530, 1600, 1470, 1460, 1370, 1187, 1177, 1070, 985, 840, 815, and 667 cm^{-1}; ^{1}H NMR δ=7.80 (2H, d, *J*=8 Hz, Ph), 7.36 (2H, d, *J*=8 Hz, Ph), 4.08 (1H, dd, *J*=6.9 and 6.9 Hz, 3-H), 3.89 (4H, m, 1-H and 4-H), 2.46 (3H, s, CH$_3$), 2.08 (1H, s, OH), 1.36 (3H, s, CH$_3$), 1.32 (3H, s, CH$_3$), 1.26 (26H, br s, CH$_2$), and 0.88 (3H, t-like, CH$_3$). Hydrolysis of the tosylate (101 mg) with 3% methanolic hydrochloric acid (3.5 ml) gave **26**, which was then treated with 2% solution of sodium hydroxide in methanol to give the epoxy diol **27** (43 mg, 72% yield), mp 61.4—62.2 °C; IR (KBr) 3380 cm^{-1}; ^{1}H NMR (CDCl$_3$+D$_2$O) δ=3.91 (1H, dd, *J*=5.7 and 3.2 Hz, CH-OD), 3.81 (1H, dd, *J*=11.7 and 3.2 Hz, HC*H*-OD), 3.60 (1H, dd, *J*=11.7 and 5.7 Hz, *H*CH-OD), 2.93 (1H, d, *J*=4.6 Hz, oxirane proton), 2.68 (1H, d, *J*=4.6 Hz, oxirane proton), 1.68 (2H, m, CH$_2$), 1.25 (24H, br s, CH$_2$), and 0.88 (3H, t-like, *J*=6.5 Hz, CH$_3$).

(2*S*)-2-Hydroxymethyl-2-tetradecyloxirane (28). Following the procedures described for the preparation of **24**, the diol **27** (41 mg) was transformed to the epoxy alcohol **28** (24 mg, 65% yield), colorless solid, $[\alpha]_D^{30}$ −11.3° (*c* 1.4, CHCl$_3$) (lit,[11b] $[\alpha]_D$ −9.5° (*c* 0.5, CHCl$_3$)); ^{1}H NMR δ=3.77 (1H, dd, *J*=12.2 and 4.2 Hz, *H*CH-OH), 3.63 (1H, dd, *J*=12.2 and 8.6 Hz, HC*H*-OH), 2.89 (1H, d, *J*=4.6 Hz, oxirane proton), 2.67 (1H, d, *J*=4.6 Hz, oxirane proton), 1.83—1.70 (1H, m, *H*CH), 1.63 (1H, dd, *J*=8.6 and 4.2 Hz, OH), 1.55—1.40 (1H, m, HC*H*), 1.25 (24H, br s, CH$_2$), and 0.88 (3H, t-like, *J*=6.5 Hz, CH$_3$).

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