sized compounds. Compounds **7a–c** were also identified by the TLC which was compared to respective standards of natural phospholipids.

Experimental Section

1,2-Dipalmitoyl-*sn*-glycero-3-phosphocholine (7a): Typical Procedure. a. Synthesis of Triester 5a. (–)-1,2-Dipalmitoyl-*sn*-glycerol [2, 1 mmol, $[\alpha]_D$ –2.28° (*c* 3.3, $CHCl_3$)] was carefully dried at room temperature in vacuo in a round-bottom, two-neck flask equipped with Teflon stopcock and magnetic stirrer and capped with a rubber septum.

While the mixture was stirred at room temperature, dry chloroform (5 mL), triethylamine (2 mmol), and chloro-(*N,N*-diisopropylamino)methoxyphosphine (1.2 mmol) were successively added into the flask by using a syringe. The progress of the condensation was monitored by following the disappearance of starting (–)-dipalmitin (**2**) (TLC on Merck silica gel plates, 3:2 ether–hexane. After the reaction was complete (5 min), the solvent and excess triethylamine were evaporated under vacuum, and solid tetrazole (4 mmol) and choline tosylate (2–3 mmol) were added, the mixture was kept under vacuum for 1 h. All reactants were solubilized by the addition of acetonitrile–THF (1:1 v/v) mixture (5–10 mL). After 30 min the solvents were removed by evaporation and replaced with anhydrous toluene (10 mL). The resulting heterogeneous mixture was treated with *tert*-butyl hydroperoxide (2 mmol). The suspension thus obtained was stirred at ambient temperature for 10 h. At this time the reaction mixture was washed with triethylammonium bicarbonate buffer (1.5 M, pH 7.0). The organic phase was concentrated, and the residue was rendered anhydrous by repeated evaporation with anhydrous benzene.

b. Deprotection of Triester 5a. The anhydrous semisolid from the above preparation was suspended in toluene (3 mL) and treated with anhydrous trimethylamine (3 mL, stored in a stoppered ampule over NaH).

The resulting solution was kept at room temperature for 10 h. After the deprotection reaction was judged complete (TLC), trimethylamine and solvent were evaporated, and the crude product was purified to homogeneity by chromatography on silica gel (2.5 × 30 cm column, Merck 230–400 mesh silica gel) using chloroform–methanol–water (66:33:4) as the eluting solvent.

1,2-Dipalmitoyl-*sn*-glycero-3-thiophosphocholine (8a). This compound was prepared by closely following the above procedure except that elemental sulfur instead of *tert*-butyl hydroperoxide was used to obtain trialkyl phosphorothioate **6a** from 4. Product purification was carried out with chloroform–methanol (1:1) for the chromatography.

1,2-Dipalmitoyl-*sn*-glycero-3-phosphoethanolamine (7b). The corresponding triester **5b** was prepared in the same manner as described for **5a** using *N*-tritylethanolamine (2 mmol) as the second hydroxyl component. The deprotection procedure involved demethylation of **5b** with Me_3N/toluene (1:1 v/v, 5 mL) at 50 °C for 20 h and detritylation with Zn/CH_3COOH (200 mg of Zn in 10 mL of CH_3COOH) at 45 °C for 9 h. The product was purified with CH_2Cl_2–MeOH–H_2O (80:20:3) as the eluting solvent for chromatography.

1,2-Dipalmitoyl-*sn*-glycero-3-thiophosphoethanolamine (8b). The intermediate trialkyl phosphorothioate **6b** was obtained similarly as described above. Deprotection of triester **6b** was performed with Me_3N/toluene (6 h at 50 °C) and with Zn/CH_3COOH (1.5 h at 40 °C). The product was purified with $CHCl_3$–MeOH (5:1) as solvent for chromatography.

1,2-Dipalmitoyl-*sn*-glycero-3′-phospho-*sn*-glycerol (7c). The respective triester **5c** was obtained in a similar manner by using 1,2-isopropylidene-*sn*-glycerol $[\alpha]^{19}_D$ + 15.17° (neat) as the second hydroxyl component. Deprotection of the resulting triester **5c** was achieved by using a solution of ethanethiol–trimethylamine in toluene (200 mg EtSH/100 mg Me_3N in 5 mL toluene) at 45 °C for 3 h. After removal of this reagent, the isopropylidene group was removed with 70% aqueous CH_3COOH (3 h at 35–40° C). Purification of **7c** was carried out with CH_2Cl–MeOH–H_2O (80:20:3) as solvent system for chromatography. Attempts at conversion of **7c** into the ammonium salt by aqueous workup of its chloroform solution with a solution of ammonium chloride failed. Elemental analysis of the final product indicated a 56% content of ammonium salt and a 46% content of the free acid.

1,2-Dipalmitoyl-*sn*-glycero-3-thiophospho-3′-*sn*-glycerol (8c). This product was prepared similarly to **7c** except trimethylamine in toluene was used to demethylate triester **5c**.

Aqueous acetic acid (70%) at room temperature was applied to remove the 1,2-isopropylidene protecting group. The product was chromatographed with acetone–CH_2Cl_2–MeOH (100:10:4) as solvent. Elemental analysis of the product showed a 24% content of ammonium salt $C_{38}H_{78}NO_9PS$ and 76% of free acid $C_{38}H_{75}O_9PS$ present in the sample, %C ± 0.4, %H ± 0.1, %N ± 0.0, %P ± 0.4.

Registry No. (–)-**2**, 30334-71-5; **5a**, 102152-55-6; **5b**, 102152-58-9; **5c**, 102210-89-9; **6a**, 102152-57-8; **6b**, 102152-59-0; (+)-**7a**, 63-89-8; (+)-**7b**, 923-61-5; (+)-**7c**, 74313-95-4; (+)-**7c**·NH_3, 102152-60-3; (+)-**8a**, 82916-29-8; (+)-**8b**, 102281-30-1; (+)-**8c**, 102152-61-4; (+)-**8c**·NH_3, 102282-26-8; chloro-(*N,N*-diisopropylamine)methoxyphosphine, 86030-43-5; choline tosylate, 55357-38-5; *N*-tritylethanolamine, 24070-16-4; (+)-1,2-isopropylidene-*sn*-glycerol, 22323-82-6.

On the Use of the *O*-Methylmandelate Ester for Establishment of Absolute Configuration of Secondary Alcohols

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With the current emphasis on obtaining enantiomerically pure compounds, methods for resolution, determination of enantiomeric purities, and determination of absolute configurations become important.[1] Reagents that function in all three regards are most desirable. Raban and Mislow[2] pointed out the utility of *O*-methylmandelate derivatives for determination of enantiomeric purity. Dale and Mosher[3] examined this approach in more detail–especially with respect to the mandelate esters and α-(trifluoromethyl)-*O*-methylmandelate esters. For these two, conformational models were developed to rationalize the sense of nonequivalence. The model chose a conformation for the former esters in which the OH group eclipses the carbonyl group of the ester due to hydrogen bonding and, for the latter esters, one in which the trifluoromethyl group eclipses the carbonyl group. No model was proposed for the *O*-methylmandelate although the trends in chemical shift differences between the diastereomeric pairs followed the mandelate esters. Little use of this empirical method for assignment of absolute configuration has been made. Furthermore, the *O*-methylmandelates have been less used because of the problems of racemization during esterification and the lack of a model for assignment of absolute configuration. Since *O*-methylmandelates appeared to represent a facile approach to all three goals for resolving

(1) For an excellent series, see: *Stereochemistry: Fundamental and Methods*; Kagan, H., Ed.; Georg Thieme: Stuttgart 1977; Vol. 1–3.
(2) Raban, M.; Mislow, K. *Top. Stereochem.* **1967**, *2*, 199.
(3) Dale, J. A.; Mosher, H. S. *J. Am. Chem. Soc.* **1973**, *95*, 512.

0022-3263/86/1951-2370$01.50/0

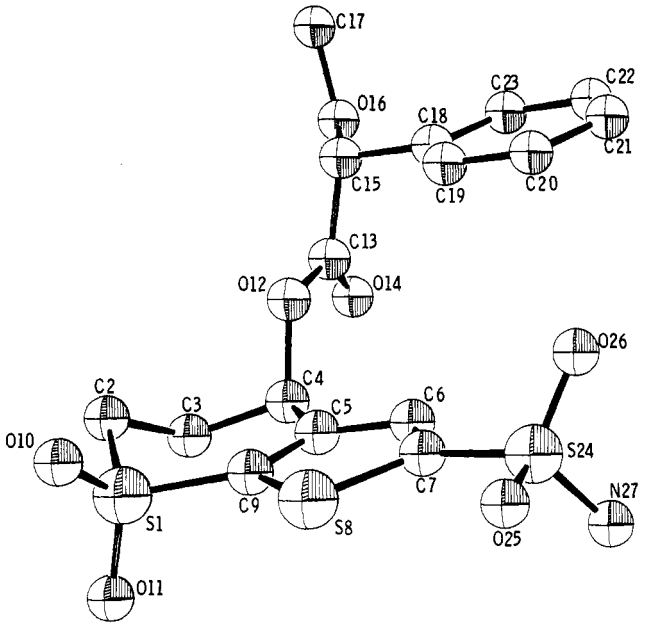


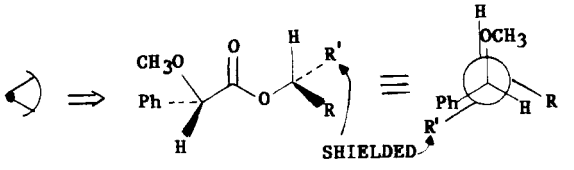
Figure 1. A computer-generated drawing of **3** derived from the X-ray coordinates with hydrogens omitted for clarity.

and analyzing secondary alcohols, we have examined their applicability in a series of more diverse and complicated alcohols than those examined by Dale and Mosher and provide evidence for a model for the *O*-methylmandelates that corresponds to that for the mandelates even though the possibility of hydrogen bonding is absent.

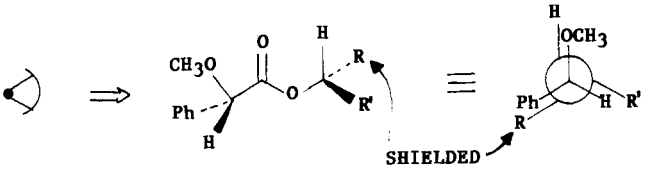
Esterification of a secondary alcohol with *O*-methylmandelic acid without racemizing the *O*-methylmandelic acid half is best achieved in one of three methods: (*1*) DCC and DMAP (method 1);[4] (2) DCC, pyridine, and 2-hydroxybenzotriazole (method 2); (3) DMF and oxalyl chloride (method 3). For example, the *O*-methylmandelates of entry 1 were prepared by method 1. Chromatographic resolution and cleavage of the *O*-methylmandelate from the 2′*S*, 5*R*, 6*S* diastereomer with methanol and potassium carbonate gave the optically pure alcohol, $[\alpha]^{25}_D$ −43.54° (*c* 1.61, $CHCl_3$) [lit.[6] $[\alpha]^{23}_D$ −43.46° (*c* 1.0, $CHCl_3$)]. If racemization occurred during esterification, chromatography would return enantiomerically impure alcohol. The alcohol obtained was enantiomerically pure. In this case, the *O*-methylmandelic acid was also recovered in 61% yield with 97% ee. The base hydrolysis may account for the slight loss of enantiomeric purity of the mandelate. Application of method 1 to entry 2 of Table I did lead to substantial racemization because of the sluggishness of the rate of esterification of the alcohol. Reasoning that DMAP was racemizing the activated acid intermediate, we turned to the less basic pyridine and the slightly less activated acyl transfer agent 2-hydroxybenzotriazole. Indeed, excellent selectivity returned and enantiomerically pure alcohol was obtained. Use of NMR chiral shift reagents established the enantiomeric purity of the 2′*S*,2*S*,3*R* isomer was >99%. Method 3 gave the most satisfactory rate of esterification for entry 3 and with minimum, if any, racemization. In this case, base hydrolysis using aqueous potassium hydroxide of the 2′*S*,1*S*,2*R*,5*S* isomer gave the free alcohol, $[\alpha]^{25}_D$ +121° (*c* 1.135, $CHCl_3$) [lit.[7] (enantiomer) $[\alpha]^{25}_D$ −124° (*c* 6, $CHCl_3$)].

In entries 1–4, the diasteromeric pair was conveniently separated by either preparative HPLC (entries 1–3) or flash chromatography (entries 3 and 4). For entries 1 and 3, the absolute configuration was established by comparison of the optically active free alcohols to the known compounds.[6–8] For entries 2 and 5, these intermediates were converted to verrucarinic acid[9] and ibogamine,[10] respectively, whose absolute stereochemistries are known. For entry 4, X-ray crystallography establishes its stereochemistry.

Based upon these correlations, the model proposed by Dale and Mosher for correlating NMR shifts and absolute stereochemistry of mandelate esters does extend to the *O*-methylmandelates. Structures **1** and **2** illustrate this Mosher model wherein it is more convenient to view the esters via an "extended Newman projection" in which the intervening ester linkage is omitted. That substituent



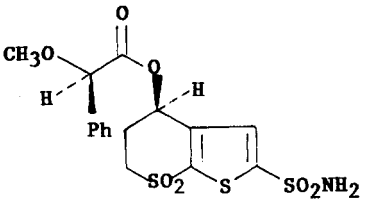
1



2

which eclipses the phenyl ring in such an extended Newman projection is then always upfield, presumably as a result of the shielding it experiences by the phenyl ring. In **1**, this group is R′, and in the enantiomeric alcohol which corresponds to diastereomer **2**, this group is R. Thus, R′ in **1** should show its proton shift upfield of the corresponding signal in **2** and the reverse should be true for the absorptions for R. As the data of Table I shows, H_a in the *S* series which corresponds to R′ in **1** always resonates at higher field than in the *R* series, and the reverse is true for H_b.

Independent support for the conformation depicted in **1** was obtained for the *R*,*R* isomer of entry 4, i.e. **3**. As Figure 1 depicts, the methoxy group is rotated by only 29° from an eclipsed conformation with the ester carbonyl oxygen in good agreement with the NMR model. While



3

it can be argued that the conformation in solution will be different than in the crystal, the excellent agreement of the observed NMR shifts with this model disarms such an argument. The source of this conformational bias may be

(4) Hassner, A.; Alexanian, V. *Tetrahedron Lett.* **1978**, 4475.
(5) Stadler, P. A. *Helv. Chim. Acta* **1978**, *61*, 1675.
(6) Elliott, W. J.; Fried, J. *J. Org. Chem.* **1976**, *41*, 2469.
(7) Whitesell, J. K.; Minton, M. A.; Felman, S. W. *J. Org. Chem.* **1983**, *48*, 2193.
(8) Kuritani, H.; Takaoka, Y.; Shingu, K. *J. Org. Chem.* **1979**, *44*, 452.
(9) Trost, B. M.; McDougal, P. G. *Tetrahedron Lett.* **1982**, *23*, 5497.
(10) Trost, B. M.; Godleski, S. A.; Genet, J.-P. *J. Am. Chem. Soc.* **1978**, *100*, 3930.

Table I. Correlation of *O*-Methylmandelate Esters

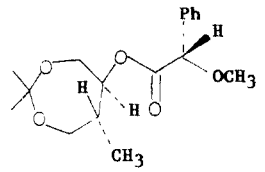
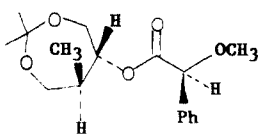
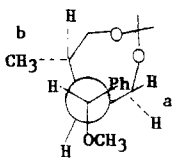
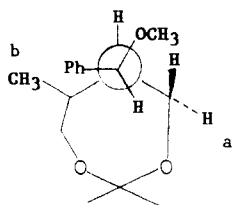
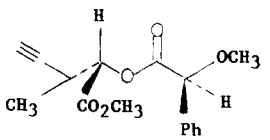
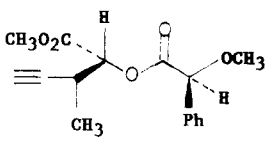
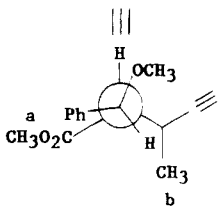
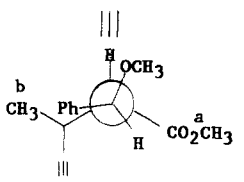
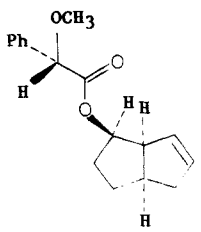
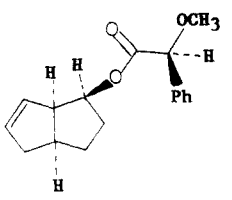
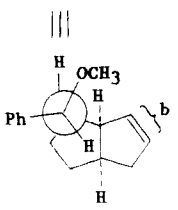
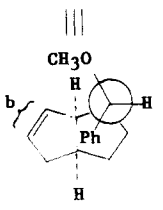
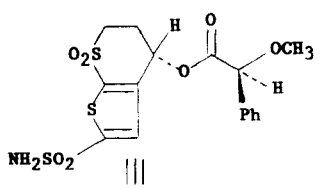
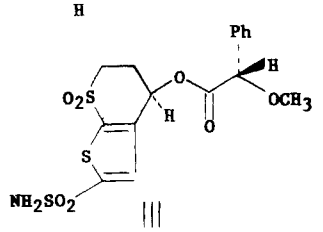
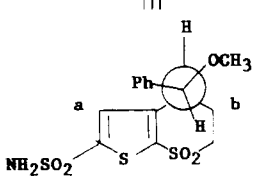
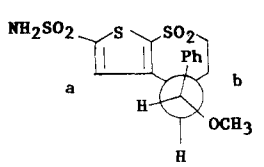
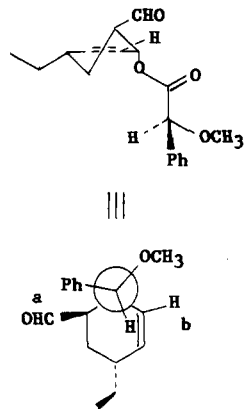
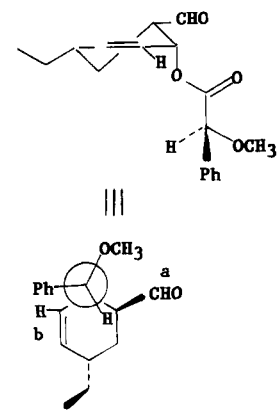
entry	*O*-methylmandelate[a] diastereomeric pair		H_a		H_b	
	S^b	R^b	S^b	R^b	S^b	R^b
1			3.5	3.67	0.85	0.64
						
2			3.59	3.74	1.21	1.12
						
3					5.38 5.68	4.86 5.40
						
4[c]			7.17[d]	7.57[e]	2.50[d] 2.74[d]	2.23[e] 2.56[e]
						

Table I (Continued)

entry	O-methylmandelate[a] diastereomeric pair		H_a		H_b	
	S^b	R^b	S^b	R^b	S^b	R^b
5			9.10	9.56	5.96	5.80

[a] In all cases, except where noted, (*S*)-O-methylmandelate ester was employed. [b] The absolute stereochemistry refers to the carbon bearing the mandelate ester. [c] In this case, the (*R*)-*O*-methylmandelate was employed. For consistency, the results have been transposed to the (*S*)-mandelate series which is depicted. [d] These numbers were measured on the enantiomeric *RR* isomer, i.e., (*R*)-mandelate series. [e] These numbers were measured on the enantiomeric *SR* isomer, i.e., (*R*)-mandelate series.

electronic and is quite interesting in light of the current use of α-alkoxycarbonyl compounds in synthesis.

It does appear that *O*-methylmandelates represent a rare case in which they allow easy chromatographic resolution so that both enantiomeric series are equally accessible, provide a NMR spectroscopic method for immediate assessment of enantiomeric purity, and allow establishment of absolute configuration also by NMR spectroscopy. The independent evidence for the Mosher-type conformation combined with the fact that, up to the present, there are no exceptions over a range of structurally diverse and complex alcohols suggests that this tool can be much more useful than it has been. A caution must be exercised in applying this method in those cases in which only one enantiomeric alcohol is available (e.g., in the case of an isolated natural product). In such a case, both the (*S*)- and (*R*)-mandelic esters must be prepared to utilize this approach. Lets say the alcohol happens to have the *S* configuration. The esters will then correspond to the *S,S* and *R,S* isomers. Since the NMR spectrum of the *R,S* isomer is identical with its mirror image *S,R* isomer, the same correlations outlined herein, but modified to realize it is the stereocenter at the carboxylic acid portion that is inverted, apply.

Experimental Section

Esterification Procedures for Preparation of *O*-Methylmandelates. Method 1. Of (5*R,6*S**)-6-Hydroxy-2,2,5-trimethyl-1,3-dioxepane.** DMAP (0.33 g, 2.70 mmol) was added all at once to a colorless solution of 4.42 g (27.6 mmol) of the title alcohol, 4.15 g (2.50 mmol) of (*S*)-*O*-methylmandelic acid, and 5.65 g (27.4 mmol) of DCC in 250 mL of methylene chloride. After 24 h, the dicyclohexylurea was removed by filtration, the filter cake was washed with three 100-mL portions of hexane, and the combined filtrates were washed with 2 × 50 mL cold 1 N aqueous hydrochloric acid, 2 × 50 mL saturated sodium bicarbonate, and 2 × 50 mL saturated brine. The organic phase was then dried ($MgSO_4$) and filtered and the solvent removed to afford a colorless oil containing some suspended white solid. Trituration with hexane and refiltration followed by removal of solvent gave ester in 90% purity (8.38 g). The crude product was dissolved in 200 mL of hexane and passed down a Florisil column (30 mL). Elution with an additional 600 mL of hexane, combination of the two hexane fractions, and removal of solvent gave an extremely pure (by NMR analysis) mixture of diastereoisomeric esters (7.04 g; 22.8 mmol; 91.4%). Washing of the Florisil column with 250 mL of chloroform followed by removal of solvent from the eluate gave additional ester contaminated with DCU (by NMR analysis 60% ester, 40% DCU; 1.43 g).

HPLC separation on a tandem cartridge Waters Prep. 500 A apparatus using 5–8% ethyl acetate in hexane of 34.64 g of a diastereomeric mixture gave 12.36 g of the less polar *S* alcohol as its *O*-methylmandelate, $[\alpha]^{25}_D$ +6.3° (*c* 1.155, $CHCl_3$), and 12.58 g of the more polar *R* alcohol as its *O*-methylmandelate, $[\alpha]^{25}_D$ +108° (*c* 1.085, $CHCl_3$).

S,R,S isomer: NMR (270 MHz, $CDCl_3$) δ 7.5–7.3 (m, 5 H), 4.79 (s, 1 H), 4.56 (q, *J* = 5 Hz, 1 H), 3.70 (d, *J* = 4.5 Hz, 2 H), 3.5–3.25 (m, 2 H), 3.44 (s, 3 H), 1.63 (m, 1 H), 1.32 (s, 3 H), 0.66 (d, *J* = 7.5 Hz, 3 H); IR ($CDCl_3$) 3020, 2980, 2940, 2920, *1755*, 1520, 1475, 1395, 1375, 1355, 1345, 1320, 1280, 1240, 1220, 1210, 1195, 1180, 1135, 1105, 1090, 1075, 1060, 1030, 1010, 900, 860 cm^{-1}.

S,S,R isomer: NMR (270 MHz, $CDCl_3$) δ 7.44–7.24 (m, 5 H), 4.77 (s, 1 H), 4.54 (dd, *J* = 4.5, 9.0 Hz, 1 H), 3.63–3.38 (m, 4 H), 3.43 (s, 3 H), 1.86 (m, 1 H), 1.28 (s, 3 H), 1.26 (s, 3 H), 0.86 (d, *J* = 7.5 Hz, 3 H); IR ($CHCl_3$) 3010, 2960, 2900, 2840, *1750*, 1520, 1390, 1380, 1365, 1330, 1285, 1185, 1170, 1125, 1090, 1030, 1000, 960, 930, 880, 855 cm^{-1}.

Anal. Calcd for $C_{17}H_{24}O_5$: C, 66.20; H, 7.85; M_r 308.1617. Found: C, 66.03; H, 7.78; M_r 308.1610.

Method 2. Of Methyl (2*S,3*R**)-2-Hydroxy-3-methyl-4-pentynoate.** *N*-Hydroxybenzotriazole (1.29 g, 11.1 mmol), 0.87 g (11.1 mmol) of pyridine, and 2.97 g (14.4 mmol) of DCC were added sequentially to a solution of 1.73 g (12.2 mmol) of the title alcohol and 1.84 g (11.1 mmol) of (*S*)-*O*-methylmandelic acid in 15 mL of THF at room temperature. After the mixture was stirred 24 h, 200 mL of ether was added, and the organic layer was washed with 50 mL of 10% aqueous sodium bisulfate and 50 mL of 10% aqueous potassium carbonate, dried ($MgSO_4$), and concentrated in vacuo to yield an oily solid. This solid was triturated well with 4 × 15 mL of ether, and the mixture was filtered through a plug of Celite. Removal of the ether in vacuo yielded 3.78 g of a yellow oil. The oil was purified by HPLC (one column, 8% ethyl acetate–hexane) to yield 2.99 g (93.2%) of a 1:1 mixture of mandelate esters. The separation of the diastereomers was achieved by using HPLC (two new columns, 8% ethyl acetate–hexane, one recycle) to yield 1.30 g (87% recovery) of the pure 2′*S*,2*S*,3*R* isomer, $[\alpha]^{23}_D$ +5.83° (*c* 1.47, acetone), a small amount of a mixture of isomers (0.14 g), and finally 1.46 g of the more polar 2′*S*,2*R*,3*S* isomer still contaminated with 5% of the other diastereomer. One more purification of this last batch by HPLC gave 1.21 g (81% recovery) of this isomer in pure form, $[\alpha]^{24}_D$ +61.8° (*c* 1.58, acetone). An analytical sample of each diastereomer was obtained by Kugelrohr distillation [130–140 °C (0.05 mm)].

2′*S*,2*S*,3*R* isomer: IR ($CHCl_3$) 3280, 1752 cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$) δ 1.21 (3 H, d, *J* = 6.9 Hz), 2.08 (1 H, d, *J* = 2.4 Hz), 3.11 (1 H, gdd, *J* = 7.0, 4.1, 2.4 Hz), 3.49 (3 H, s), 3.59 (3 H, s), 4.90 (1 H, s), 5.21 (1 H, d, *J* = 4.2 Hz), 7.38 (3 H, m), 7.49

(2 H, dd, J = 7.1, 2.2 Hz). Calcd for $C_{16}H_{18}O_5$: 290.1154. Found: 290.1152.

2′*S*,2*R*,3*S* isomer: IR ($CHCl_3$) 3305, 1756 (br) cm^{-1}; ^1H NMR (270 MHz, $CDCl_3$) δ 1.12 (3 H, d, J = 6.9 Hz), 1.90 (1 H, d, J = 2.4 Hz), 3.01 (1 H, qdd, J = 7.0, 4.6, 2.4 Hz), 3.47 (3 H, s), 3.74 (3 H, s), 4.93 (1 H, s), 5.14 (1 H, d, J = 4.8 Hz), 7.34 (3 H, m), 7.48 (2 H, dd, J = 7.4, 2 Hz). Calcd for $C_{16}H_{18}O_5$: 290.1154. Found: 290.1155.

Method 3. Of (1*R,2*S**,5*R**)-Bicyclo[3.3.0]oct-7-en-*endo*-2-ol.** (*S*)-*O*-Methylmandelic acid (1.00 g, 6.02 mmol) was added to a white suspension prepared by the slow addition of 0.578 mL (6.62 mmol) of oxalyl chloride to 0.698 mL (9.03 mmol) of DMF in 20 mL of acetonitrile at 0 °C. After 5 min, a solution of 821 mg (6.62 mmol) of the title alcohol in 1.07 mL (13.2 mmol) of pyridine was added over a 5-min period and the resultant mixture stirred at 0 °C for 20 min. The pale yellow reaction mixture was diluted with 100 mL of ether, the organic phase washed twice with saturated aqueous cupric sulfate and dried over sodium sulfate, and the solvent removed in vacuo to give a yellow oil.

Purification by flash chromatography (3 cm, ether/hexanes, 1:4) gave 1.45 g (88%) of clear oil. A small amount of each diastereomer could be obtained pure utilizing a Waters analytical HPLC (10 Porasil radial-pak column, 1:9 ethyl acetate/hexanes, 2 mL/min flow rate), retention times 4.93 and 7.33 min. On a preparative scale, the following procedure was used for separation. The mixture of diastereomers obtained from the esterification above (1.45 g) was flash chromatographed (6 cm × 17.78 cm column, 1:19 ethyl acetate/hexanes, 50-mL fractions) to obtain the (*S*)-*O*-methylmandelate ester of (1*S*,2*R*,5*S*)-*cis*-bicyclo-[3.3.0]oct-7-en-*endo*-2-ol, a mixture of the two diastereomers, and the (*S*)-O-methylmandelate ester of (1*R*,2*S*,5*R*)-*cis*-bicyclo-[3.3.0]oct-7-en-*endo*-2-ol. The mixture obtained above was rechromatographed on the same column above under the same conditions to give that pure 1*S*,2*R*,5*S* isomer, (combined total 702 mg, 97% recovery), $[\alpha]^{26}_D$ +157° (*c* 4.44, methanol), and the pure 1*R*,2*S*,5*R* isomer (combined total 692 mg, 95% recovery), $[\alpha]^{26}_D$ −19.2° (*c* 2.54, methanol).

2′*S*,1*S*,2*R*,5*S* isomer: IR ($CHCl_3$) 1740 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 7.4 (m, 5 H), 5.68 (m, 1 H), 5.36 (m, 1 H), 5.15 (q, J = 8.2 Hz, 1 H), 4.73 (s, 1 H), 3.42 (s, 3 H), 3.40 (m, 1 H), 2.8–2.5 (m, 2 H), 2.05 (m, 1 H), 1.9–1.2 (m, 4 H).

Calcd for $C_{27}H_{30}O_3$: 272.1407. Found: 272.1415.

2′*S*,1*R*,2*S*,5*R* isomer: IR ($CHCl_3$) 1740 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 7.4 (m, 5 H), 5.40 (m, 1 H), 5.16 (q, J = 8.2 Hz, 1 H), 4.86 (m, 1 H), 4.71 (s, 1 H), 3.40 (s, 3 H), 3.23 (m, 1 H), 2.53 (m, 2 H), 2.1–1.2 (m, 5 H).

Calcd for $C_{27}H_{30}O_3$: 272.1407. Found: 272.1415.

X-ray Crystal Structure Analysis of 3. Large crystals of **3** ($C_{16}H_{17}NO_7S_3$) suitable for X-ray diffraction studies formed from ethanol with space group symmetry of $P2_12_12_1$ and cell constants of a = 10.740 (3) Å, b = 11.724 (4) Å, and c = 15.142 (3) Å for z = 4 and a calculated density of 1.503 g/cm^3. Of the 1492 reflections measured with an automatic four-circle diffractometer equipped with Cu radiation, 1444 were observed ($I \geq 3I$). The structure was solved with a multisolution tangent formula approach and difference Fourier analysis and refined by using full-matrix least-squares techniques.[11] Hydrogens were assigned isotropic temperature factors corresponding to their attached atoms. The function $\sum w(|F_o| - |F_c|)^2$ with $w = 1/(\sigma F_o)^2$ was minimized to give an unweighted residual of .064. Tables I–III containing the final fractional coordinates, temperature parameters, bond distances, and bond angles are available as supplementary material. Figure 1 is a computer-generated perspective drawing of **3** from the final X-ray coordinates showing the relative stereochemistry.

Acknowledgment. We thank the National Institutes of Health for their generous support of the programs at Wisconsin.

(11) The following library of crystallographic programs was used: Multan 80, P. Main et al., University of York, York, England, 1980; Ortep-II, C. K. Johnson, Oak Ridge National Laboratory, Oak Ridge, TN, 1970; SDP Plus V1.1, Y. Okaya et al., B. A. Frenz and Associates, College Station, TX, 1984.

Registry No. **3**(isomer 1), 101859-94-3; **3**(isomer 2), 101859-95-4; (±)-(5R*,6S*)-6-hydroxy-2,2,5-trimethyl-1,3-dioxepane, 59005-38-8; (*S*)-*O*-methylmandelic acid, 26164-26-1; 6-mandelate-2,2,5-trimethyl-1,3-dioxepane (isomer 1), 101859-92-1; 6-mandelate-2,2,5-trimethyl-1,3-dioxepane (isomer 2), 101976-97-0; (±)-methyl (2S*,3R*)-2-hydroxy-3-methyl-4-pentynoate, 82998-91-2; methyl 2-mandelate-3-methyl-4-pentynoate (isomer 1), 101859-93-2; methyl 2-mandelate-3-methyl-4-pentynoate (isomer 2), 101976-98-1; (±)-1R*,2S*,5R*)-bicyclo[3.3.0]oct-7-en-*endo*-2-ol, 68317-62-4; bicyclo[3.3.0]oct-7-en-2-ol(mandelate isomer 1), 86971-84-8; bicyclo[3.3.0]oct-7-en-2-ol(mandelate isomer 2), 86971-85-9; 2-mandelate-5-ethyl-cyclohex-3-en-1-carboxaldehyde (isomer 1), 101859-96-5; 2-mandelate-5-ethyl-cyclohex-3-en-1-carboxaldehyde (isomer 2), 101859-97-6; (*R*)-*O*-methylmandelic acid, 3966-32-3.

Supplementary Material Available: Tables of the atomic positional and thermal parameters, bond distances, and bond angles for **3** (4 pages). Ordering information is given on any current masthead page.

Opposite Regioselectivity in the Epoxidation of Geraniol and Linalool with Molybdenum and Tungsten Peroxo Complexes

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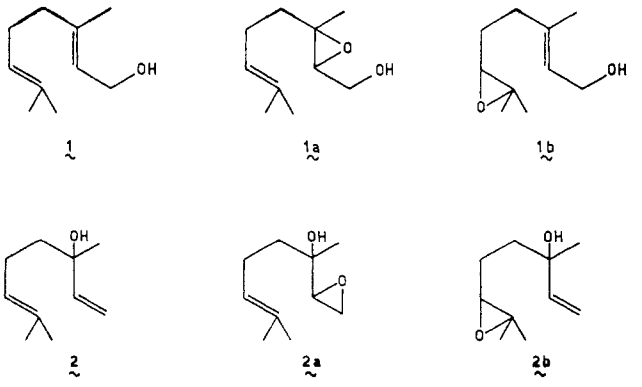
The epoxidation of geraniol (**1**) and linalool (**2**) with *tert*-butyl hydroperoxide and vanadium or titanium catalysts is remarkably faster than that of simple olefins and is regiospecific.[1,2] Only the monoepoxides 2,3-epoxygeraniol (**1a**) and 1,2-epoxylinalool (**2a**) are formed whereas no appreciable amounts of the 6,7-epoxides **1b** and **2b** are found.



1 **1a** **1b**

2 **2a** **2b**

It is also well-known that the Sharpless reagent, *t*-$BuO_2H/Ti(O\text{-}i\text{-}Pr)_4$/DET, enantiospecifically epoxidizes prochiral allylic alcohols.[3]

(1) Sharpless, K. B.; Michaelson, R. C. *J. Am. Chem. Soc.* **1973**, *95*, 6136.
(2) Sharpless, K. B.; Verhoven, T. R. *Aldrichimica Acta* **1979**, *12*, 63.
(3) Sharpless, K. B.; Katsuki, T. *J. Am. Chem. Soc.* **1980**, *102*, 5976.

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