FAB MS. FAB mass spectra were obtained using a VG70SEQ Tandem Hybrid mass spectrometer. A neutral xenon beam was used at 8 keV energy, and the accelerating potential of the ions was 8 kV. Magnetic field scanning from m/z 50 to 1200 was repeated at 10-s intervals. A 1-μL sample of approximately 80 mM solution of menthofuran and dimethyldioxirane in acetone was kept at −78 °C and was mixed with 2 μL of 3-nitrobenzyl alcohol as the matrix on the stainless steel target of the FAB probe. The probe was immediately inserted into the ion source of the mass spectrometer.

GS/MS. GC conditions were the same as described for GC analysis except an analytical DB-5 (30-m × 0.32-mm) column was used. (*R*)-(+)-3-Methylcyclohexanone was used as the internal standard. Mass spectrometer conditions were ion source temperature, 200 °C; emission current, 200 μA; accelerating voltage, 8 kV. Spectra were recorded at a nominal resolution of $M/\Delta M$ = 1000 (10% valley). High-resolution mass spectra were obtained at a resolution of 20 000 over a range of 50–250 amu with perfluorokerosene as a standard.

Methyl 4(*R*)-methyl-2-oxocyclohexanecarboxylate (2): ^{1}H NMR δ 12.10 (s, 1 H, exchanges with D_2O, enol OH), 3.75 (s, 3 H, $COCH_3$), 1.70–2.36 (m, 7 H, cyclohexyl hydrogens), 1.03 (d, 3 H, J = 6.0 Hz, $CHCH_3$).

Ethylene ketal of methyl 4(*R*)-methyl-2-oxocyclohexanecarboxylate (3): ^{1}H NMR δ 3.90–3.96 (m, 4 H, $-OCH_2CH_2O-$), 3.68, 3.67 (2 s, 3 H, diastereomeric CO_2CH_3), 2.55–2.72 (m, 1 H, $CHCO_2CH_3$), 1.20–1.94 (m, 7 H, cyclohexyl hydrogens), 0.94, 0.90 (2 d, 3 H, J = 6.5 Hz, diastereomeric ring methyl hydrogens); ^{13}C NMR δ 172.68 ($^{13}COCH_3$), 109.03 (ketal carbon), 65.10, 64.74 ($-O^{13}CH_2{}^{13}CH_2O-$).

Ethylene ketal of 1(*R*/*S*)-[2-([1,3-$^{13}C_2$]-2-hydroxylpropyl)]-4(*R*)-methyl-2-oxocyclohexane (4): ^{1}H NMR δ 4.78, 4.47 (2 d, 1 H, exchange with D_2O, diastereomeric OH), 3.85–4.09 (m, 4 H, $-OCH_2CH_2O-$), 1.37–1.57 (4 partially overlapping d, 6 H, $C(OH)(13CH_3)_2$), 0.86, 0.95 (2 d, 3 H, diastereomeric ring methyl hydrogens); ^{13}C NMR δ 31.0, 28.5 (two diastereomeric methyl carbons); IR 3495.5 cm^{-1} (OH).

Ethylene ketal of 1(*R*/*S*)-[2-([1,3-$^{13}C_2$]-1-propenyl)]-4-(*R*)-methyl-2-oxocyclohexane (5): ^{1}H NMR δ 4.84 (m, 2 H, $J_{^{13}C,H}$ = 153.89 Hz, vinylic protons), 3.82–3.94 (m, 4 H, $-OCH_2CH_2O-$), 2.20 (m, 1 H, $CHC(CH_3)=CH_2$), 2.81 (dd, 3 H, $J_{^{13}C,H}$ = 122.79 Hz, $J_{C(CH_3),CH_2}$ = 6.00 Hz, $C(CH_3)=CH_2$), 0.91 (d, 3 H, J = 6.2 Hz, ring methyl hydrogens); ^{13}C NMR δ 113.21 ($C(CH_3)=^{13}CH_2$), 23.46 ($^{13}C(CH_3)=CH_2$); IR 3083.5 (=CH), 1644.0 cm^{-1} (C=C).

Ethylene ketal of epoxide 6: ^{1}H NMR δ 3.82–4.05 (m, 4 H, $-OCH_2CH_2O-$), 2.17–3.15 (m, 2 H, $(CH_3)COCH_2$), 1.05–1.61 (3 dd, 3 H, $(CH_3)CO$), 0.90 (d, J = 6.4 Hz, ring methyl hydrogens); ^{13}C NMR δ 55.78, 53.49, 52.30 ($CO^{13}CH_2$), 22.24, 20.45, 18.99 ($(^{13}CH_3)COCH_2$); IR 948.7, 936.7, 846.0, 818.8, 803.1 cm^{-1} (epoxide).

[2,8-$^{13}C_2$]-(*R*)-Menthofuran (7): ^{1}H NMR δ 7.04 (d, 1 H, J = 198.22 Hz, furan proton), 2.93 (ddd, 3 H, J = 126.78, 7.38, 1.31 Hz), 1.09 (d, 3 H, J = 6.67 Hz, ring methyl hydrogens); ^{13}C NMR δ 136.64 (2^{13}C), 8.22 (8^{13}C); GC, the retention time was the same as a standard sample; GC/MS m/z 152 $[M]^{\cdot+}$, 137 $[M - CH_3]^+$, 110 $[M - C_2H_2O]^+$ (base peak). Selected ion monitoring (SIM) revealed that the incorporation of two ^{13}C atoms was 96.34%. HRMS: required 152.1229 ($C_8{}^{13}C_2H_{14}O$), found 152.1256.

2(*Z*)-(2′-Keto-4′-methylcyclohexylidene)propanal. The γ-keto enal was prepared according to Manfredi et al.[4] A solution of 1.1 g (6.7 mmol) of menthofuran and 1.3 g (7.4 mmol) of *m*-CPBA in 50 mL of CH_2Cl_2 was stirred at 25 °C for 15 min. The reaction was washed successively with 10% $Na_2S_2O_3$, 10% $NaHCO_3$, and brine and dried over anhydrous K_2CO_3. The excess of *m*-CPBA was removed by passing the organic layer rapidly through a column containing activated alumina. Evaporation of the solvent at reduced pressure yielded 0.86 g of a crude product as a pale yellow oil: ^{1}H NMR δ 9.65 (s, 1 H), 1.82 (s, 3 H), 1.03 (d, 3 H); ^{13}C NMR δ 200.1, 185.0, 151.3, 144.5, 41.2, 31.7, 29.6, 21.7, 20.8, 8.4.

Registry No. 1, 13368-65-5; 2, 13368-66-6; 3 (isomer 1), 139238-79-2; 3 (isomer 2), 139238-81-6; 4 (isomer 1), 139131-57-0; 4 (isomer 2), 139238-82-7; 5 (isomer 1), 139131-58-1; 5 (isomer 2), 139238-83-8; 6, 139131-59-2; 7, 139131-60-5; 8, 132183-58-5; 9 (isomer 1), 139131-61-6; 9 (isomer 2), 139238-80-5.

Chiral Base-Induced [2,3] Wittig Rearrangement of Acyclic α-(Propargyloxy)acetic Acids and Amides

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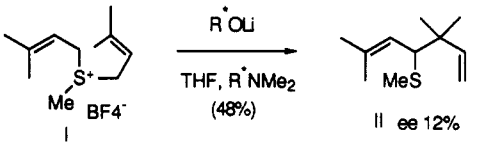
Base-initiated [2,3] sigmatropic rearrangements have only recently been employed to effect stereoselective transformations in acyclic systems.[1] Rearrangements of allylic ethers ([2,3] Wittig)[2] and sulfonium salts are especially important as they effect carbon chain homologation, often with high diastereoselectivity. Nonracemic allylic ethers and sulfonium salts rearrange with essentially complete 1,3-stereocenter transfer.[2,3] In some cases chiral auxiliaries have been employed to effect enantioselective rearrangements of otherwise achiral allylic ethers.[4] In principle, such rearrangements might be effected with a chiral base. However, to date only a few examples of this approach have been recorded.

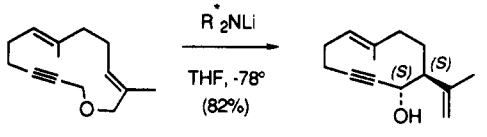
Trost was the first to examine chiral base initiated [2,3] rearrangement of a sulfonium salt.[5] He found that treatment of the bis-allylic system I with the Li alkoxide of (*S*)-1-phenyl-2,2,2-trifluoroethanol in the presence of a chiral amino ether cosolvent afforded the rearranged sulfide II of undetermined absolute configuration with an ee of 12% (eq 1). Some years later we effected a [2,3]



I II ee 12% (1)

R*OLi = (S)-PhCH(CF$_3$)OLi, R*NMe$_2$ = (S,S)-[Me$_2$NCH$_2$CH(OMe)]$_2$

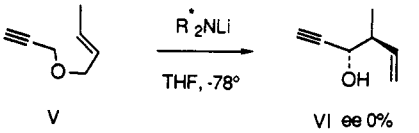
Wittig rearrangement of the 13-membered allylic ether III with lithiated bis[(*S*,*S*)-1-phenylethylamine] affording the ring-contracted propargylic alcohol IV of 70% ee (eq 2).[6]



III IV ee 70% (2)

R*$_2$NLi = (S,S)-[PhCH(CH$_3$)]$_2$NLi

However, a 17-membered homologue of III gave the corresponding 14-membered propargylic alcohol of only 30% ee, and the acyclic ether V rearranged to the racemic alcohol VI (eq 3). We also found that the acyclic α-(al-



V VI ee 0% (3)

(1) Hoffmann, R. W. *Angew. Chem., Int. Ed. Engl.* **1979**, *18*, 563.
(2) Nakai, T.; Mikami, K. *Chem. Rev.* **1986**, *86*, 885. Mikami, K.; Nakai, T. *Synthesis* **1991**, 594. Marshall, J. A. In *Comprehensive Organic Synthesis*; Trost, B. M., Ed.; Pergamon Press: New York, 1991; Vol. 3, pp 975–1014.
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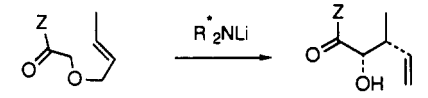
lyloxy)acetic acid VII and amide VIII derivatives afforded only racemic rearranged products IX and X upon treatment with the chiral phenethyl amide base under a variety of conditions (eq 4).[6] Thus, the cyclic ether III appeared



(4)

VII Z = OH
VIII Z = N(CH2)4

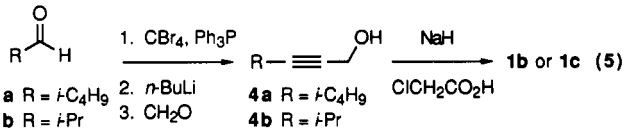
IX ee 0%
X ee 0%

to represent a special case in which conformational constraints imposed by the ring system amplified energetic differences in the diastereomeric transition states of the deprotonation and ensuing [2,3] rearrangement. With larger rings increased flexibility diminished these differences, and with acyclic systems the effect was lost.

In view of the foregoing observations we were surprised to find that the α-(propargyloxy)acetic acid (**1a**) underwent chiral base initiated [2,3] rearrangement to the allenyl alcohol **2a** of 33% ee (Table I).[7,8] Alcohol (*R*)-**2a** was the major product when the (*S,S*)-base was employed (entry 1). The (*R,R*)-base led mainly to (*S*)-**2a** of comparable ee (entry 2). The use of pentane as a cosolvent afforded material of considerably lower ee (entry 3) as previously noted for ether III.[6]

The isobutyl-substituted alkyne **1b** rearranged analogously (Table I, entries 4 and 5). Rearrangement of the isopropyl derivative **1c** proceeded with the highest enantioselectivity, but the reaction was slow (entry 6). In addition to recovered propargylic ether (as the methyl ester derivative, 21% yield), the ether-cleavage product, 4-methyl-2-pentyn-1-ol, was isolated in 40% yield. This alcohol could arise from α-elimination of the intermediate carboxylic dianion. Analogous cleavage of ethers **1a** and **1b** was not observed.

Ethers **1b** and **1c** were prepared from aldehydes **3a** and **3b** by Corey–Fuchs Wittig homologation followed by dehydrobromination (eq 5).[9]



3a R = *i*-C4H9
3b R = *i*-Pr

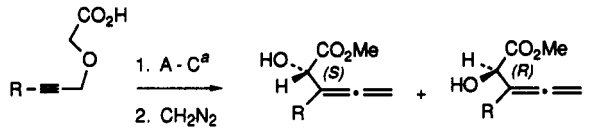
4a R = *i*-C4H9
4b R = *i*-Pr

1b or **1c** (5)

We also briefly examined chiral base-induced [2,3] rearrangement of the enantioenriched ((*R*)-propargyloxy)-acetic acids **5a** and **5b** (Table II).[7] In both cases the (*S,S*)-amide base gave rise to a lower ratio of diastereomeric allenylcarbinols (*S,R*)-**6**:(*R,R*)-**6** than the (*R,R*)-amide base (entries 1 vs 2 and 4 vs 5).[8] Furthermore, the achiral base LDA led to ratios of intermediate value, thus indicating a matching and mismatching of chiral base and substrate.

The contrasting influence of chiral base on [2,3] rearrangements of (allyloxy)acetic acids such as VII and the analogous propargyloxy systems **1** and **5** imply that the amide base is more intimately associated with the transition state in the latter systems. Cohen and Verner have recently shown that for certain allylic ethers, [2,3] Wittig rearrangement proceeds with inversion at the initiating

Table I. [2,3] Wittig Rearrangement of the Achiral α-(Propargyloxy)acetic Acids 1a–c



1a R = *n*-C7H15
1b R = *i*-C4H9
1c R = *i*-Pr

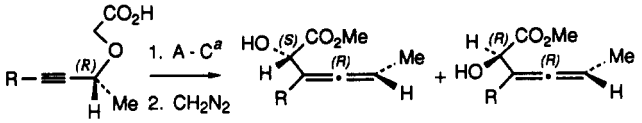
(*S*)-**2a** R = *n*-C7H15
(*S*)-**2b** R = *i*-C4H9
(*S*)-**2c** R = *i*-Pr

(*R*)-**2a** R = *n*-C7H15
(*R*)-**2b** R = *i*-Bu
(*R*)-**2c** R = *i*-Pr

entry	R	conditions[a]	% yield	(*S*)-**2**:(*R*)-**2**	$[\alpha]_D$, deg (*c*)[b]
1	*n*-C7H15 (**1a**)	A	57	33:67	−23.6 (2.48)
2	*n*-C7H15 (**1a**)	B	71	70:30	+24.9 (0.88)
3	*n*-C7H15 (**1a**)	C	26	~50:50	−3.5 (1.35)
4	*i*-Bu (**1b**)	A	58	33:67	−20.8 (0.73)
5	*i*-Bu (**1b**)	B	54	65:35	+19.9 (0.80)
6	*i*-Pr (**1c**)	B	33	74:26	+33.3 (1.10)

[a] A = (*S,S*)-[PhCH(Me)]2NLi, THF, −78 °C; B = (*R,R*)-[PhCH(Me)]2NLi, THF, −78 °C; C = (*S,S*)-[PhCH(Me)]2NLi, 9:1 pentane/THF, −78 °C, 5 h. [b] In $CHCl_3$.

Table II. Diastereoselective [2,3] Wittig Rearrangement of the Enantioenriched α-(Propargyloxy)acetic Acids 5a and 5b



5a R = C4H9
5b R = C7H15

(*S,R*) - **6a**
(*S,R*) - **6b**

(*R,R*) - **6a**
(*R,R*) - **6b**

entry	R	conditions[a]	% yield	(*S,R*):(*R,R*)[b]
1	C_4H_9 (**5a**)	A	75	76:24
2	C_4H_9 (**5a**)	B	71	92:8
3	C_4H_9 (**5a**)	C	84	84:16
4	C_7H_{15} (**5b**)	A	81	81:19
5	C_7H_{15} (**5b**)	B	79	>99:1[c]
6	C_7H_{15} (**5b**)	C	80	93:7

[a] A = (*S,S*)-[PhCH(Me)]2NLi, THF, −78 °C; B = (*R,R*)-[PhCH(Me)]2NLi, THF, −78 °C; C = LDA, THF, −78 °C. [b] Acids **5** were prepared from alcohols of 90–92% ee.[7] The amines used for the amide bases were of >98% ee. Therefore, these ratios are somewhat lower for matched and higher for mismatched pairs than would be observed with enantiomerically pure acids. [c] The (*R,R*)-isomer was undetectable by capillary GC analysis.

carbanionic center.[10] We had previously suggested such a possibility for rearrangements of allyl propargylic ethers.[6,11] Houk's ab initio calculations are also in accord with this conclusion.[12] With the allylic ethers V, VII, and VIII we might attribute the lack of enantioselectivity to a relatively early transition state in which the chiral R* substituents are sufficiently distant from the developing anionic center (at G) to render the diastereomeric alternatives A and B isoenergetic (Figure 1). If the transition state for the propargylic ether rearrangement comes relatively later along the reaction coordinate, we might expect a closer approach by the amide base and a correspondingly greater energy difference between the diastereomeric arrangements C and D.[13] Unfortunately, an attempted

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(8) The ee and absolute configuration of these alcohols was ascertained through ^1H NMR analysis of the methyl mandelates as previously described.[7]
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(11) Marshall, J. A.; Lebreton, J. *J. Org. Chem.* **1988**, *53*, 4108.
(12) Wu, Y. D.; Houk, K. N.; Marshall, J. A. *J. Org. Chem.* **1990**, *55*, 1421.
(13) Ab initio molecular orbital calculations for [2,3] Wittig rearrangement of $LiCH_2OCH_2C{\equiv}CH$ and $LiCH_2OCH_2CH{=}CH_2$ showed these distances to be 2.256 and 2.393 Å, respectively, in the 6-31+G transition structures. However, the base was not included in these calculations. Houk, K. N.; Wu, Y. D., unpublished.

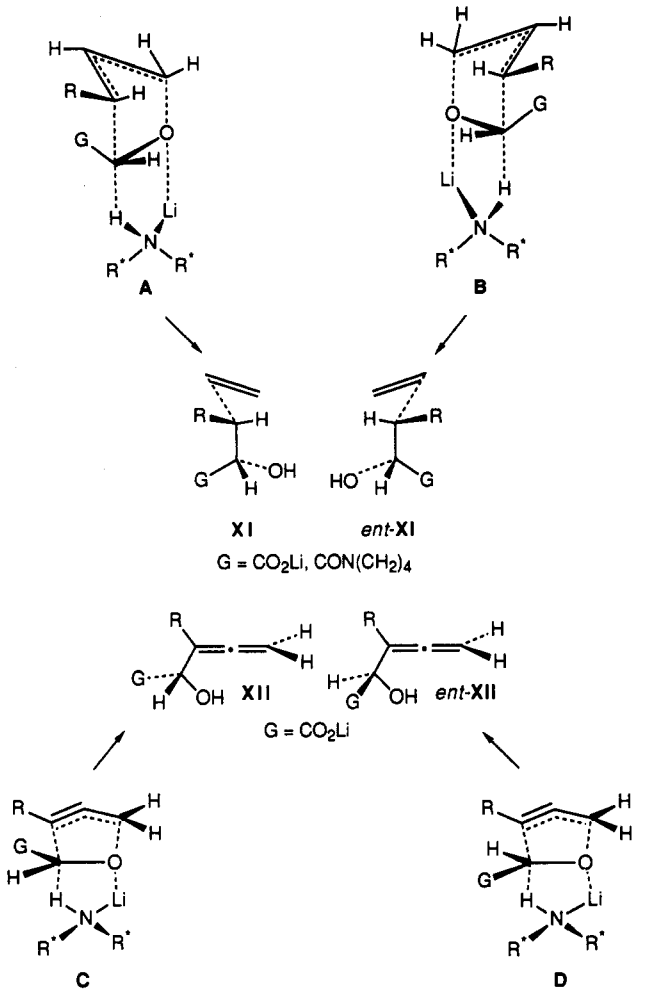
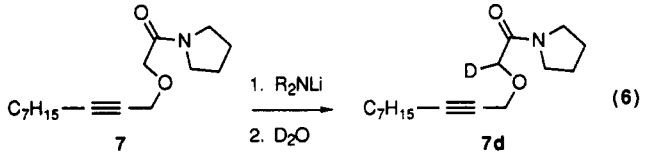


Figure 1. Diastereomeric transition states for [2,3] rearrangements of (allyloxy)- and (propargyloxy)acetic acids.

extension of the rearrangement to amide **7**, a propargyloxy analogue of VIII, failed. Treatment of **7** with excess (*R,R*)-amide base or LDA at −78 °C to room temperature gave only recovered starting material. In the latter case quenching with D_2O gave the deuterated amide **7d**, indicating formation of an enolate species which for unknown reasons does not rearrange (eq 6).



(6)

Experimental Section[14]

1-(2-Decynyloxy)acetic Acid (1a). To a solution of 2.00 g (16.10 mmol) of 1-nonyne in 60 mL of THF was slowly added 6.1 mL (17.71 mmol) of 2.90 M *n*-BuLi at −78 °C. The resulting mixture was stirred for 1 h. To the mixture was added 1.5 g (50.0 mmol) of paraformaldehyde. The mixture was warmed to room temperature, stirred for 1 h, neutralized with 10% HCl, and extracted with ether. The organic layer was washed with saturated aqueous $NaHCO_3$ and brine and then dried over $MgSO_4$. After removal of solvent, the residue was distilled at reduced pressure to give 2.45 g (98%) of 2-decyn-1-ol: IR (film) ν 3422, 2225 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.24 (dt, J = 1.7, 6.1 Hz, 2 H, CH_2OH), 2.22–2.16 (m, 2 H, propargylic CH_2), 1.51–1.26 (m, 10 H, $(CH_2)_5$), 0.87 (t, J = 6.7 Hz, 3 H, CH_2CH_3).

To a suspension of 1.37 g (57.06 mmol) of NaH in 100 mL of THF was added a solution of 2.45 g (15.88 mmol) of the above alcohol in 50 mL of THF at 0 °C. After 30 min, 2.25 g (23.80 mmol) of chloroacetic acid was added to the mixture in several portions at 0 °C. The resulting mixture was refluxed for 18 h, acidified with 10% HCl, and then extracted with ether. The extracts were dried over $MgSO_4$ and concentrated. The residue was purified by chromatography on silica gel (hexane/ether, 4:1, then ether) to yield 3.37 g (100%) of acid **1a**: IR (film) 3600–2500, 2225 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.28 (t, J = 2.1 Hz, 2 H, $C{\equiv}CCH_2O$), 4.22 (s, 2 H, OCH_2CO_2H), 2.20 (dt, J = 2.1, 4.8 Hz, 2 H, propargylic CH_2), 1.51–1.26 (m, 10 H, $(CH_2)_5$), 0.86 (t, J = 6.7 Hz, 3 H, CH_2CH_3); MS *m/e* 153 (7, $M^+ - CH_2CO_2H$), 128 (100).

1-[(5-Methyl-2-hexynyl)oxy]acetic Acid (1b). According to the above procedure, acid **1b** was prepared from alcohol **4a** in 96% yield: IR (film) 3600–2500, 2250 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.30 (t, J = 2.2 Hz, 2 H, OCH_2), 4.22 (s, 2 H, CH_2CO_2H), 4.12 (s, 1 H, CO_2H), 2.10 (dt, J = 2.2, 6.5 Hz, 2 H, $(CH_3)_2CHCH_2$), 1.84–1.75 (m, 1 H, $(CH_3)_2CH$), 0.95 (d, J = 6.6 Hz, 6 H, $(CH_3)_2CH$); HRMS calcd for $C_8H_{11}O_3$ ($M - CH_3$) 155.0708, found 155.0705.

1-[(4-Methyl-2-pentynyl)oxy]acetic Acid (1c). According to the above procedure, acid **1c** was prepared from alcohol **4b** in 92% yield: IR (film) 3600–2500, 2253 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.28 (t, J = 2.0 Hz, 2 H, OCH_2), 4.21 (s, 2 H, CH_2CO_2H), 4.12 (s, 1 H, CO_2H), 2.60–2.53 (m, 1 H, $(CH_3)_2CH$), 1.15 (d, J = 6.9 Hz, 6 H, $(CH_3)_2CH$); HRMS calcd for $C_8H_{11}O_3$ (M − H) 155.0708, found 155.0708.

Methyl (*R*)-2-Hydroxy-3-heptyl-3,4-pentadienecarboxylate [(*R*)-2a]. To a solution of 1.15 g (5.09 mmol) of (*S,S*)-bis(1-methylbenzyl)amine in 5 mL of THF was added 1.75 mL (5.09 mmol) of 2.78 M *n*-BuLi at 0 °C. The mixture was stirred at 0 °C for 30 min and cooled to −78 °C. To the mixture was added dropwise 400 mg (1.88 mmol) of acid **1a** in 5 mL of THF. The reaction mixture was stirred at −78 °C for 1 h, acidified with 10% HCl, and extracted with ether. The extracts were dried over $MgSO_4$ and concentrated. The residue was directly used for esterification without purification.

To a solution of the above crude oil in 10 mL of ether was added excess diazomethane in 10 mL of ether. The reaction mixture was stirred at room temperature until the TLC showed no trace of the starting material. The excess diazomethane was destroyed by acetic acid. Concentration of the mixture and chromatography of the crude product on silica gel (hexane/ether, 3:1) afforded 243 mg (57%) of allenyl alcohol (*R*)-**2a**, a 67:33 mixture of enantiomers according to GC analysis of the (*R*)- and (*S*)-methyl mandelate derivatives:[7] $[\alpha]_D$ −23.6° ($CHCl_3$, *c* 2.48); IR (film) ν 3500, 1965, 1745 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 4.90–4.87 (m, 2 H, 2 vinyl H), 4.58 (d, J = 7.6 Hz, 1 H, $HOCHCO_2Me$), 3.78 (s, 3 H, CO_2CH_3), 2.88 (d, J = 7.6 Hz, 1 H, OH), 2.07–1.90 (m, 2 H, vinyl CH_2), 1.42–1.25 (m, 10 H, $(CH_2)_5$), 0.86 (t, J = 6.8 Hz, 3 H, CH_2CH_3); HRMS calcd for $C_{13}H_{22}O_3$ 226.1569, found 226.1565. Anal. Calcd for $C_{13}H_{22}O_3$: C, 68.99; H, 9.80. Found: C, 68.88; H, 9.82.

Methyl (*S*)-2-Hydroxy-3-heptyl-3,4-pentadienecarboxylate [(*S*)-2a]. By the above procedure with the (*R,R*)-amide base, allenyl alcohol (*S*)-**2a** was obtained in 71% yield as a 70:30 mixture of enantiomers according to GC analysis of the (*R*)- and (*S*)-methyl mandelate derivatives:[7] $[\alpha]_D$ +24.9° ($CHCl_3$, *c* 0.88).

Methyl (*R*)-2-Hydroxy-3-(2-methylpropyl)-3,4-pentadienecarboxylate [(*R*)-2b]. By the above procedure with the (*S,S*)-amide base, allenyl alcohol (*R*)-**2b** was obtained in 58% yield as a 67:33 mixture of enantiomers according to GC analysis of the (*R*)-methyl mandelate derivative:[7] $[\alpha]_D$ −20.8° ($CHCl_3$, *c* 0.73); IR (film) ν 3485, 1958, 1743 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.88 (m, 2 H, 2 vinyl H), 4.56 (d, J = 7.7 Hz, 1 H, $HOCHCO_2Me$), 3.77 (s, 3 H, CO_2CH_3), 2.86 (d, J = 7.7 Hz, 1 H, OH), 1.95–1.83 (m, 2 H, vinyl CH_2), 1.79–1.70 (m, 1 H, $(CH_3)_2CH$), 0.90 (d, J = 6.5 Hz, 3 H, CH_3), 0.89 (d, J = 6.5 Hz, 3 H, CH_3): HRMS calcd for $C_{11}H_{18}O_3$ 198.1258, found 198.1256.

Methyl (*S*)-2-Hydroxy-3-(2-methylpropyl)-3,4-pentadienecarboxylate [(*S*)-2b]. By the above procedure with the (*R,R*)-bis(1-methylbenzyl)amide base, allenyl alcohol (*S*)-**2b** was obtained in 54% yield as a 65:35 mixture of enantiomers according to GC analysis of the (*R*)-methyl mandelate derivative:[7] $[\alpha]_D$ +19.9° ($CHCl_3$, *c* 0.80).

(14) For a listing of experimental protocols, see: Marshall, J. A.; Wang, X.-j. *J. Org. Chem.* **1991**, *56*, 4913.

Methyl (*S*)-2-Hydroxy-3-isopropyl-3,4-pentadienecarboxylate [(*S*)-2c]. By the above procedure with the (*R*,*R*)-amide base, allenyl alcohol (*S*)-**2c** was obtained in 33% yield as a 74:26 mixture of enantiomers according to GC analysis of the (*R*)-methyl mandelate derivative:[7] $[\alpha]_D$ +33.3° ($CHCl_3$, *c* 1.10); IR (film) ν 3482, 1956, 1742 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.91 (m, 2 H, 2 vinyl H), 4.63 (d, J = 8.1 Hz, 1 H, HOC*H*CO_2Me), 3.77 (s, 3 H, CO_2CH_3), 2.83 (d, J = 8.1 Hz, 1 H, OH), 2.32 (m, 1 H, $(CH_3)_2CH$), 1.06 (d, J = 6.6 Hz, 3 H, CH_3), 1.04 (d, J = 6.6 Hz, 3 H, CH_3); HRMS calcd for $C_9H_{14}O_3$ 170.0943, found 170.0938.

(*R*)-Methyl Mandelate of the Allenyl Alcohol 2b from the (*S*,*S*)-Amide Base. A mixture of 14.5 mg (0.079 mmol) of alcohol **2b** (from the (*S*,*S*)-amide base), 19 mg (0.12 mmol) of (*R*)-1-methoxy-1-phenylacetic acid, and 24 mg (0.12 mmol) of DCC in 2 mL of CH_2Cl_2 containing a catalytic amount of DMAP was stirred at room temperature for 30 min, and then it was directly chromatographed on silica gel (hexane/ether, 4:1) to yield the (*R*)-methyl mandelate quantitatively as a 67:33 mixture of diastereomers according to GC analysis: IR (film) ν 1957, 1743 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.45–7.24 (m, 5 H, ArH), 5.46 (s, 1 H, MeOCH), 4.89–4.79 (m, 3 H, 2 vinyl H and COC*H*OH), 3.61 (s, 3 H, CO_2CH_3), 3.47 (s, 3 H, CH_3O), 2.84 (m, 2 H, vinyl CH_2), 1.70–1.62 (m, 1 H, $(CH_3)_2CH$), 0.85 (d, J = 6.5 Hz, 6 H, $(CH_3)_2$). The peaks of the minor product could be seen at δ 5.42 (s, 1 H, MeOCH), 3.73 (s, 3 H, CO_2CH_3), 3.43 (s, 3 H, CH_3O), 0.75 (d, J = 6.5 Hz, 3 H, CH_3), 0.72 (d, J = 6.5 Hz, 3 H, CH_3); HRMS calcd for $C_{19}H_{24}O_5$ 332.1624, found 336.1620.

(*R*)-Methyl Mandelate of the Allenyl Alcohol 2c. By the above procedure, the (*R*)-methyl mandelate of allenyl alcohol **2c** from the (*R*,*R*)-amide was obtained quantitatively as a 74:26 mixture of diastereomers according to ^1H NMR analysis: IR (film) ν 1955, 1745 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.45–7.31 (m, 5 H, ArH), 5.47 (t, J = 1.9 Hz, 1 H, MeOCH), 4.91–4.88 (m, 3 H, 2 vinyl H and COC*H*OH), 3.76 (s, 3 H, CO_2CH_3), 3.43 (s, 3 H, CH_3O), 1.97 (m, 1 H, vinyl CH), 1.70–1.62 (m, 1 H, $(CH_3)_2CH$), 0.85 (d, J = 7.1 Hz, 3 H, CH_3), 0.83 (d, J = 7.1 Hz, 3 H, CH_3). The peaks of the minor diastereomer could be seen at δ 5.54 (s, 1 H, MeOCH), 3.60 (s, 3 H, CO_2CH_3), 3.47 (s, 3 H, CH_3O), 2.10 (m, 1 H, vinyl CH), 0.99 (d, J = 6.8 Hz, 3 H, CH_3), 0.98 (d, J = 6.8 Hz, 3 H, CH_3); HRMS calcd for $C_{17}H_{19}O_4$ (M − OCH_3) 287.1282, found 287.1283.

5-Methyl-2-hexyn-1-ol (4a). To a solution of 7.31 g (27.88 mmol) of Ph_3P in 25 mL of CH_2Cl_2 was added 4.62 g (13.93 mmol) of CBr_4 in one portion. After 15 min, 0.75 mL (6.97 mmol) of isovaleraldehyde was added. The mixture was stirred at room temperature for 1 h, and then it was evaporated to dryness. The residue was washed with hexane, and the combined extracts were concentrated. The residue was chromatographed on silica gel (hexane/ether, 20:1) to afford 1.07 g (64%) of dibromide.

To a solution of 1.06 g (4.38 mmol) of the above dibromide in 15 mL of THF was added 3.80 mL (9.20 mmol) of 2.42 M *n*-BuLi in hexane at −78 °C. After 30 min, the mixture was allowed to warm to room temperature and stirred for 1 h, and then it was cooled to −78 °C and 263 mg (8.76 mmol) of paraformaldehyde was added. The resulting mixture was stirred at room temperature for 1 h, neutralized with 10% HCl, and extracted with ether. The organic layer was washed with saturated aqueous $NaHCO_3$ and brine and then dried over $MgSO_4$. After removal of solvent, the residue was distilled at reduced pressure to give 2.45 g (98%) of alcohol **4a**: IR (film) ν 3341, 2228 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.24 (dt, J = 2.0, 6.0 Hz, 2 H, CH_2OH), 2.09 (dt, J = 2.2, 6.6 Hz, 2 H, $(CH_3)_2CHCH_2$), 1.82–1.74 (m, 1 H, $(CH_3)_2CH$), 0.95 (d, J = 6.6 Hz, 6 H, $(CH_3)_2CH$).

4-Methyl-2-pentyn-1-ol (4b). Alcohol **4b** was obtained by the above procedure in 81% yield from the corresponding dibromide: IR (film) ν 3400, 2231 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.23 (dd, J = 2.0, 6.0 Hz, 2 H, CH_2OH), 2.61–2.52 (m, 1 H, $(CH_3)_2CH$), 1.47 (t, J = 6.0 Hz, 1 H, OH), 1.15 (d, J = 6.9 Hz, 6 H, $(CH_3)_2CH$).

Methyl (2*S*,4*R*)-2-Hydroxy-3-heptyl-3,4-hexadienecarboxylate [(*S*,*R*)-6b]. A. LDA Base. To a solution of 0.65 mL (4.5 mmol) of diisopropylamine in 5 mL of THF was added 1.5 mL (4.2 mmol) of 2.78 M *n*-BuLi at 0 °C. The mixture was stirred at 0 °C for 30 min and cooled to −78 °C. To the mixture was added dropwise 380 mg (1.7 mmol) of (*R*)-acid **5b** in 5 mL of THF.[7] The reaction mixture was stirred at −78 °C for 1 h, acidified with 10% HCl, and extracted with ether. The extracts were dried over $MgSO_4$ and concentrated. The residue was directly used for esterification without purification.

To a solution of the above crude oil in 10 mL of ether was added excess diazomethane in 10 mL of ether. The reaction mixture was stirred at room temperature until the TLC showed no trace of the starting material. The excess diazomethane was destroyed by acetic acid. Concentration of the mixture and chromatography of the crude product on silica gel (hexane/ether, 4:1) afforded 320 mg (80%) of alcohols (*S*,*R*)-**6b** and (*R*,*R*)-**6b** as a 93:7 mixture of diastereomers according to GC analysis: $[\alpha]_D$ +33.8° ($CHCl_3$, *c* 2.13); IR (film) ν 3500, 1967, 1745 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 5.31–5.27 (m, 1 H, vinyl H), 4.53 (bs, 1 H, HOC*H*CO_2Me), 3.75 (s, 3 H, CO_2CH_3), 2.84 (bs, 1 H, OH), 2.06–1.89 (m, 2 H, vinyl CH_2), 1.64 (d, J = 7.1 Hz, 3 H, CH_3), 1.40–1.23 (m, 10 H, $(CH_2)_5$), 0.85 (t, J = 7.0 Hz, 3 H, CH_2CH_3); HRMS calcd for $C_{14}H_{24}O_3$ 240.1725, found 244.1717. Anal. Calcd for $C_{14}H_{24}O_3$: C, 69.97; H, 10.06. Found: C, 70.02; H, 10.11.

B. (*S*,*S*)-Amide Base. By the above procedure, alcohols (*S*,*R*)-**6b** and (*R*,*R*)-**6b** were obtained in 81% yield as a 81:19 mixture of diastereomers according to GC analysis on treatment of the (*R*)-acid **5b** with the (*S*,*S*)-amide base:[7] $[\alpha]_D$ +23.8° ($CHCl_3$, *c* 1.05).

C. (*R*,*R*)-Amide Base. By the above procedure, alcohol (*S*,*R*)-**6b** was obtained in 79% yield as the only detectable diastereomer according to GC analysis on treatment of the (*R*)-acid **5b** with the (*R*,*R*)-amide base:[7] $[\alpha]_D$ +40.4° ($CHCl_3$, *c* 0.96).

Methyl (2*S*,4*R*)-2-Hydroxy-3-butyl-3,4-hexadienecarboxylate [(*S*,*R*)-6a]. A. LDA Base. (*S*,*R*)-**6a** and (*R*,*R*)-**6a** were obtained in 84% yield as an 84:16 mixture of diastereomers according to GC analysis on treatment of the (*R*)-acid **5a** with LDA:[7] $[\alpha]_D$ +35.1° ($CHCl_3$, *c* 1.14); IR (film) ν 3478, 1966, 1738 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 5.31 (m, 1 H, vinyl H), 4.54 (d, J = 8.0 Hz, 1 H, HOC*H*CO_2Me), 3.76 (s, 3 H, CO_2CH_3), 2.81 (d, J = 8.0 Hz, 1 H, OH), 1.98 (m, 2 H, vinyl CH_2), 1.66 (d, J = 7.0 Hz, 3 H, CH_3), 1.40–1.23 (m, 4 H, $(CH_2)_2$), 0.85 (t, J = 7.0 Hz, 3 H, CH_2CH_3); HRMS calcd for $C_{11}H_{18}O_3$ 198.1256, found 198.1258. Anal. Calcd for $C_{11}H_{18}O_3$: C, 66.64; H, 9.15. Found: C, 66.73; H, 9.16.

B. (*S*,*S*)-Amide Base. By the above procedures, alcohols (*S*,*R*)-**6a** and (*R*,*R*)-**6a** were obtained as a 76:24 mixture of diastereomers according to GC analysis in 75% yield on treatment of the (*R*)-acid **5a** with the (*S*,*S*)-amide base:[7] $[\alpha]_D$ +25.1° ($CHCl_3$, *c* 0.90).

C. (*R*,*R*)-Amide Base. By the above procedure, alcohols (*S*,*R*)-**6a** and (*R*,*R*)-**6a** were obtained in 71% yield as a 92:8 mixture of diastereomers according to GC analysis on treatment of the (*R*)-acid **5a** with the (*R*,*R*)-amide base:[7] $[\alpha]_D$ +43.2° ($CHCl_3$, *c* 1.03).

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Registry No. **1a**, 127130-50-1; **1b**, 139527-34-7; **1c**, 139527-35-8; (*R*)-**2a**, 127130-51-2; (*S*)-**2a**, 139627-61-5; (*R*)-**2b**, 139527-38-1; (*R*)-**2b** (*R*)-methyl mandelate, 139527-40-5; (*S*)-**2b**, 139527-36-9; (*S*)-**2b** (*R*)-methyl mandelate, 139527-41-6; (*R*)-**2c**, 139527-39-2; (*R*)-**2c** (*R*)-methyl mandelate, 139527-42-7; (*S*)-**2c**, 139527-37-0; (*S*)-**2c** (*R*)-methyl mandelate, 139527-43-8; **3a**, 590-86-3; **3b**, 78-84-2; **4a**, 34452-35-2; **4b**, 15787-92-5; (*R*)-**5a**, 124126-27-8; (*R*)-**5b**, 124126-39-2; (*R*,*R*)-**6a**, 139627-63-7; (*S*,*R*)-**6a**, 139627-62-6; (*R*,*R*)-**6b**, 127130-41-0; (*S*,*R*)-**6b**, 127130-40-9; **7**, 139527-33-6; **7b**, 139527-45-0; 1-nonyne, 3452-09-3; 2-decyn-1-ol, 4117-14-0; chloroacetic acid, 79-11-8; (*S*,*S*)-bis(α-methylbenzyl)amine, 56210-72-1; (*R*,*R*)-bis(α-methylbenzyl)amine, 23294-41-9; (*R*)-α-methoxy-α-phenylacetic acid, 3966-32-3; 1,2-dibromo-4-methyl-1-pentene, 90701-59-0; 1,2-dibromo-3-methyl-1-butene, 32363-92-1; [(propargyloxy)methyl]lithium, 139527-44-9; [(2-propenyloxy)methyl]lithium, 117421-74-6.

Supplementary Material Available: ^1H NMR spectra of **1a**, **1b**, **1c**, **2a**, **2b**, **2c**, methyl mandelate of **2b**, and **2c**, **4a**, **4b**, **5a**, and **6a** (13 pages). This material is contained in many libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.