(2*E*)-1-[*N*-(*tert*-Butoxycarbonyl)amino]-5-ethyl-2,4-heptadiene (35i). Prepared as above by treating **33*E*** (1.131 g, 3.68 mmol) in THF (29.4 mL) at −78 °C with a 1.0 M solution of sodium bis(trimethylsilyl)amide in THF (7.70 mL, 7.70 mmol). After the yellow solution was stirred at −78 °C for 20 min, 3-pentanone (0.288 g, 3.34 mmol) was added. The solution was then allowed to warm to 0 °C over a 5-h period, and workup as above to provide a yellow oil. This oil was purified by radial chromatography (2.5% ethyl acetate in hexane) to provide 0.373 g (47%) of a colorless oil. ^{1}H NMR analysis of the product indicated the presence of ca. 6% of the 2*Z* isomer. Unless otherwise stated, the following NMR data are for the 2*E* isomer (**35i**): ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.39 (dd, $J_{2,3}$ = 15.04 Hz, $J_{3,4}$ = 10.93 Hz, $NCH_2CH{=}CHCH{=}C$, 2*E* isomer), 6.01 (d, $J_{3,4}$ = 10 Hz, $NCH_2CH{=}CHCH{=}C$, 2*Z* isomer), 5.75 (d, $J_{3,4}$ = 11.00 Hz, 1 H, $NHCH_2CH{=}CHCH{=}C$), 5.57 (dt, $J_{2,3}$ = 15.01 Hz, $J_{1,2}$ = 6.37 Hz, 1 H, $NHCH_2CH{=}CHCH$), 5.32 (dt, $J_{2,3}$ = 10 Hz, $J_{1,2}$ = 6.83 Hz, $NHCH_2CH{=}CHCH$, 2*Z* isomer), 4.55 (b s, 1 H, $NHCH_2CH{=}CH$), 3.90 (b t, $NHCH_2CH{=}CH$, 2*Z* isomer), 3.77 (b t, J = 5.85 Hz, 2 H, $NHCH_2CH{=}CH$), 2.17 (q, J = 7.41 Hz, 2 H, $C{=}CCH_2CH_3$), 2.08 (q, J = 7.47 Hz, 2 H, $C{=}CCH_2CH_3$), 1.45 (s, 9 H, $OC(CH_3)_3$), 1.02 (t, J = 7.41 Hz, 3 H, $C{=}CCH_2CH_3$), 1.00 (t, J = 7.62 Hz, 3 H, $C{=}CCH_2CH_3$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 155.70 ($NHC{=}O$), 147.09, 128.18, 127.08, 121.83, 79.25 ($OC(CH_3)_3$), 42.84 ($CHCH_2NH$), 29.43 (CH_2CH_3), 28.39 ($OC(CH_3)_3$), 23.79 (CH_2CH_3), 13.41 (CH_2CH_3), 12.57 (CH_2CH_3); mass spectrum EI (rel intensity) 239 (18, M^+), 183 (65, $M^+ - C_4H_8$), 154 (62), 122 (94), 59 (100, C_4H_9).

Anal. Calcd for $C_{14}H_{25}NO_2$: C, 70.25; H, 10.53. Found: C, 70.05; H, 10.40.

(2*E*,4*E*)-1-[*N*-(*tert*-Butoxycarbonyl)amino]-5,6,6-trimethyl-2,4-heptadiene (35j). Prepared as above by treating **33*E*** (1.27 g, 4.13 mmol) in THF (33.0 mL) at −78 °C with a 1.0 M solution of sodium bis(trimethylsilyl)amide in THF (8.45 mL, 8.45 mmol). After the yellow solution was stirred at −78 °C for 20 min, pinacolone (0.376 g, 3.75 mmol) was added. The solution was then allowed to warm to 0 °C over a 5-h period and worked up as above to provide a yellow oil. This oil was purified by radial chromatography (2.5% ethyl acetate in hexane) to provide 0.485 g (51%) of **35j** as a colorless oil. ^{1}H and ^{13}C NMR analysis of the product indicated only the 2*E* isomer had been formed: ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.40 (b dd, $J_{2,3}$ = 14.95 Hz, $J_{3,4}$ = 10.71 Hz, 1 H, $HNCH_2CH{=}CHCH{=}C(CH_3)$), 5.90 (d, $J_{3,4}$ = 10.56 Hz, 1 H, $CH{=}CHCH{=}C(CH_3)$), 5.63 (dt, $J_{2,3}$ = 14.97 Hz, $J_{1,2}$ = 6.08 Hz, 1 H, $HNCH_2CH{=}CHCH{=}C$), 4.58 (b s, 1 H, $HNCH_2CH{=}CH$), 3.78 (b t, 2 H, $HNCH_2CH{=}CHCH$), 1.75 (s, 3 H, $CH{=}C(CH_3)C(CH_3)_3$), 1.45 (s, 9 H, $OC(CH_3)_3$), 1.05 (s, 9 H, $CH{=}C(CH_3)C(CH_3)_3$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 155.70 ($NHC{=}O$), 147.06, 129.03, 127.70, 120.34, 79.24 ($OC(CH_3)_3$), 42.79 ($CHCH_2NH$), 36.36 ($CH{=}C(CH_3)C(CH_3)_3$), 28.86 ($CH{=}C(CH_3)$), 28.39 ($OC(CH_3)_3$), 13.25 ($CH{=}C(CH_3)C(CH_3)_3$); mass spectrum EI (rel intensity) 253 (8, M^+), 197 (50, $M^+ - C_4H_8$), 140 (100), 57 (82, C_4H_9).

Anal. Calcd for $C_{15}H_{27}NO_2$: C, 71.10; H, 10.74. Found: C, 71.00; H, 10.81.

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Efficient Synthesis of Sterically and Optically Pure *E,Z* Conjugated Hydroxy Dienes. A New Approach to Hydroxyeicosatetraenoic Acids

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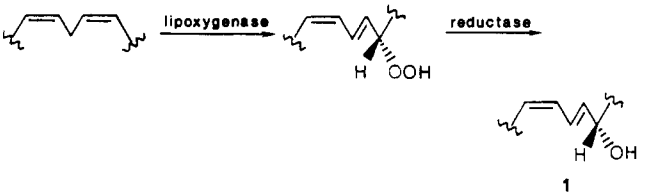
A new strategy for the synthesis of optically active *E,Z* conjugated hydroxy dienes, important intermediates for the synthesis of HETEs, is described. It involves as its key steps two successive chirality transfers starting from the tricyclic lactol **5**, easily obtained via an enzymatic pathway. This method is exemplified by the efficient synthesis of pure *S* and *R* enantiomers of 6-acetoxy-2(*Z*),4(*E*)-undecadien-1-ol (**6**).

Lipoxygenation of arachidonic acid, first observed in mammalian platelets,[1] has been now reported to occur in a number of different tissues and has been shown to lead to metabolites of great biological importance such as leukotrienes and HETEs[2] (hydroxyeicosatetraenoic acids). All the biological and biochemical properties of these substances are still not known, and since they are obtained only in minute amounts from natural sources, considerable synthetic efforts have been recently devoted to finding efficient methods for their synthesis.

Six different possible monohydroxylated metabolites (5-, 8-, 9-, 11-, 12-, and 15-HETEs) can be produced via the lipoxygenase pathway, depending on the oxidation site of arachidonic acid. But, regardless of the site involved, the final result is always the transformation of a (*Z,Z*)-1,4-diene moiety of arachidonic acid to an *E,Z* conjugated diene with a hydroxy group of *R* or *S* configuration next to the *E* double bond.



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(2) See: (a) Samuelsson, B. *Science* **1983**, *220*, 568. (b) *The Leukotrienes, Chemistry and Biology*; Chakrin, L. W., Barley, D. M., Eds.; Academic Press: London, 1984.

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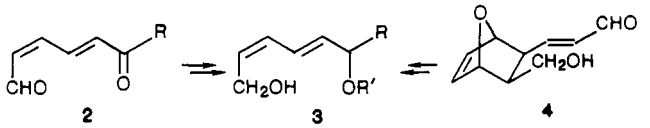
Table I. Diastereoselectivity of the Addition of Acetylide Anions to the Lactol 5

RC≡CM[a]	solvent	% yield[b]	7/8[c]
$C_5H_{11}C{\equiv}CMgBr$	ether	92	63/37
$C_5H_{11}C{\equiv}CMgBr + ZnI_2$ (0.1 equiv)	ether	85	60/40
$C_5H_{11}C{\equiv}CMgBr$	THF	87	86/14
$C_5H_{11}C{\equiv}CMgBr + ZnI_2$ (0.1 equiv)	THF	80	88/12
$C_5H_{11}C{\equiv}CTi(OiPr)_3$	THF	60	9/91
$C_5H_{11}C{\equiv}CLi$	ether	66	75/25
$C_8H_{17}C{\equiv}CMgBr$	THF	80	85/15
$C_8H_{17}C{\equiv}CMgBr + ZnI_2$ (0.1 equiv)	THF	84	86/14

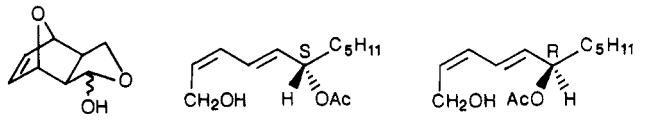
[a] All the reactions were carried on with a large excess (5–7 equiv) of organometallic reagent. [b] Yields are given for pure isolated compounds. [c] The ratios 7/8 were determined on the crude products by ^1H NMR spectroscopy at 250 MHz: the two singlets due to the bridgehead protons were found at higher field for 8 than for 7 ($\Delta\delta$ 0.1 ppm).

Thus, an efficient synthesis of sterically and optically pure hydroxy dienes of type **1** would be a good approach to a general synthesis of HETEs. Different methodologies have been recently used to obtain such conjugated dienes, most of them relying on the formation of the *Z* double bond through a Wittig reaction which is not always highly stereoselective.[3] Rokach has reported a general synthesis of dienes **3** from dicarbonyl compounds **2** obtained by addition of α-diazocarbonyl compounds to furan, followed by a rearrangement.[4] The C_{20} carbon skeleton of various racemic HETEs has then been completed by coupling the dienic bromides corresponding to **3** with the appropriate acetylenic synthons.



2 **3** **4**

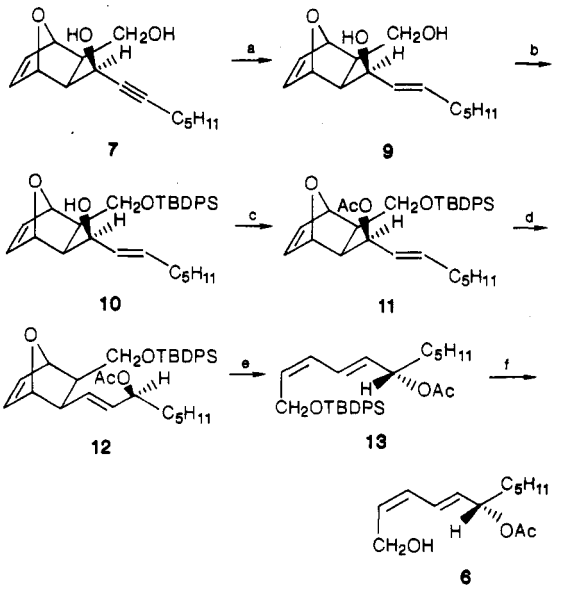
This original method suffers from the lack of selectivity of the rearrangement leading to **2** since up to 25% of the (*Z,Z*)-diene can be formed. Therefore we have recently developed[5] a highly stereoselective synthesis of (*E,Z*)-dienes **3** via hydroxy aldehyde **4**, which seems however difficult to apply to the optically active compounds. We describe here a totally different way for the synthesis of both enantiomers of *E,Z* conjugated hydroxy dienes **3**, from optically active lactol **5**,[6] which is illustrated by the synthesis of 6(*S*)- and 6(*R*)-acetoxy-2(*Z*),4(*E*)-undecadien-1-ol (**6** and its enantiomer).



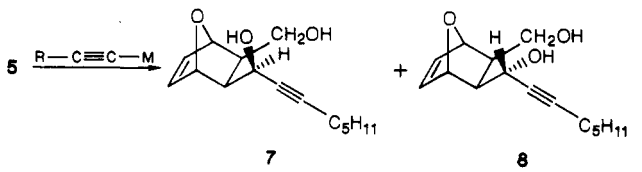
5 **6** **6'**

We have recently shown that the stereoselectivity of the addition of alkyl organometallic species to the carbonyl group of the open form of the lactol **5** can be easily controlled to give either one or the other diastereoisomer coming from an addition either to the *Re* or *Si* face of the carbonyl function.[7] As reported in Table I, we found that this control is also effective for the addition of metallic acetylides to **5**, allowing the isolation of pure diastereoisomers **7** or **8** after a simple flash chromatography.

Scheme I[a]



[a] Reagents: (a) Red-Al, ether; (b) t-BuPh$_2$SiCl/imidazole, DMF; (c) Ac$_2$O/Et$_3$N, DMAP, CH$_2$Cl$_2$; (d) PdCl$_2$(CH$_3$CN)$_2$ 0.04 equiv, THF; (e) 130 °C, xylene; (f) *n*-Bu$_4$NF, THF.



7 **8**

The configuration about the newly created asymmetric center in **7** and **8** was assigned by examination of the 250-MHz ^1H NMR spectra of the corresponding lactones obtained by Jones oxidation of the diols.[7] As this work was in progress, selective additions of acetylide anions to α-alkoxy aldehydes have been described, the best selectivity being obtained with alkynyl zinc reagents.[8a] In our case, we also observed a good selectivity with analogous reagents. But, in contrast with a recent report,[8b] the addition of acetylenic titanium compounds RC≡CTi(OiPr)$_3$ led to a complete reversal of selectivity, which can be explained by the absence of chelation of the aldehyde carbonyl group.[7]

The synthesis of 6(*S*)-acetoxy-2(*Z*),4(*E*)-undecadien-1-ol (**6**) was then accomplished from the pure stereoisomer **7** derived from optically active lactol **5**[6] via Scheme I. The triple bond of the propargylic alcohol was selectively reduced to a trans double bond ($E \geq 98\%$) by the action of sodium bis(2-methoxyethoxy)aluminum hydride (Red-Al, Aldrich) in ether.[9] The primary alcohol was then selectively protected as its *tert*-butyldiphenylsilyl ether **10**, and acetylation of the secondary alcohol gave the allylic acetate **11**. Allylic isomerization of this acetate constituted one key step of this synthesis. It has been established that catalytic amounts of palladium(II) salts equilibrate allylic

(3) Recents syntheses of optically active HETEs: (a) Djuric, S. W.; Miyashiro, J. M.; Penning, T. D. *Tetrahedron Lett.* **1988**, *29*, 3459. (b) Taffer, I. M.; Zipkin, R. E. *Tetrahedron Lett.* **1987**, *28*, 6543. (c) Yadagiri, P.; Lumin, S.; Mosset, P.; Capdevila, J.; Falck, J. R. *Tetrahedron Lett.* **1986**, *27*, 6039. (d) Leblanc, Y.; Fitzsimmons, B. J.; Adams, J.; Perez, F.; Rokach, J. *J. Org. Chem.* **1986**, *51*, 789. (e) Nicolaou, K. C.; Ladduwahetty, T.; Taffer, I. M.; Zipkin, R. E. *Synthesis* **1986**, 344. (f) Just, G.; Wang, Z. Y. *J. Org. Chem.* **1986**, *51*, 4796. (g) See also: Corey, E. J.; Hashimoto, S. *Tetrahedron Lett.* **1981**, *22*, 299.

(4) Rokach, J.; Adams, J. *Acc. Chem. Res.* **1985**, *18*, 87 and references therein.

(5) Bloch, R.; Gasparini, G.; Girard, C. *Chem. Lett.* **1988**, 1927.

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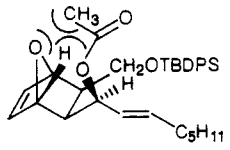
(8) (a) Mead, K. T. *Tetrahedron Lett.* **1987**, *28*, 1019. (b) Krause, N.; Seebach, D. *Chem. Ber.* **1987**, *120*, 1845.

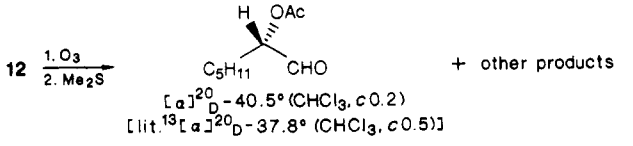
(9) Denmark, S. E.; Jones, T. K. *J. Org. Chem.* **1982**, *47*, 4595.

acetates[10] and that this rearrangement can be made with clean suprafacial stereochemistry, leading to excellent transfers of chirality.[11] Therefore, allylic acetate **11** was treated at 25 °C with a catalytic amount of bis(acetonitrile)palladium (II) chloride (0.04 equiv) in dry tetrahydrofuran for 24 h. Workup provided a single, optically pure, rearranged allylic acetate **12**. The stereoisomeric and enantiomeric purities were determined by ^{1}H NMR spectroscopy at 250 MHz, the latter with the aid of the chiral lanthanide shift reagent [Eu(hfc)$_3$]; with a molar ratio Eu(hfc)$_3$/**12** = 0.4, the signal due to the acetoxy methyl group of the racemic compound was split into two singlets ($\Delta\delta$ = 8.5 Hz) while only one singlet could be observed in the same conditions for optically active **12**.[12] The shift of the equilibrium **11** ⇄ **12**, totally in favor of **12**, is certainly due to the conformational rigidity of the bicyclic system, which entails steric congestion around the acetoxy group of **11**.



11

When heated at 130 °C in xylene, acetate **12** extruded furan to give the *E,Z* conjugated diene **13** in excellent yield. Removal of the silyl protecting group with tetra-*n*-butylammonium fluoride led to sterically and optically pure (*S*)-6-acetoxy-2(*Z*),4(*E*)-undecadien-1 ol (**6**). The *S* absolute configuration of the asymmetric carbon followed from the mode of formation and was confirmed by oxydative degradation of **12** to the known (*S*)-(−)-2-acetoxyheptanal.[13]



Starting from the optically pure diastereoisomer **8**, the same reaction sequence afforded the enantiomer of **6** ((*R*)-6-acetoxy-2(*Z*),4(*E*)-undecadien-1-ol).

In conclusion, an efficient (seven steps from lactol **5**, 25–30% overall yield) and highly selective synthesis of (*R*)- or (*S*)-hydroxy *E,Z* conjugated dienes has been established via two successive transfers of chirality. The stereochemistry of the *Z* double bond was kept intact through the whole reactions sequence by protection as a Diels–Alder adduct with furan. Furthermore the properties (chelating ability and steric hindrance) of this protective group were used to induce the stereoselective reactions necessary for complete transfers of chirality.

Experimental Section

General. Tetrahydrofuran (THF) was distilled from sodium and benzophenone immediately prior to use. All reactions were carried out under an inert atmosphere of argon and were monitored by thin-layer chromatography (TLC). TLC was performed on Merck silica gel 60F-254 precoated on glass. Mass spectra were obtained with a GC/MS R10-10 spectrometer. ^{1}H NMR spectra were recorded in $CDCl_3$ (250 MHz). Optical rotations were measured in a 1-dm cell.

(1*R*,2*R*,3*R*,4*S*,1′*R*)-3-*exo*-(1′-Hydroxy-2′-octyn-1′-yl)-7-oxabicyclo[2.2.1]hept-5-ene-2-*exo*-methanol (7). To a stirred solution of 1-heptynylmagnesium bromide (40 mmol) in THF (40 mL) was added at 0 °C a solution of lactol **5** (924 mg, 6 mmol) in THF (20 mL). The reaction mixture was allowed to reach room temperature and was stirred for 1 h. The solution was hydrolyzed with a saturated ammonium chloride solution (60 mL), the organic layer was separated, and the aqueous solution was extracted with CH_2Cl_2 (3 × 50 mL). The combined organic layers were dried over magnesium sulfate and concentrated in vacuo, and the residue was purified by flash chromatography (ether) to afford 878 mg (59%) of pure **7** as an oil and 410 mg (28%) of a mixture of **7** and **8**. The spectral data for **7** follow. $[\alpha]^{20}_D$ −36° ($CHCl_3$, *c* 1). IR (film): 3380, 3080, 1110, 1025 cm^{-1}. CIMS (NH_3) *m/e* (relative intensity): 268 (MNH_4^+, 45), 251 (MH^+, 22), 250 (M^+, 21), 182 (100). ^{1}H NMR: δ 0.91 (3 H, br t, CH_3), 1.2–1.4 (4 H, m, $(CH_2)_2CH_3$), 1.4–1.55 (2 H, m, $\equiv CCH_2CH_2$), 1.8–2 (2 H, m, $\equiv CCH_2$), 2.1–2.2 (2 H, m, H-2, H-3), 3.55 (2 H, br s, O*H*), 3.7 (1 H, dd, *J* = 10.8 and 7.6 Hz, CH_2OH), 4.05 (1 H, dd, *J* = 10.8 and 4.8 Hz, CH_2OH), 4.4 (1 H, d, *J* = 5.5 Hz, C*H*OH), 4.9 (1 H, s, H-1), 5.1 (1 H, s, H-4), 6.4 (2 H, m, C*H*=C*H*). Anal. Calcd for $C_{15}H_{22}O_3$: C, 72.00; H, 8.80. Found: C, 71.93; H, 8.81.

(1*R*,2*R*,3*R*,4*S*,1′*S*)-3-*exo*-(1′-Hydroxy-2′-octyn-1′-yl)-7-oxabicyclo[2.2.1]hept-5-ene-2-*exo*-methanol (8). To a stirred solution of 1-heptynyllithium (17.25 mmol) generated from heptyne (2.25 mL, 17.25 mmol) in THF (15 mL) and *n*-BuLi (1.6 M) in hexane (10.8 mL, 17.25 mmol), was added at −78 °C a solution of chlorotitanium triisopropoxide (4.1 mL, 17.25 mmol) in THF (10 mL). The solution was allowed to warm to 0 °C and then was added to 525 mg (3.43 mmol) of lactol **5** in THF (10 mL). The resulting mixture was stirred at 0 °C for 1 h, and the reaction was quenched by the addition of 10% aqueous HCl (30 mL). After separation of the organic layer, the aqueous phase was extracted with CH_2Cl_2 (3 × 30 mL). The combined organic extracts were dried over anhydrous magnesium sulfate, and the solvent was removed at reduced pressure. Flash chromatography of the residue (ether) afforded 274 mg (32%) of a mixture of **7** and **8** and 248 mg (29%) of pure **8** as an oil: $[\alpha]^{20}_D$ −25° ($CHCl_3$, *c* 0.5). ^{1}H NMR: δ 0.9 (3 H, br t, CH_3), 1.2–1.45 (4 H, m, $(CH_2)_2CH_3$), 1.45–1.6 (2 H, m, $\equiv CCH_2CH_2$), 1.9–2.05 (2 H, m, $\equiv CCH_2$), 2.25 (2 H, m, H-2, H-3), 2.9 (2 H, br s, O*H*), 3.9 (2 H, m, CH_2OH), 4.55 (1 H, d, *J* = 9.8 Hz, C*H*OH), 4.65 (1 H, s, H-1), 5.0 (1 H, s, H-4), 6.45 (2 H, m, C*H*=C*H*).

(1*R*,2*R*,3*S*,4*S*,1′*S*)-3-*exo*-(1′-Hydroxy-2′(*E*)-octen-1′-yl)-7-oxabicyclo[2.2.1]hept-5-ene-2-*exo*-methanol (9). A solution of sodium bis(methoxyethoxy)aluminum hydride (3.4 M) in toluene (1.25 mL, 4.25 mmol) was diluted with ether (15 mL). To this cooled (0 °C) solution was added dropwise a solution of propargylic diol **7** (648 mg, 2.6 mmol) in ether (15 mL). The solution was warmed to 20 °C and stirred overnight. The reaction mixture was again cooled to 0 °C, cautiously quenched with H_2O (20 mL), and extracted with ether (3 × 50 mL). The combined organic phases were dried over magnesium sulfate, the solvent was removed, and the residue was purified by chromatography on silica gel (ether) to afford 552 mg (84%) of (*E*)-allylic diol **9** as a colorless oil: $[\alpha]^{20}_D$ −18.5° ($CHCl_3$, *c* 1). IR (film): 3380, 1670, 1100, 1025, 900 cm^{-1}. CIMS (NH_3) *m/e* (relative intensity): 270 (MNH_4^+, 22), 252 (M^+, 14), 184 (42), 167 (100). ^{1}H NMR: δ 0.85 (3 H, br t, CH_3), 1.2–1.45 (6 H, m, $(CH_2)_3CH_3$), 1.7–1.8 (2 H, m, H-2 and H-3), 1.95–2.05 (2 H, m, $=CCH_2$), 2.45 (2 H, br s, O*H*), 3.8 (1 H, dd, *J* = 10.8 and 7.2 Hz, CH_2OH), 3.9 (1 H, dd, *J* = 10.8 and 4.7 Hz, CH_2OH), 4.25 (1 H, dd, *J* = 6.5 and 5.3 Hz, C*H*OH), 4.85 (1 H, s, H-1), 4.95 (1 H, s, H-4), 5.5 (1 H, dd, *J* = 15.3 and 6.7 Hz, CHOHC*H*=), 5.7 (1 H, dt, *J* = 15.3 and 7.1 Hz, CHOHCH=C*H*), 6.45 (2 H, m, C*H*=C*H*). Anal. Calcd for $C_{15}H_{24}O_3$: C, 71.38; H, 9.59. Found: C, 71.22; H, 9.53.

(1*R*,2*R*,3*S*,4*S*,1′*S*)-3-*exo*-[[(*tert*-Butyldiphenylsilyl)oxy]methyl]-α-(1(*E*)-heptenyl)-7-oxabicyclo[2.2.1]hept-5-ene-2-*exo*-methanol (10). A solution of the diol **9** (530 mg, 2.1 mmol), *tert*-butylchlorodiphenylsilane (2 equiv, 1 mL), and imidazole (2.5 equiv, 0.357 g) in dry DMF (10 mL) was stirred at room temperature for 0.5 h. Water (20 mL) was added, and the resulting mixture was extracted with ether (3 × 20 mL). The combined ether extracts were washed with brine (30 mL) and dried

(10) For a review see: Overman, L. E. *Angew. Chem., Int. Ed. Engl.* **1984**, *23*, 579.

(11) (a) Grieco, P. A.; Takigawa, T.; Bongers, S. L.; Tanaka, H. *J. Am. Chem. Soc.* **1980**, *102*, 7588. (b) Grieco, P. A.; Tuthill, P. A.; Sham, H. L. *J. Org. Chem.* **1981**, *46*, 5005. (c) Takatsuto, S.; Ishiguro, M.; Ikekawa, N. *J. Chem. Soc., Chem. Commun.* **1982**, 258.

(12) The optical purities (ee ≥95%) of compounds **11**, **13**, **6**, and **6′** have been checked with the aid of the same chiral shift reagent: Eu(hfc)$_3$.

(13) Noyori, R.; Tomino, I.; Yamada, M.; Nishizawa, M. *J. Am. Chem. Soc.* **1984**, *106*, 6717.

over anhydrous magnesium sulfate. Removal of solvent in vacuo and purification by column chromatography (60:40 ether–hexane) gave the pure silyl ether **10** as a colorless oil: 0.835 g (81%). $[\alpha]^{20}_D$ −15° ($CHCl_3$, *c* 0.5). IR (film): 3380, 1120 cm^{-1}. CIMS (NH_3) *m/e* (relative intensity): 490 (M^+, 2), 405 (16), 218 (18), 217 (100). ^1H NMR: δ 0.85 (3 H, br t, CH_3), 1.05 (9 H, s, tBu), 1.25–1.4 (6 H, m, $(CH_2)_3CH_3$), 1.75 (1 H, dd, *J* = 6.7 and 4.5 Hz, H-3), 1.85–2 (3 H, m, H-2 and CH_2CH=), 2.6 (1 H, br s, O*H*), 3.8 (1 H, t, *J* = 9 Hz, CH_2OSi), 3.95 (1 H, dd, *J* = 9 and 4.5 Hz, CH_2OSi), 4.1 (1 H, m, C*H*OH), 5.0 (1 H, s, H-1), 5.05 (1 H, s, H-4), 5.45 (1 H, dd, *J* = 15 and 6 Hz, CHOHC*H*=), 5.55 (1 H, dt, *J* = 15 and 7 Hz, =C*H*CH_2), 6.35 (2 H, m, C*H*=C*H*), 7.4–7.75 (10 H, m, Ph). Anal. Calcd for $C_{31}H_{42}O_3Si$: C, 75.86; H, 8.63. Found: C, 75.95; H, 8.87.

(1*R*,2*R*,3*S*,4*S*,1′*S*)-2-*exo*-[(*tert*-Butyldiphenylsilyl)oxy]-3-*exo*-(1′-acetoxy-2′(*E*)-octen-11′-yl)-7-oxabicyclo[2.2.1]hept-5-ene (11). To a solution of the alcohol **10** (802 mg, 1.63 mmol) in dichloromethane (30 mL) were added successively acetic anhydride (1.5 equiv, 0.23 mL), triethylamine (1.5 equiv, 0.34 mL), and (dimethylamino)pyridine (0.08 equiv, 16 mg). The resulting mixture was stirred for 3 h at room temperature, and 10% aqueous hydrochloric acid (30 mL) was added. The organic layer was separated, and the aqueous solution was extracted with ether (3 × 50 mL). The combined organic extracts were washed with aqueous sodium bicarbonate (50 mL) and water (50 mL) and dried over anhydrous magnesium sulfate, and the solvent was removed at reduced pressure. Chromatography of the residue on silica gel (20:80 ether–hexane) gave the acetate **11** as an oil: 835 mg (96%); $[\alpha]^{20}_D$ +12.5° ($CHCl_3$, *c* 1). IR (film): 1745, 1230, 1025 cm^{-1}. CIMS (NH_3) *m/e* (relative intensity): 550 (MNH_4^+, 100), 405 (42), 241 (65), 217 (97). ^1H NMR: δ 0.8 (3 H, br t, CH_3), 1.05 (9 H, s, t-Bu), 1.05–1.2 (6 H, m, $(CH_2)_3CH_3$), 1.65–1.8 (2 H, m, H-2 and H-3), 1.8–1.9 (2 H, m, CH_2C=), 1.95 (3 H, s, CH_3CO), 3.6 (1 H, m, CH_2OSi), 3.95 (1 H, dd, *J* = 10.6 and 4.3 Hz, CH_2OSi), 4.75 (1 H, s, H-1), 5.05 (1 H, t, *J* = 6.7 Hz, C*H*OAc), 5.22 (1 H, s, H-4), 5.25 (1 H, dd, *J* = 15.7 and 6.7 Hz, =C*H*CHOAc), 5.55 (1 H, dt, *J* = 15.7 and 6.5 Hz, =C*H*CH_2), 6.4 (2 H, s, C*H*=C*H*), 7.3–7.7 (10 H, m, Ph). Anal. Calcd for $C_{33}H_{44}O_4Si$: C, 74.38; H, 8.33. Found: C, 74.33; H, 8.26.

(1*R*,2*R*,3*R*,4*S*,3′*S*)-2-*exo*-[(*tert*-Butyldiphenylsilyl)oxy]-3-*exo*-(3′-acetoxy-1′(*E*)-octen-1′-yl)-7-oxabicyclo[2.2.1]hept-5-ene (12). To a solution of acetate **11** (342 mg, 0.64 mmol) in dry THF (10 mL) was added 8 mg (0.05 equiv) of bis(acetonitrile)palladium(II) chloride. The mixture was stirred at room temperature for 24 h and then was diluted with ether (10 mL) and washed with brine (10 mL). The aqueous phase was extracted with ether (2 × 10 mL), and the combined organic extracts were dried over magnesium sulfate. Evaporation of the solvent in vacuo left 360 mg of a crude, which was chromatographed on 10 g of silica gel. Elution with hexane–ether (80:20) gave 302 mg (88%) of rearranged acetate **12** as an oil: $[\alpha]^{20}_D$ −39.5° ($CHCl_3$, *c* 1). IR (film): 1745, 1240, 1115, 1010 cm^{-1}. CIMS (NH_3) *m/e* (relative intensity): 550 (MNH_4^+, 100), 405 (22), 241 (23), 217 (43). ^1H NMR: δ 0.8 (3 H, br t, CH_3), 1.05 (9 H, s, t-Bu), 1.05–1.4 (8 H, m, $(CH_2)_4CH_3$), 1.85 (1 H, m, H-2), 1.95 (3 H, s, CH_3CO), 2.25 (1 H, dd, *J* = 8 and 8.5 Hz, H-3), 3.5 (1 H, t, *J* = 10.3 Hz, CH_2OSi), 3.6 (1 H, dd, *J* = 10.3 and 4.3 Hz, CH_2OSi), 4.6 (1 H, s, H-1), 5.03 (1 H, m, C*H*OAc), 5.05 (1 H, s, H-4), 5.4 (2 H, m, H-1′, H-2′), 6.35 (2 H, m, C*H*=C*H*), 7.3–7.7 (10 H, m, Ph). Anal. Calcd for $C_{33}H_{44}O_4Si$: C, 74.38; H, 8.33. Found: C, 74.11; H, 8.40.

1-[(*tert*-Butyldiphenylsilyl)oxy]-6(*S*)-acetoxy-2(*Z*),4(*E*)-undecadiene (13). A solution of acetate **12** (226 mg, 0.42 mmol) in xylene (10 mL) was heated at 130 °C for 3 h. The solvent was removed in vacuo, and the residue was purified by flash chromatography (hexane–ether, 90:10) to give 168 mg (85%) of the diene **13** as an oil: $[\alpha]^{20}_D$ −8.9° ($CHCl_3$, *c* 0.5). IR (film): 1745, 1600, 1240, 1110 cm^{-1}. CIMS (NH_3) *m/e* (relative intensity): 482 (MNH_4^+, 49), 465 (MH^+, 4), 422 (80), 406 (63), 405 (100). ^1H NMR: δ 0.8 (3 H, br t, CH_3), 1.05 (9 H, s, t-Bu), 1.15–1.75 (8 H, m, $(CH_2)_4CH_3$), 1.95 (3 H, s, CH_3CO), 4.35 (2 H, d, *J* = 6.7 Hz, CH_2OSi), 5.2 (1 H, m, C*H*OAc), 5.5 (1 H, dd, *J* = 15.4 and 7.2 Hz, =C*H*CHOAc), 5.6 (1 H, dt, *J* = 11.3 and 6.7 Hz, =C*H*CH_2OSi), 5.95 (1 H, dd, *J* = 11.3 and 10.8 Hz, C*H*=$CHCH_2OSi$), 6.25 (1 H, dd, *J* = 15.4 and 10.8 Hz, C*H*=CHCHOAc), 7.3–7.7 (10 H, m, Ph). Anal. Calcd for $C_{29}H_{40}O_3Si$: C, 74.94; H, 8.68. Found: C, 74.64; H, 8.89.

6(*S*)-Acetoxy-2(*Z*),4(*E*)-undecadien-1-ol (6). To a stirred solution of diene **13** (107 mg, 0.23 mmol) in dry THF (1.5 mL) was added a 1 M solution of tetra-*n*-butylammonium fluoride in THF (0.345 mL, 1.5 equiv). The mixture was stirred for 1 h at room temperature, the solvent was removed in vacuo, and ether (5 mL) and water (5 mL) were added to the residue. The organic layer was separated, and the aqueous phase was extracted with ether (3 × 5 mL). The combined organic extracts were dried over magnesium sulfate and concentrated in vacuo. The residue was purified by chromatography on 10 g of silica gel (ether–hexane, 70:30) to afford 47 mg (90%) of dienol **6** as a liquid: $[\alpha]^{20}_D$ −16.7° ($CHCl_3$, *c* 0.5). IR (film): 3410, 1740, 1240 cm^{-1}. CIMS (NH_3) *m/e* (relative intensity): 244 (MNH_4^+, 5), 184 (88), 167 (100). ^1H NMR: δ 0.8 (3 H, br t, CH_3), 1.2–1.4 (8 H, m, $(CH_2)_4CH_3$), 1.6 (1 H, br s, O*H*), 2.0 (3 H, s, CH_3CO), 4.35 (2 H, d, *J* = 7.3 Hz, CH_2OH), 5.25 (1 H, m, C*H*OAc), 5.62 (1 H, dt, *J* = 11 and 7.3 Hz, =C*H*CH_2OH), 5.68 (1 H, dd, *J* = 14.6 and 6.7 Hz, =C*H*CHOAc), 6.05 (1 H, dd, *J* = 11 and 11.5 Hz, C*H*=CHCH_2OH), 6.5 (1 H, dd, *J* = 14.6 and 11.5 Hz, C*H*=CHCHOAc). Anal. Calcd for $C_{13}H_{22}O_3$: C, 68.98; H, 9.80. Found: C, 68.80; H, 9.63.

6(*R*)-Acetoxy-2(*Z*),4(*E*)-undecadien-1-ol. Starting from the diol **8**, the same sequence of reactions, as above, led to the enantiomer of dienol **6**. $[\alpha]^{20}_D$ +15.4° ($CHCl_3$, *c* 0.4).

Oxidative Degradation of 12. A cooled (−78 °C) solution of ozone in dichloromethane (0.04 M, 4 mL, 0.16 mmol) was added to a solution of **12** (21 mg, 0.04 mmol) in dichloromethane (5 mL) at −78 °C, and the resulting mixture was stirred for 1 h at −78 °C. Dimethyl sulfide (0.036 mL, 0.4 mmol) was added, and the mixture was allowed to warm to room temperature and was stirred overnight. The solvent was removed in vacuo, and the residue was purified by chromatography on silica gel (hexane–ether, 60:40) to give 4.5 mg (65%) of (*S*)-2-acetoxyheptanal, $[\alpha]^{20}_D$ −40.5° ($CHCl_3$, *c* 0.2) [lit.[13] $[\alpha]^{20}_D$ −37.8° ($CHCl_3$, *c* 0.5)].