group participation by silicon is not involved, at least for the 6,6-bis-TMS derivative (3).[3] The results are consistent with a specially favorable electronic effect for the 6-*exo*-TMS substituent in a *W* conformation, although an additional steric effect reducing the reactivity of the 6-*endo*-TMS compound (2) cannot be excluded. A wider range of solvolytic reactivity is now accessible by convenient syntheses from alcohols of very reactive mesylates. Kinetic data obtained by rapid-injection kinetic methods provide an alternative to conventional kinetic studies of substrates having less reactive leaving groups (e.g. trifluoroacetates[2,22,28] and *p*-nitrobenzoates[3]).

Experimental Section

Syntheses of starting materials and product studies are reported in detail elsewhere.[3] The unstable mesylates were prepared from the corresponding alcohols (ca. 10 mg), dissolved in dry dichloromethane (200–400 μL) at −10 °C; triethylamine (2.5 equiv) was then injected, followed by portionwise addition of methanesulfonyl chloride (0.9 equiv) with magnetic stirring.[6] (In a parallel experiment the reaction leading to 1 was shown by NMR to be rapid in $CDCl_3$ at −10 °C.) After 10 min, aliquots (50 μL) of solvent were evaporated under reduced pressure at −10 °C, and the remaining solid was partially dissolved in cold acetonitrile (50 μL). Most of this solution was transferred to a cold syringe (using a glass wool plug to avoid the transfer of solid materials), and rapid injection kinetic studies could then be performed as described previously.[7] Other conductimetric kinetic studies were carried out by standard methods.[12] Kinetic studies by HPLC (in sealed 1-mL ampoules) required no internal standard or additional calculations,[29] because of the highly reproducible (±1%) injection volumes possible with an autosampler (Perkin Elmer ISS 101).

Acknowledgment. This paper is dedicated to Professor Paul Schleyer on the occasion of his 60th birthday. We are also grateful to Y. Apeloig and D. Lenoir for helpful comments and to the SERC (U.K.) for financial support toward the purchase of equipment.

Registry No. 1 (X = mesylate), 124717-77-7; 1 (X = *p*-nitrobenzoate), 124816-93-9; 2 (X = mesylate), 124816-92-8; 2 (X = *p*-nitrobenzoate), 124717-79-9; 3 (X = mesylate), 124717-78-8; 3 (X = *p*-nitrobenzoate), 120852-95-1; 4 (X = mesylate), 16427-41-1; 5 (X = mesylate), 25236-60-6; 6 (X = mesylate), 28627-77-2; 6 (X = *p*-nitrobenzoate), 10472-43-2; 7 (X = mesylate), 28627-78-3; 7 (X = brosylate), 840-89-1; 8 (X = mesylate), 124816-94-0; 8 (X = brosylate), 124098-88-0; 9 (X = brosylate), 124152-00-7; 10 (X = brosylate), 124098-91-5.

(29) Bentley, T. W.; Gream, G. E. *J. Org. Chem.* **1985**, *50*, 1776.

Synthesis of Polypropionate Subunits by S_N2' Addition of Cuprates to Nonracemic Acyclic Vinyloxiranes

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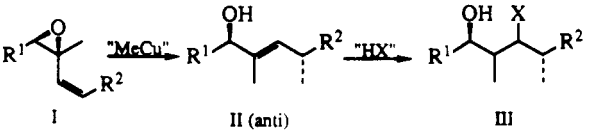
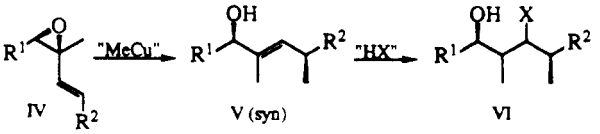
Synthetic sequences have been devised for conversion of the chiral pool ester 1 to differentially protected polypropionate subunit polyols 11, 13, 18, and 20. The following stereochemically significant steps were employed: (1) reagent directed Sharpless epoxidation of allylic alcohol 4 (75:25); (2) substrate directed anti S_N2' addition of MeCu(CN)Li to vinyloxirane 8 (>95:5); (3) substrate directed homogeneous hydrogenation of homoallylic alcohol 10 (94:6); (4) substrate directed hydroboration of allylic alcohol 14 (88:12). The stereochemistry of alcohol 13 was confirmed through conversion to lactone 27 an intermediate in Suzuki's synthesis of protomycinolide.

Within the past decade considerable effort has been devoted to the development of methodology for the synthesis of carbon chains with alternating methyl and hydroxyl substituents.[1] The driving force for these activities comes from the vast array of biologically and medicinally important polypropionate or polyketide natural products such as macrolides and polyether antibiotics.[2] In recent years we have been developing a new approach to such compounds employing highly stereoselective S_N2' additions of methyl cuprates to nonracemic vinyloxiranes such as I and IV to afford 1,4-anti and syn intermediates such as II and V (eq 1 and 2).[3]



I II (anti) III (1)



IV V (syn) VI (2)

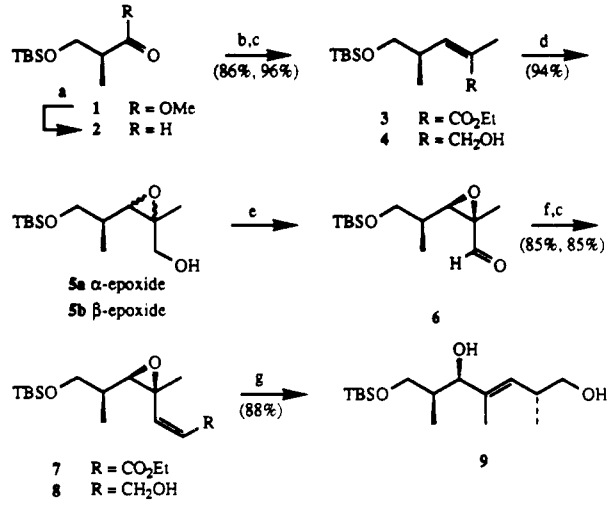
These allylic alcohol intermediates should be transformable to a variety of potential polypropionate subunits III and VI (X = H or OH) by precedented contemporary methodology. The present report describes the successful application of this strategy to differentially protected 1,4-anti arrays such as III. One important aspect of these applications is the ability to prepare α,ω-diols protected at either terminus, thereby permitting a high degree of flexibility in subsequent chain elongation protocols.

The starting material for these studies, ester 1, was prepared from (*S*)-(+)-methyl 3-hydroxy-2-methylpropionate.[4] The derived aldehyde 2, upon condensation with Still's trifluoroethyl phosphonopropionate Horner–Emmons reagent, afforded the *Z* conjugated ester 3[5]

(1) For a recent review, see: Hoffmann, R. W. *Angew. Chem., Int. Ed. Engl.* **1987**, *26*, 489.
(2) Masamune, S. *Aldrichimica Acta* **1978**, *11*, 23.
(3) Marshall, J. A.; Trometer, J. D.; Blough, B. E.; Crute, T. D. *J. Org. Chem.* **1988**, *53*, 4274.
(4) Aldrich Chemical Co. Inc., Milwaukee, WI.
(5) Still, W. C.; Gennari, C. *Tetrahedron Lett.* **1983**, *24*, 4405.

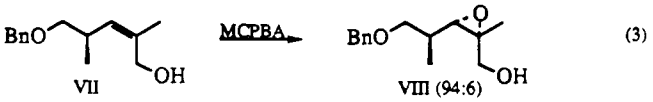
0022-3263/90/1955-1540$02.50/0

Scheme I[a]



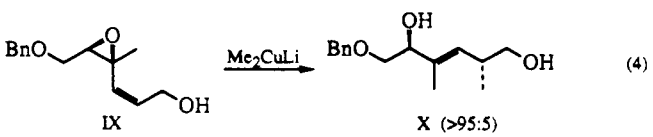
[a] (a) DIBAH, CH_2Cl_2, −78 °C; $(COCl)_2$, DMSO, Et_3N, CH_2Cl_2, −78 °C; (b) $(CF_3CH_2O)_2POCH(Me)CO_2Et$, KHMDS, THF, 18-C-6, −78 °C; (c) DIBAH, CH_2Cl_2, −78 °C; (d) L-(+)-DET, $Ti(O\text{-}iPr)_4$, t-BuOOH, CH_2Cl_2, −12 °C; (e) $(COCl)_2$, DMSO, Et_3N, CH_2Cl_2, −78 °C; (f) $(CF_3CH_2O)_2POCH_2CO_2Et$, KHMDS, THF, 18-C-6, −78 °C; (g) MeCu(CN)Li, Et_2O, −23 °C to 0 °C.

(Scheme I). This was reduced to the allylic alcohol **4** with DIBAH.[6] Epoxidation of allylic alcohol **4** with the Sharpless L-(+)-DET[6] reagent yielded a 75:25 mixture of readily separable diastereoisomers **5b** and **5a**.[7] The initial assignment of stereochemistry was based on the expected reagent directed epoxidation preference. In support of this assignment, epoxidation of allylic alcohol **4** with MCPBA[6] afforded the same two epoxides as a 90:10 mixture favoring **5a**. This latter result closely parallels Kishi's finding with allylic alcohol VII (eq 3).[8] Alcohol **5b** was found to have an enantiomeric excess greater than 95% through ^1H NMR analysis of the *O*-methyl mandelate derivative.



(3)

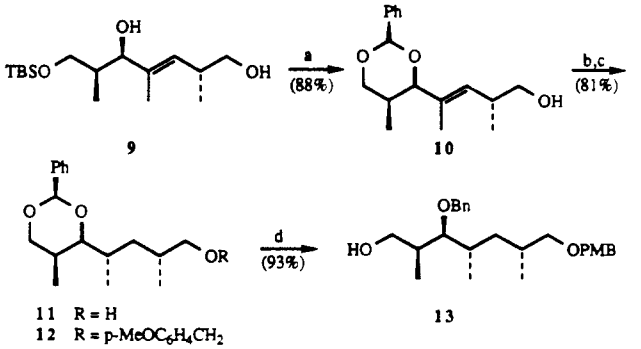
Swern oxidation[9] of the β-epoxy alcohol **5b** followed by Still–Horner–Emmons condensation[5] and reduction led to the *cis*-(*Z*)-vinyloxirane **8** as the sole detectable isomer. Upon treatment with MeCu(CN)Li in ether at −23 °C epoxide **8** underwent a highly selective S_N2' displacement leading to the diol **9** in 88% yield. The steric course of this step follows from the close analogy shown in eq 4.[3]



(4)

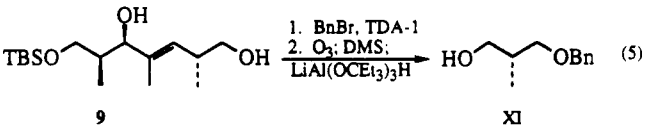
Additional evidence for the stereochemistry of diol **9** was

Scheme II[a]



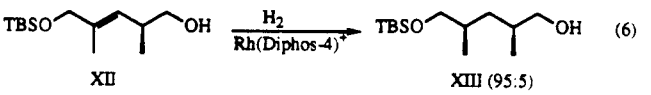
[a] (a) PPTS, EtOH; remove EtOH; C_6H_5CHO, PPTS, CH_2Cl_2; (b) H_2, [Rh(NBD)Diphos-4]$^+$ BF_4^-, CH_2Cl_2; (c) p-$MeOC_6H_4CH_2Cl$, NaH, DMF; (d) DIBAH (hexanes), CH_2Cl_2, room temperature.

obtained through ozonolysis of the benzyl ether derivative to the known alcohol XI, $[\alpha]_D$ +17.2° (eq 5).[10] The optical rotation of XI exactly matched the reported value. Thus, the S_N2' displacement proceeds with essentially complete anti diastereoselectivity.



(5)

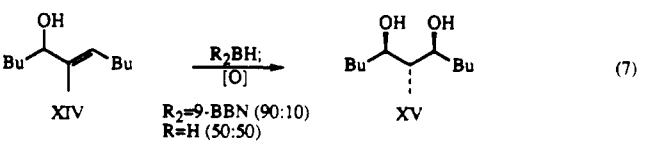
Evans has examined stereoselective hydroxyl-directed homogeneous hydrogenations with Rh(I) and Ir(I) catalysts.[11] Homoallylic alcohols such as XII were found to be excellent substrates (eq 6). Application of this meth-



(6)

odology to diol **9** led to a mixture of products and recovered starting material. Suspecting interference by the allylic OH grouping, we converted diol **9** to the benzylidene derivative **10** as shown in Scheme II. Evans hydrogenation of **10** proceeded smoothly, affording a separable 94:6 mixture of diastereoisomers presumed to favor **11** by analogy with the example shown in eq 6.[11] Alcohol **11** was converted to the differentially protected triol **13** through p-methoxybenzylation[12] followed by selective hydrogenolysis of the benzylidene acetal with DIBAH.[13] Alcohols **11** and **13** are potentially useful intermediates for macrolide synthesis.

Allylic alcohols such as XIV have been found to undergo selective hydroboration with hindered boranes to the anti products XV.[14] It was of interest to examine the hydroboration of allylic alcohol **9** as a possible route to differ-



(7)

(6) Abbreviations: 9-BBN = 9-borabicyclo[3.3.1]nonane; DBU = 1,8-diazabicyclo[5.4.0]undec-7-ene; DDQ = 2,3-dichloro-5,6-dicyano-1,4-benzoquinone; DET = diethyl tartrate; DIBAH = $(i\text{-Bu})_2AlH$; DIPHOS-4 = $Ph_2P(CH_2)_4PPh_2$; DMF = Me_2NCHO; DMS = Me_2S; DMSO = Me_2SO; KHMDS = $KN(SiMe_3)_2$; MCPBA = m-$ClC_6H_4CO_3H$; NBD = norboradiene; PDC = pyridinium dichromate; PMB = p-$MeOC_6H_4CH_2$; PMP = p-$MeOC_6H_4$; PPTS = pyridinium p-toluenesulfonate; TDA-1 = $(MeOCH_2CH_2OCH_2CH_2)_3N$.

(7) Cf.: Hanson, R. M.; Sharpless, K. B. *J. Org. Chem.* **1986**, *51*, 1922.

(8) Johnson, M. R.; Nakatu, T.; Kishi, Y. *Tetrahedron Lett.* **1979**, 4343. Johnson, M. R.; Kishi, Y. *Tetrahedron Lett.* **1979**, 4347.

(9) Omucka, K.; Swern, D. *Tetrahedron* **1978**, 1651. Mancuso, A. J.; Swern, D. *Synthesis* **1981**, 165.

(10) Nagaoka, H.; Kishi, Y. *Tetrahedron* **1981**, *37*, 3873.

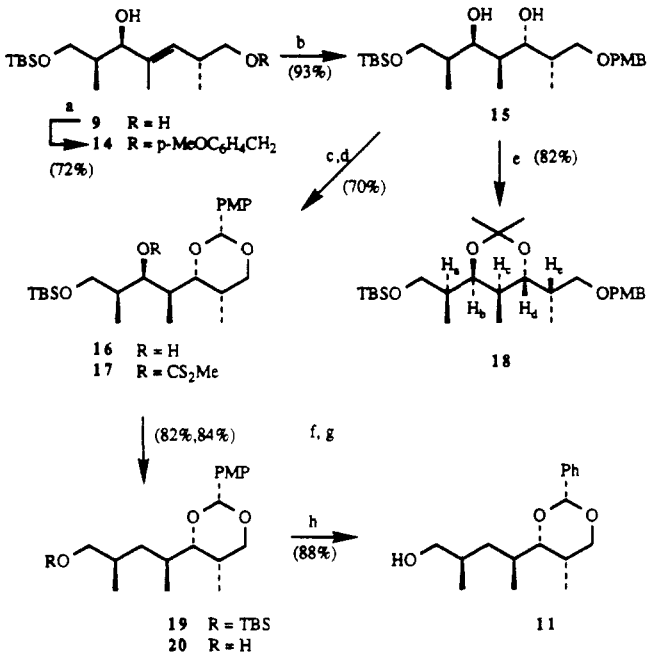
(11) Evans, D. A.; Morrissey, M. M. *J. Am. Chem. Soc.* **1984**, *106*, 3866. Evans, D. A.; Morrissey, M. M.; Dow, R. L. *Tetrahedron Lett.* **1985**, *26*, 6005.

(12) Cf.: Horita, K.; Yoshioka, T.; Tanaka, T.; Oikawa, Y.; Yonemitsu, O. *Tetrahedron* **1986**, *42*, 3021.

(13) Cf.: Takano, S.; Kurotaki, A.; Sekiguchi, Y.; Satoh, S.; Hiramo, M.; Ogasawara K. *Synthesis* **1986**, 811. Schreiber, S. L.; Wang, Z. *Tetrahedron Lett.* **1988**, *29*, 4085.

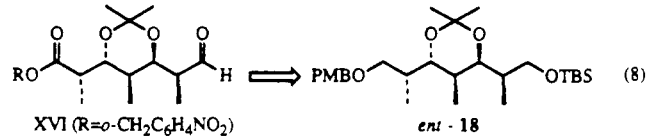
(14) Still, W. C.; Barrish, J. C. *J. Am. Chem. Soc.* **1983**, *105*, 2487.

Scheme III[a]



[a] (a) *p*-$MeOC_6H_4CH_2Cl$, TDA-1, KOH, CH_2Cl_2; (b) BH_3·DMS, THF, 0 °C to room temperature; NaOH, H_2O_2, THF, reflux; (c) DDQ, CH_2Cl_2, room temperature; (d) CS_2, DBU, THF, reflux; CH_3I; (e) $(Me)_2C(OMe)_2$, PPTS; (f) Bu_3SnH, AIBN, PhH, reflux; (g) TBAF, THF 0 °C; (h) 5% Pd/C, H_2, EtOH; C_6H_5CHO, PPTS, CH_2Cl_2.

entially protected tetrol subunits of macrolides. In order to facilitate product isolation, and to avoid possible interference by the homoallylic hydroxyl substituent, diol **9** was converted to the PMB[6] ether **14** prior to hydroboration (Scheme III).[12] Reaction with 9-BBN[6] was slow and led to a complex mixture of products. However, BH_3·DMS cleanly added to allylic alcohol **14** giving a 8:1 separable mixture of diol isomers after oxidation. The methine protons H_b, H_c, and H_d of the acetonide derivative **18** showed coupling of 7.3 and 4.9 Hz in accord with the indicated structure.[15] The anti isomer analogous to XV would expectedly show diaxial coupling for these protons.[16] Thus, the hydroboration of **14** is appreciably more stereoselective than that of XIV. Evidently the additional stereocenters present in allylic alcohol **14** impose a significant steric bias on double bond additions. Acetonide **18** possesses the relative stereochemistry of XVI, an intermediate in Evan's synthesis of premonensin (eq 8).[18]



(8)

Additional support for the stereochemistry of **15** was secured by direct correlation with alcohol **11**. Thus, upon treatment with DDQ[6] alcohol **15** yielded the *p*-methoxybenzylidene derivative **16**.[19] The derived xanthate **17** underwent free-radical hydrogenolysis with Bu_3SnH to the protected triol **19**.[20] Deprotection with PPTS[6] in ethanol followed by addition of benzaldehyde, without isolation of the intermediate triol, gave alcohol **11** identical with the material prepared by hydrogenation (Scheme II).

Final confirmation of stereochemistry for these intermediates was obtained through conversion of alcohol **13** to lactone **28** (Scheme IV), an intermediate in Suzuki's synthesis of protomycinolide.[21] Homologation of **13** by the Swern–Wittig–DIBAH[22] sequence afforded the (*E*)-allylic alcohol **23**. The derived benzyl ether **24** was selectively deprotected by treatment with DDQ[6] in aqueous methylene chloride. PDC[6] oxidation[23] of the resulting alcohol **25** yielded the carboxylic acid **26**. Subsequent debenzylation by Na–NH_3 and acidification led to the lactone **27**. The identity of this material was confirmed through comparison of spectra and optical rotation with authentic material.

In summary, we have demonstrated that nonracemic allylic alcohols, prepared efficiently and in high purity from vinyloxiranes, are suitable intermediates for the synthesis of differentially protected triol and tetrol subunits of macrolides.

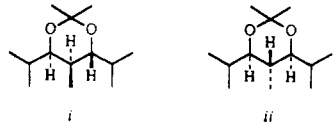
Experimental Section

(*Z*)-(4*R*)-Ethyl 5-[(*tert*-Butyldimethylsilyl)oxy]-2,4-dimethyl-2-pentenoate (3). To a solution of 10.0 g (43.0 mmol) of ester **1** in 108 mL of dry methylene chloride under argon at −78 °C was added 216 mL (216 mmol) of 1.0 M diisobutylaluminum hydride in hexanes. The mixture was allowed to stir for 1 h, whereupon 10 mL of methanol was slowly added. The mixture was allowed to stir with 300 mL of saturated Rochelle's salt at room temperature until two distinct phases were apparent. The phases were separated, and the aqueous layer was extracted with methylene chloride. The combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The resulting oil was used directly to minimize 1,3 silyl transfer.

To a solution of 5.63 mL (64.5 mmol) of oxalyl chloride in 108 mL of dry methylene chloride under argon at −78 °C was added 9.2 mL (129 mmol) of dimethyl sulfoxide.[9] The mixture was allowed to stir for 20 min, and then 8.80 g (43.0 mmol) of crude alcohol in 20 mL of dry methylene chloride was added. After 1.5 h, the reaction was quenched with 30 mL (215 mmol) of triethylamine and warmed to 0 °C with stirring. The thick mixture was diluted with 50 mL of water, and the phases were separated. The organic phase was washed with water, dried over sodium sulfate, and concentrated under reduced pressure. The residue, aldehyde **2**, was used directly in the next step: IR (film) ν 2940, 2920, 2845, 1725, 1465, 1245, 1090, 830, 770 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 9.72 (d, 1 H, J = 1.6 Hz, aldehyde H), 3.84, 3.78 (AB of ABX, J_{AB} = 10.2 Hz, J_{AX} = 5.1 Hz, J_{BX} = 6.4 Hz, $CHCH_2$), 2.50 (m, 1 H, $CHCH_3$), 1.07 (d, 3 H, J = 7.1 Hz, $CHCH_3$), 0.86

(15) The coupling constants were obtained through 2D *J*-resolved analysis. Because of the symmetry of **15** it was not possible to distinguish H_b from H_d. We thank A. R. Garber and H. Cohen for assistance with this experiment.

(16) Molecular mechanics calculations were performed on the isopropyl analogues i and ii of acetonide **18** by means of the Multiconformer routine of Still's MacroModel program, Version 2.0.[17] The cis,trans isomer i was found to adopt a twist boat conformer in the four lowest energy structures (E = 45.1, 45.6, 48.4, and 53.8 kJ). The trans,trans isomer ii, on the other hand, showed a strong preference for the chair conformation (E = 31.3 and 41.4 kJ for the lowest energy structures).



i ii

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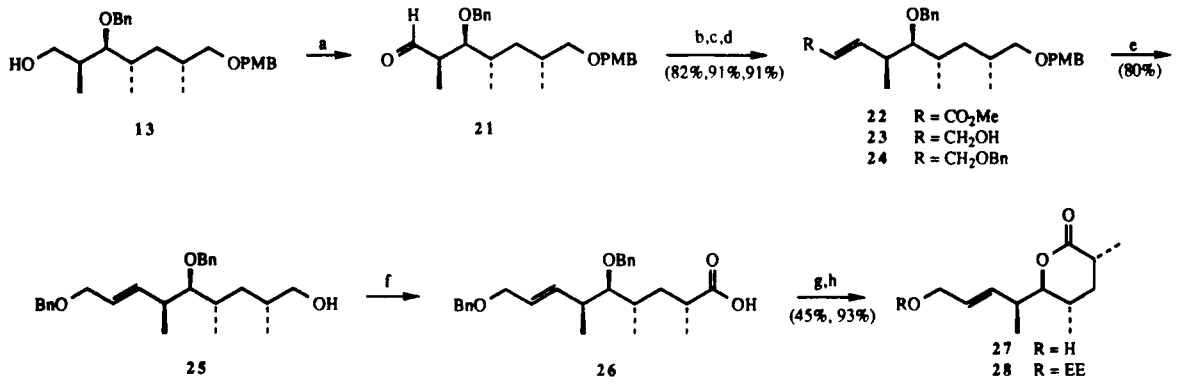
Scheme IV[a]



[a] (a) $(COCl)_2$, DMSO, Et_3N, CH_2Cl_2, −78 °C; (b) $Ph_3P{=}CHCO_2Me$, CH_2Cl_2; (c) DIBAH, CH_2Cl_2, −78 °C; (d) $PhCH_2Br$, TDA-1, KOH, CH_2Cl_2; (e) DDQ, 18:1 CH_2Cl_2–H_2O, room temperature; (f) PDC, DMF; (g) Na^0, NH_3, THF, −78 °C; 10% HCl; (h) $CH_2{=}CHOCH_2CH_3$, PPTS, CH_2Cl_2.

(s, 9 H, $SiC(CH_3)_3$), 0.03 (s, 6 H, $Si(CH_3)_2$).

To a solution of 16.3 g (47.0 mmol) of bis(2,2,2-trifluoroethyl)(methoxycarbonylethyl)phosphonate in 200 mL of dry tetrahydrofuran under argon at room temperature was added 25 g (98.0 mmol) of 18-crown-6.[5] The mixture was cooled to 0 °C, whereupon 95 mL (47.0 mmol) of 0.5 M potassium hexamethyldisilazide in toluene was added dropwise. The mixture was allowed to stir for 10 min and then cooled to −78 °C, and 8.71 g (43.0 mmol) of crude aldehyde **2** in 20 mL of dry tetrahydrofuran was added. The mixture was stirred for 0.5 h and then quenched with 150 mL of saturated ammonium chloride. After warming to room temperature the phases were separated, and the aqueous phase was extracted with ether. The combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel. Elution with 9:1 hexane–ether afforded 10.51 g (86%) of ester **3**: IR (film) ν 2970, 2940, 2870, 1710, 1465, 1260, 1230, 1095, 845 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 5.72 (d, 1 H, J = 9.7 Hz, vinyl H), 4.17 (q, 2 H, J = 7.1 Hz, CH_3CH_2O), 3.49, 3.43 (AB of ABX, J_{AB} = 9.7 Hz, J_{AX} = 5.9 Hz, J_{BX} = 6.0 Hz, $CHCH_2$), 3.25 (m, 1 H, $CHCH_2$), 1.88 (s, 3 H, vinyl CH_3), 1.28 (t, 3 H, J = 7.1 Hz, CH_3CH_2O), 0.98 (d, 3 H, J = 6.7 Hz, $CHCH_3$), 0.86 (s, 9 H, $SiC(CH_3)_3$), 0.005 (s, 6 H, $Si(CH_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.0, 144.9, 127.2, 67.5, 60.0, 36.2, 25.8 (3 C), 20.8, 18.3, 16.8, 14.2, −5.3, −5.4; $[\alpha]^{20}_D$ −23.9° (*c* 2.41, $CHCl_3$); HRMS calcd for $C_{14}H_{27}O_3Si$ (M − CH_3) 271.1729, found *m/e* 271.1722. Anal. Calcd for $C_{15}H_{30}O_3Si$: C, 62.89; H, 10.55. Found: C, 63.08; H, 10.59.

(*Z*)-(4*R*)-5-[(*tert*-Butyldimethylsilyl)oxy]-2,4-dimethyl-2-penten-1-ol (4). To a solution of 7.41 g (25.9 mmol) of ester **3** in 65 mL of dry methylene chloride under argon at −78 °C was added 65 mL (65 mmol) of 1.0 M DIBAH[6] in hexanes. The mixture was allowed to stir for 30 min, whereupon 10 mL of methanol and 200 mL of saturated Rochelle's salt was added at room temperature and stirring was continued until two distinct phases were apparent. The phases were separated, and the aqueous layer was extracted with methylene chloride. The combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The resulting oil was purified by flash chromatography on silica gel. Elution with 1:1 hexane–ether afforded 6.04 g (96%) of allylic alcohol **4**: IR (film) ν 3310, 2945, 2850, 1450, 1250, 1080, 1005, 830, 770 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 4.98 (d, 1 H, J = 9.9 Hz, vinyl H), 4.21, 3.79 (AB of ABX, J_{AB} = 11.8 Hz, J_{AX} = 3.6 Hz, J_{BX} = 8.2 Hz, CH_2OH), 3.51, 3.21 (AB of ABX, J_{AB} = 9.4 Hz, J_{AX} = 4.9 Hz, J_{BX} = 9.3 Hz, $CHCH_2$), 2.70 (m, 1 H, $CHCH_3$), 2.57 (X of ABX, J_{AX} = 3.5 Hz, J_{BX} = 8.2 Hz, OH), 1.79 (s, 3 H, vinyl CH_3), 0.88 (d, 3 H, J = 7.0 Hz, $CHCH_3$), 0.87 (s, 9 H, $SiC(CH_3)_3$), 0.04 (s, 6 H, $Si(CH_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 136.59, 131.62, 68.11, 61.95, 35.04, 25.98 (3 C), 22.41, 18.53, 17.23, −5.45, −5.46; $[\alpha]^{23}_D$ +13.05° (*c* 2.34, $CHCl_3$); MS (70 eV) calcd for $C_{13}H_{28}O_2Si$ 187.33, found *m/e* 187 (M^+), 105 (base peak). Anal. Calcd for $C_{13}H_{28}O_2Si$: C, 63.88; H, 11.54. Found: C, 63.68; H, 11.53.

(2*R*,3*S*,4*S*)-5-[(*tert*-Butyldimethylsilyl)oxy]-2,4-dimethyl-2,3-epoxy-1-pentanol (5b) and (2*S*,3*R*,4*S*)-5-[(*tert*-Butyldimethylsilyl)oxy]-2,4-dimethyl-2,3-epoxy-1-pentanol (5a). To a slurry of 0.54 g of 3-Å molecular sieves and 17 mL of dry methylene chloride under argon at −5 °C (methanol–ice bath) was added 123 μL (0.72 mmol) of L-(+)-diethyl tartrate followed by 164 μL (0.55 mmol) of titanium(IV) isopropoxide.[7] The mixture was cooled to −20 °C and charged with 4.28 mL (16.5 mmol) of 3.9 M *tert*-butyl hydroperoxide in isooctane. The mixture was allowed to age with stirring for 20 min, after which 2.69 g (11.0 mmol) of alcohol **4** in 5 mL of dry methylene chloride was added dropwise. The mixture was stirred at −20 °C for 10 h. The reaction was then quenched with 1.5 mL of water and allowed to warm to 0 °C. To ease the purification process the tartrate was hydrolyzed by adding 1 mL of 30% NaOH in saturated NaCl. The solution was allowed to stir until a distinct phase separation was apparent. The layers were separated, and the aqueous phase was extracted with methylene chloride. The combined organic phases were dried over sodium sulfate and concentrated under reduced pressure. The crude oil contained two epoxides in a 3.7:1 ratio according to the ^1H NMR spectrum. The residue was purified by flash chromatography on silica gel. Elution with 3:1 hexane–ether afforded 1.96 g (68%) of epoxy alcohol **5b** and 0.750 g (26%) of the diastereomer **5a**.

5b: IR (film) ν 3445, 2950, 2860, 1460, 1255, 1070, 840, 780 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 3.64 (m, 2 H, CH_2OR), 3.44 (m, 2 H, CH_2OR), 2.45 (d, 1 H, J = 9.7 Hz, epoxide H), 1.74 (m, 1 H, $CHCH_3$), 1.54 (br s, 1 H, OH), 1.42 (s, 3 H, epoxide CH_3), 0.99 (d, 3 H, J = 6.7 Hz, $CHCH_3$), 0.91 (s, 9 H, $SiC(CH_3)_3$), 0.1, 0.09 (s, 6 H, $Si(CH_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 68.03, 66.87, 65.16, 35.28, 31.63, 26.00 (3C), 20.51, 18.61, 14.10, −5.53, −5.60; $[\alpha]^{23}_D$ +40.82° (*c* 4.00, $CHCl_3$); MS (70 eV) calcd for $C_{13}H_{28}O_3Si$ 260.45, found *m/e* 261 (M + 1), 203 ($M^+ - C_4H_9$), 75 (base peak). Anal. Calcd for $C_{13}H_{28}O_3Si$: C, 59.95; H, 10.84. Found: C, 60.04; H, 10.84. Analysis of the *O*-methyl mandelate derivatives by ^1H NMR indicated an ee of >95% for this alcohol.

5a: IR (film) ν 3450, 2940, 2920, 2850, 1460, 1385, 1250, 1100, 1020, 835 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 3.60 (m, 4 H, 2 CH_2OR), 2.68 (d, 1 H, J = 9.5 Hz, epoxide H), 2.40 (t, 1 H, J = 5.4 Hz, OH), 1.61 (m, 1 H, $CHCH_3$), 1.35 (s, 3 H, epoxide CH_3), 0.94 (d, 3 H, J = 6.9 Hz, $CHCH_3$), 0.85 (s, 9 H, $SiC(CH_3)_3$), 0.01 (d, 6 H, J = 1.4 Hz, $Si(CH_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 66.2, 65.5, 63.8, 60.6, 35.3, 25.8 (3 C), 20.2, 18.3, 13.6, −5.4, −5.5; $[\alpha]^{22}_D$ −16.48° (*c* 2.64, $CHCl_3$); HRMS calcd for $C_{13}H_{27}O_2Si$ (M − OH) 243.1780, found *m/e* 243.1789. Anal. Calcd for $C_{13}H_{28}O_3Si$: C, 59.95; H, 10.84. Found: C, 59.84; H, 10.88.

(*Z*)-(4*S*,5*R*,6*S*)-Ethyl 7-[(*tert*-Butyldimethylsilyl)oxy]-3,5-dimethyl-3,4-epoxy-2-heptenoate (7). To a solution of 0.61 mL (7.0 mmol) of oxalyl chloride in 12 mL of dry methylene chloride under argon at −78 °C was added 1.0 mL (14.1 mmol) of dimethyl sulfoxide.[9] The mixture was allowed to stir for 25 min, then 1.22 g (4.7 mmol) of alcohol **5** in 5 mL of dry methylene chloride was added, and the mixture was allowed to stir for 1.5 h. The reaction was quenched with 3.26 mL (23.4 mmol) of triethylamine and warmed to 0 °C with stirring. The thick mixture was diluted with 15 mL of water, and the phases were separated.

The organic phase was washed with water, dried over sodium sulfate, and concentrated under reduced pressure. The residue, aldehyde **6**, was used directly in the next step: IR (film) ν 2945, 2855, 1720, 1460, 1255, 1090, 830, 780 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.29 (s, 1 H, CHO), 3.56, 3.41 (AB of ABX, J_{AB} = 10.1 Hz, J_{AX} = 4.5 Hz, J_{BX} = 9.2 Hz, 1 H, $CHCH_2$), 2.82 (d, 1 H, J = 9.71 Hz, epoxide H), 1.89 (m, X of ABX, 1 H, CH_2CH), 1.41 (s, 3 H, epoxide CH_3), 1.08 (d, J = 6.70 Hz, 3 H, $CHCH_3$), 0.84 (s, 9 H, $(CH_3)_3CSi$), -0.01 (s, 6 H, $(CH_3)_2Si$); MS (70 eV) calcd for $C_{13}H_{26}O_3Si$ 258.45, found m/e 257 ($M^+ - 1$), 75 (base peak).

To a solution of 2.0 g (6.32 mmol) of bis(2,2,2-trifluoroethyl)(ethoxycarbonylmethyl)phosphonate in 23 mL of dry tetrahydrofuran under argon at room temperature was added 3.70 g (14.0 mmol) of 18-crown-6.[5] The mixture was cooled to 0 °C, whereupon 12.6 mL (6.32 mmol) of 0.5 M potassium hexamethyldisilazide in toluene was added dropwise. After 10 min the mixture was cooled to -78 °C and crude aldehyde **6** in 5 mL of dry tetrahydrofuran was added. The reaction mixture was allowed to stir for 10 min, and then it was quenched with 20 mL of saturated ammonium chloride. After warming to room temperature the phases were separated, and the aqueous phase was extracted with ether and ethyl acetate. The combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel. Elution with 3:1 hexane–ether afforded 1.18 g (85%) of ester **7**: IR (film) ν 2955, 2825, 2855, 1715, 1460, 1410, 1260, 1210, 1175, 1090, 835, 780 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.26 (d, 1 H, J = 12.0 Hz, vinyl H), 5.88 (d, 1 H, J = 11.95 Hz, vinyl H), 4.19 (q, 2 H, J = 7.2 Hz, $CO_2CH_2CH_3$), 3.54, 3.48 (AB of ABX, J_{AB} = 9.9 Hz, J_{AX} = 5.9 Hz, J_{BX} = 6.4 Hz, $CHCH_2$), 2.71 (d, 1 H, J = 9.0 Hz, epoxy), 1.5 (s, 3 H, epoxy CH_3), 1.37 (m, 1 H, $CHCH_3$), 1.29 (t, 3 H, J = 7.1 Hz, $CO_2CH_2CH_3$), 0.99 (d, 3 H, J = 6.7 Hz, $CHCH_3$), 0.87 (s, 9 H, $(CH_3)_3CSi$), 0.02 (s, 3 H, $(CH_3)_2Si$), 0.005 (s, 3 H, $(CH_3)_2Si$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.4, 144.5, 122.4, 68.0, 65.2, 61.3, 60.3, 36.7, 25.8 (3 C), 22.0, 18.2, 14.1, 14.0, -5.5 (2 C); $[\alpha]^{20}_D$ +64.0° (c 1.86, $CHCl_3$). Anal. Calcd for $C_{17}H_{32}O_4Si$: C, 62.15; H, 9.82. Found: C, 62.26; H, 9.88.

(*Z*)-(4*S*,5*R*,6*S*)-7-[(*tert*-Butyldimethylsilyl)oxy]-3,5-dimethyl-3,4-epoxy-2-hepten-1-ol (8). A solution of 1.61 g (8.3 mmol) of epoxy ester **7** in 21 mL of dry methylene chloride was reduced with 17.4 mL (17.4 mmol) of 1.0 M DIBAH[6] in hexanes according to the procedure described for alcohol **4**. The resulting oil was purified by flash chromatography on silica gel. Elution with 1:1 hexane–ether afforded 2.03 g (85%) of vinyl epoxide **8**: IR (film) ν 3410, 2950, 2920, 2860, 1470, 1250, 1090, 1025, 840, 775 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.68 (m, 2 H, vinyl H), 4.27, 4.14 (AB of ABX, J_{AB} = 13.5 Hz, J_{AX} = 6.0 Hz, J_{BX} = 6.0 Hz, CH_2OH), 3.54, 3.42 (AB of ABX, J_{AB} = 10.0 Hz, J_{AX} = 4.9 Hz, J_{BX} = 8.0 Hz, CH_2OTBS), 2.75 (br s, 1 H, OH), 2.57 (d, 1 H, J = 9.2 Hz, epoxide H), 1.55 (m, 1 H, $CHCH_3$), 1.37 (s, 3 H, epoxide CH_3), 0.94 (d, 3 H, J = 6.8 Hz, $CHCH_3$), 0.86 (s, 9 H, $SiC(CH_3)_3$), 0.009 (s, 6 H, $Si(CH_3)_2$); ^{13}C NMR (75MHz, $CDCl_3$) δ 132.25, 129.76, 68.00, 66.04, 61.90, 59.14, 35.87, 25.93 (3 C), 23.42, 18.35, 13.81, -5.46, -5.50; $[\alpha]^{23}_D$ +18.7° (c 2.78, $CHCl_3$); MS (70 eV) calcd for $C_{15}H_{30}O_3Si$ 286.5, found m/e 229 ($M^+ - C_4H_9$), 75 (base peak). Anal. Calcd for $C_{15}H_{30}O_3Si$: C, 62.89; H, 10.55. Found: C, 62.80; H, 10.60.

(*E*)-(2*R*,5*R*,6*S*)-7-[(*tert*-Butyldimethylsilyl)oxy]-2,4,6-trimethyl-3-heptene-1,5-diol (9). To a solution of 2.83 g (31.6 mmol) of freshly dried copper cyanide (water removed by azeotropic distillation with benzene) in 80 mL of dry ether at -23 °C under argon was added 23.0 mL (31.6 mmol) of 1.4 M methyllithium in ether. The solution was stirred for 10 min, a solution of 1.81 g (6.33 mmol) of vinyloxirane **8** in 20 mL of dry ether was added, and the solution was allowed to stir overnight with warming to 0 °C. The reaction was quenched with 80 mL of 1:1 3% aqueous ammonium hydroxide–saturated ammonium chloride, and the mixture was allowed to stir until a blue aqueous layer appeared. The phases were separated, and the aqueous layer was extracted with ether. The combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The resulting oil was purified by flash chromatography on silica gel. Elution with 2:1 ether–hexane afforded 1.68 g (88%) of diol **9**: IR (film) ν 3340, 2940, 2875, 1460, 1250, 1090, 1020, 835, 770 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.22 (d, 1 H, J = 9.6 Hz, vinyl H), 4.15 (br s, 1 H, $CHCOH$), 3.69, 3.63 (AB of ABX, J_{AB} = 9.8 Hz, J_{AX} = 4.2 Hz, J_{BX} = 4.6 Hz, CH_2OTBS), 3.47, 3.36 (AB of ABX, J_{AB} = 10.7 Hz, J_{AX} = 6.0 Hz, J_{BX} = 8.1 Hz, CH_2OH), 3.10 (m, 1 H, OH), 2.66 (m, 1 H, $CHCH_2OH$), 1.81 (m, 1 H, $CHCH_3$), 1.65–1.58 (m, 1 H, OH), 1.61 (s, 3 H, vinyl CH_3), 0.94 (d, 3 H, J = 6.7 Hz, $CHCH_3$), 0.88 (s, 9 H, $(CH_3)_3CSi$), 0.85 (d, 3 H, J = 7.0 Hz,$CHCH_3$), 0.05 (s, 6 H, $(CH_3)_2Si$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 137.38, 127.88, 78.53, 67.88, 67.59, 37.18, 35.17, 25.86 (3 C), 18.19, 16.92, 13.54, 10.60, -5.56, -5.60; $[\alpha]^{23}_D$ +22.7° (c 1.66, $CHCl_3$); MS (70 eV) calcd for $C_{16}H_{34}O_3Si$ 302.53, found m/e 302 (M^+), 75 (base peak). Anal. Calcd for $C_{16}H_{34}O_3Si$: C, 63.52; H, 11.33. Found: C, 63.58; H, 11.35.

(2*S*,3*R*,5*R*)-1,3-(Benzylidenedioxy)-2,4,5-trimethyl-4-hepten-7-ol (10). To a stirred solution of 140.2 mg (0.46 mmol) of diol **9** in 1.2 mL of dry ethanol under nitrogen at room temperature was added 11.6 mg (0.05 mmol) of pyridinium *p*-toluenesulfonate. After stirring for 3 h at room temperature, the mixture was concentrated under reduced pressure and dried in vacuo. The thick yellow oil was diluted with 5 mL of dry methylene chloride, 0.19 mL (1.85 mmol) of benzaldehyde was added, and the mixture was stirred overnight. The reaction was quenched with 10 mL of 1:1 water–methylene chloride, and the aqueous layer was extracted with methylene chloride. The combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The residual oil was purified by flash chromatography on silica gel. Elution with 1:1 hexane–ether afforded 112.4 mg (88%) of alcohol **10**: IR (film) ν 3400, 2950, 2920, 2855, 1450, 1400, 1150, 1120, 1030, 755, 700 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.54 (m, 2 H, phenyl H), 7.36 (m, 3 H, phenyl H), 5.57 (s, 1 H, benzylidene H), 5.32 (d, 1 H, J = 9.7 Hz, vinyl H), 4.32 (br s, 1 H, carbinyl H), 4.14 (A of ABX, J_{AB} = 11.2 Hz, J_{AX} = 2.4 Hz, $ROCH_2$), 4.06 (B of ABX, J_{AB} = 11.2 Hz, J_{BX} = 1.4 Hz, $ROCH_2$), 3.46 (A of ABX, J_{AB} = 10.0 Hz, J_{AX} = 7.1 Hz, $HOCH_2$), 3.37 (B of ABX, J_{AB} = 10.4 Hz, J_{BX} = 7.7 Hz, $HOCH_2$), 2.67 (m, 1 H, $CHCH_2OH$), 1.80 (m, 1 H, $CHCH_2$), 1.64 (s, 3 H, vinyl CH_3), 1.41 (br s, 1 H, CH_2OH), 0.96 (d, 3 H, J = 6.9 Hz, $CHCH_3$), 0.96 (d, 3 H, J = 6.7 Hz, $CHCH_3$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.88, 134.32, 128.8, 128.23 (2 C), 126.71, 126.26 (2 C), 101.62, 81.85, 73.41, 67.83, 35.18, 30.61, 16.93, 13.68, 11.31; $[\alpha]^{21}_D$ +47.4° (c 2.02, $CHCl_3$); HRMS calcd for $C_{17}H_{24}O_3$ 276.1725, found m/e 276.1733 (M^+).

(2*S*,3*S*,4*S*,6*R*)-1,3-(Benzylidenedioxy)-2,4,5-trimethylheptan-7-ol (11). A. From Alcohol 10. To a steel screw-cap high-pressure bomb was added 66.5 mg (0.241 mmol) of alcohol **10** followed by 34 mg (0.048 mmol) of [Rh(NBD)Diphos-4]BF_4 and 4.0 mL of dry methylene chloride.[11] The pressure gauge block was attached, and the bomb was flushed three times with hydrogen and then was filled to 650 psi of hydrogen. After being stirred for 10 min the solution was filtered through silica gel and concentrated under reduced pressure. The orange oil was purified by flash chromatography on silica gel. Elution with 1:1 ether–hexane afforded 61.9 mg (92%) of alcohol **11** and 4.0 mg (6%) of a stereoisomer.

B. From Alcohol 20. To a stirred solution of 4.8 mg (0.016 mmol) of alcohol **20** in 160 μL of ethanol at room temperature was added 4 mg of 5% Pd/C. The flask was evacuated and filled with 1 atm of hydrogen gas by means of a balloon. The black slurry was stirred overnight and filtered through Celite. The clear solution was concentrated under reduced pressure, affording a crude triol to which was added 160 μL of dry methylene chloride, 4 mg (16 μmol) of pyridinium *p*-toluenesulfonate, and 6.4 μL (63 μmol) of benzaldehyde. The solution was stirred overnight and was then quenched with 1 mL of water, and the aqueous layer was extracted with methylene chloride. The combined extracts were dried over magnesium sulfate and concentrated under reduced pressure. The pale yellow oil was purified by flash chromatography on silica gel. Elution with 1:1 ether–hexane afforded 3.8 mg (88%) of alcohol **11**: IR (film) ν 3450, 2970, 2930, 2860, 1455, 1385, 1115, 1030, 735, 700 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.5–7.3 (m, 5 H, phenyl H), 5.48 (s, 1 H, benzylidene H), 4.03 (s, 2 H, OCH_2), 3.47–3.44 (m, 3 H, $CHOR$ and CH_2OH), 1.9–1.7 (m, 3 H, three CH_3CH), 1.55 (s, 1 H, OH), 1.14 (d, 3 H, J = 6.9 Hz, $CHCH_3$), 1.08 (dd, 2 H, J = 7.5, 6.8 Hz, $CHCH_2CH$), 0.99 (d, 3 H, J = 6.4 Hz, $CHCH_3$), 0.89 (d, 3 H, J = 6.6 Hz, $CHCH_3$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.8, 128.8, 128.2 (2 C), 126.0 (2 C), 102.0, 85.2, 74.0, 67.2, 37.4, 33.6, 32.4, 30.2, 18.7, 15.5, 10.9; $[\alpha]^{23}_D$

−30.0° (*c* 1.76, $CHCl_3$). Anal. Calcd for $C_{17}H_{26}O_3$: C, 73.34; H, 9.41. Found, C, 73.24; H, 9.42.

(2*S*,3*S*,4*S*,6*R*)-1,3-(Benzylidenedioxy)-7-[(*p*-methoxybenzyl)oxy]-2,4,6-trimethylheptane (12). To a stirred solution of 120.3 mg (0.432 mmol) of alcohol **11** in 2.1 mL of dry dimethylformamide at room temperature under nitrogen was added 13 mg (0.52 mmol) of 97% NaH. The mixture was stirred for 3 h after which 87.9 mL (0.65 mmol) of *p*-methoxybenzyl chloride was added dropwise. After stirring overnight, the reaction was quenched with 3 mL of saturated sodium bicarbonate, and the aqueous layer was extracted with ether. The combined extracts were dried over magnesium sulfate and concentrated under reduced pressure. The oil was purified by flash chromatography on silica gel deactivated with triethylamine. Elution with 5:1 hexane–ether afforded 146 mg (88%) of ether **12**: IR (film) ν 2980, 2940, 2870, 1600, 1520, 1465, 1255, 1120, 1040, 760, 710 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.47 (m, 2 H, phenyl H), 7.32 (m, 3 H, phenyl H), 7.20 (d, 2 H, J = 8.7 Hz, aryl H) 6.81 (d, 2 H, J = 8.7 Hz, aryl H), 5.45 (s, 1 H, benzylidene H), 4.40, 4.35 (AB q, 2 H, J = 11.6 Hz, benzyl H), 4.02 (m, 2 H, CH_2CH), 3.77 (s, 3 H, OCH_3), 3.43 (dd, 1 H, J = 2.1, 9.9 Hz, CHOR), 3.35, 3.12 (AB of ABX, J_{AB} = 9.2 Hz, J_{AX} = 4.9 Hz, J_{BX} = 7.3 Hz, CH_2CH), 1.85 (m, 1 H, CHCH$_2$), 1.73 (m, 1 H, CHCH$_2$), 1.65 (m, 1 H, CHCH$_2$), 1.13 (d, 3 H, J = 6.9 Hz, CHCH_3), 0.95 (d, 3 H, J = 6.6 Hz, CHCH_3), 0.91 (m, 2 H, CHCH_2CH), 0.83 (d, 3 H, J = 6.7 Hz, CHCH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 159.0, 139.2, 131.0, 129.0 (2 C), 128.5, 128.1, (2 C), 126.0 (2 C), 113.7 (2 C), 101.6, 85.0, 75.4, 74.1, 72.6, 55.3, 38.2, 32.4, 31.2, 30.2, 19.2, 15.0, 11.0; $[\alpha]^{20}_D$ −22.4° (*c* 2.16, $CHCl_3$); HRMS calcd for $C_{25}H_{34}O_4$ 398.2457, found *m/e* 398.2454 (M^+). Anal. Calcd for $C_{25}H_{34}O_4$: C, 75.34; H, 8.60. Found: C, 75.14; H, 8.62.

(2*S*,3*S*,4*S*,6*R*)-3-(Benzyloxy)-7-[(*p*-methoxybenzyl)oxy]-2,4,6-trimethyl-1-heptanol (13). To a stirred solution of 29.4 mg (0.074 mmol) of acetal **12** in 0.7 mL of methylene chloride at 0 °C under nitrogen was added 0.22 mL (0.221 mmol) of 1.0 M diisobutylaluminum hydride in hexanes.[13] The mixture was stirred for 6 h with warming to room temperature, and then the reaction was quenched with 2 mL of ethanol and stirred overnight with 10 mL of saturated Rochelle's salts. The aqueous phase was extracted with methylene chloride, and the combined extracts were dried over magnesium sulfate and concentrated under reduced pressure. The clear oil was purified by flash column chromatography on silica gel. Elution with 1:1 ether–hexanes afforded 27.4 mg (93%) of alcohol **13**: IR (film) ν 3430, 2980, 2940, 2880, 1620, 1515, 1460, 1250, 1100, 1035, 745, 710 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.3 (m, 5 H, phenyl H), 7.23 (d, 2 H, J = 8.7 Hz, aryl H), 6.84 (d, 2 H, J = 8.7 Hz, aryl H), 4.61, 4.50 (AB q, 2 H, J = 11.5 Hz, benzyl H), 4.41, 4.37 (AB q, 2 H, J = 11.6 Hz, benzyl H), 3.77 (s, 3 H, OCH_3) 3.53 (m, 2 H, CH_2OH), 3.32 (m, 1 H, CHOBn), 3.31, 3.17 (AB of ABX, J_{AB} = 9.0 Hz, J_{AX} = 5.3 Hz, J_{BX} = 6.7 Hz, CH_2OPMB), 1.91 (m, 2 H, 2 CHCH$_2$), 1.84 (m, 1 H, CHCH$_2$), 1.75 (br s, 1 H, OH), 1.62 (m, 2 H, CHCH_2CH), 0.95 (d, 3 H, J = 6.8 Hz, CHCH_3), 0.93 (d, 3 H, J = 6.7 Hz, CHCH_3), 0.92 (d, 3 H, J = 6.5 Hz, CHCH_3); ^{13}C NMR (125MHz, $CDCl_3$) δ 159.0, 139.0, 130.8, 129.1 (2 C), 128.3 (2 C), 127.6 (2 C), 127.4, 113.7 (2 C), 84.2, 75.2, 73.8, 72.7, 66.7, 55.3, 37.6, 37.3, 33.2, 31.1, 19.0, 16.9, 11.7; $[\alpha]^{20}_D$ +3.54° (*c* 1.53, $CHCl_3$). Anal. Calcd for $C_{25}H_{36}O_4$: C, 74.96; H, 9.06. Found: C, 74.85; H, 9.09.

(*E*)-(2*R*,5*R*,6*S*)-7-[(*tert*-Butyldimethylsilyl)oxy]-1-[(*p*-methoxybenzyl)oxy]-2,4,6-trimethyl-3-hepten-5-ol (14). To a stirred solution of 75.2 mg (249 μmol) of diol **9** in 1.2 mL of dry methylene chloride at 0 °C were added 8 μL (24.9 μmol) of tris[2-(2-methoxyethoxy)ethyl]amine, 28 mg (497 μmol) of crushed potassium hydroxide pellets, and 37 μL (0.274 mmol) of *p*-methoxybenzyl chloride. The mixture was stirred for 2 days, the reaction was quenched with water, and the aqueous layer was extracted with ether. The combined extracts were dried over sodium sulfate and concentrated under reduced pressure, affording a yellow oil, which was purified by flash chromatography on silica gel. Elution with 9:1 hexane–ether yielded 75.9 mg (72%) of alcohol **14**: IR (film) ν 3450, 2980, 2860, 1610, 1510, 1460, 1245, 1090, 835, 755 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.23 (d, 2 H, J = 8.6 Hz, aryl H), 6.85 (d, 2 H, J = 8.6, aryl H), 5.25 (d, 1 H, J = 9.3 Hz, vinyl H), 4.44, 4.39 (AB q, 2 H, J = 11.6 Hz, benzyl H), 4.12 (d, 1 H, J = 3.3 Hz, carbinyl H), 3.78 (s, 3 H, OCH_3), 3.67, 3.62 (AB of ABX, J_{AB} = 9.8 Hz, J_{AX} = 4.4 Hz, J_{BX} = 4.7 Hz, CH_2OPMB), 3.30, 3.23 (AB of ABX, J_{AB} = 9.1 Hz, J_{AX} = 6.4 Hz, J_{BX} = 7.1 Hz, CH_2OTBS), 2.84 (br s, 1 H, OH), 2.75 (m, 1 H, CHCH$_3$), 1.78 (m, 1 H, CHCH$_3$), 1.57 (s, 3 H, vinyl CH_3), 0.98 (d, 3 H, J = 6.7 Hz, CHCH_3), 0.88 (s, 9 H, SiC$(CH_3)_3$, 0.84 (d, 3 H, J = 7.0 Hz, CHCH_3), 0.04 (s, 6 H, Si$(CH_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 159.0, 135.6, 130.8, 129.0 (2 C), 127.9, 113.7 (2 C), 78.2, 75.2, 72.6, 67.7, 55.2, 37.2, 32.7, 25.8 (3 C), 18.2, 17.7, 13.6, 10.2, −5.5, −5.6; $[\alpha]^{23}_D$ −10.34° (*c* 1.02, EtOH). Anal. Calcd for $C_{24}H_{42}O_4Si$: C, 68.20; H, 10.02. Found: C, 68.18; H, 10.07.

(2*R*,3*R*,4*R*,5*R*,6*S*)-7-[(*tert*-Butyldimethylsilyl)oxy]-1-[(*p*-methoxybenzyl)oxy]-2,4,6-trimethylheptane-3,5-diol (15). To a stirred solution of 50.7 mg (0.12 mmol) of alcohol **14** in 1.2 mL of dry tetrahydrofuran at 0 °C under nitrogen was added 0.120 mL (1.2 mmol) of 10.0 M borane–dimethyl sulfide in dimethyl sulfide. After the mixture was stirred for 2 h with warming to room temperature, the excess borane was quenched at 0 °C with 1.0 mL of ethanol. To the white slurry was added 0.136 mL (1.2 mmol) of 30% aqueous hydrogen peroxide and 0.172 mL (1.2 mmol) of 7.0 M aqueous sodium hydroxide. The solution was heated to reflux for 2 h, and after cooling it was diluted with 4 mL of 1:1 ether–water solution. The organic layer was washed with sodium bicarbonate, the aqueous layer was extracted with ether, and the combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The cloudy oil was purified by flash chromatography on silica gel. Elution with 1:1 ether–hexane afforded 43.2 mg (82%) of diol **15**: IR (film) ν 3450, 2970, 2940, 2870, 1615, 1510, 1465, 1250, 1095, 840, 790 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.22 (d, 2 H, J = 8.7 Hz, aryl H), 6.85 (d, 2 H, J = 8.7 Hz, aryl H), 4.42 (s, 2 H, benzyl H), 3.88 (br s, 1 H, carbinyl H), 3.79 (s, 3 H, OCH_3), 3.74 (br s, 1 H, carbinyl H), 3.53 (d, 2 H, J = 4.9 Hz, CH_2OR), 3.50 (d, 2 H, J = 4.7 Hz, CH_2OR), 3.24 (br s, 1 H, OH), 2.87 (br s, 1 H, OH), 1.84 (m, 3 H, 3 CHCH$_3$), 1.02 (d, 3 H, J = 6.8 Hz, CHCH_3), 0.96 (d, 3 H, J = 7.0 Hz, CHCH_3), 0.87 (s, 9 H, SiC$(CH_3)_3$), 0.84 (d, 3 H, J = 7.0 Hz, CHCH_3), 0.03 (s, 6 H, Si$(CH_3)_2$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 159.2, 130.2, 129.2 (2 C), 76.5, 75.1, 74.8, 73.1, 67.4, 55.3, 38.3, 37.8, 35.5, 25.9 (3 C), 21.7, 13.3, 11.5, 10.2, −5.5 (2 C); $[\alpha]^{23}_D$ +3.47° (*c* 1.24, $CHCl_3$).

(2*R*,3*R*,4*R*,5*R*,6*S*)-7-[(*tert*-Butyldimethylsilyl)oxy]-1,3-[(*p*-methoxybenzylidene)dioxy]-2,4,6-trimethylheptan-5-ol (16). To a stirred solution of 8.6 mg (19.7 μmol) of diol **15** and 25 mg of 4-Å sieves in 0.2 mL of dry methylene chloride under argon at room temperature was added 7 mg (29.5 μmol) of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone.[12] The mixture was stirred for 2 h after which the slurry was filtered through a pad of silica gel and concentrated under reduced pressure. The oil was purified by flash chromatography on silica gel. Elution with 1:1 ether–hexane afforded 6.0 mg (70%) of alcohol **16**: IR (film) ν 3480, 2950, 2930, 2850, 1615, 1590, 1515, 1460, 1250, 1110, 835, 780 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.37 (d, 2 H, J = 8.6 Hz, aryl H), 6.85 (d, 2 H, J = 8.6 Hz, aryl H), 5.43 (s, 1 H, benzylidene H), 4.06, 4.00 (AB q, 2 H, J = 11.2 Hz, $ROCH_2$), 3.89 (br s, 1 H, carbinyl H), 3.85 (d, 1 H, J = 10.1 Hz, carbinyl H), 3.78 (s, 3 H, OCH_3), 3.53 (br s, 2 H, $ROCH_2$), 2.43 (br s, 1 H, OH), 1.93 (m, 1 H, CHCH$_3$), 1.83 (m, 1 H, CHCH$_3$), 1.57 (m, 1 H, CHCH$_3$), 1.16 (d 3 H, J = 6.9 Hz, CHCH_3), 0.96 (d, 3 H, J = 6.8 Hz, CHCH_3), 0.86 (s, 9 H, SiC$(CH_3)_3$), 0.84 (d, 3 H, J = 7.0 Hz, CHCH_3), 0.02 (s, 6 H, Si$(CH_3)_2$); $[\alpha]^{23}_D$ −12.3° (*c* 0.81, $CHCl_3$); HRMS calcd for $C_{24}H_{42}O_5Si$ 438.2802, found *m/e* 438.2778 (M^+).

(2*R*,3*R*,4*R*,5*R*,6*S*)-7-[(*tert*-Butyldimethylsilyl)oxy]-3,5-(isopropylidenedioxy)-1-[(*p*-methoxybenzyl)oxy]-2,4,6-trimethylheptane (18). To a stirred solution of 15.0 mg (35.7 μmol) of diol **15** in 0.36 mL of 2,2-dimethoxypropane under nitrogen was added a catalytic amount of pyridinium *p*-toluenesulfonate. The mixture was allowed to stir overnight at room temperature. The reaction was quenched with 3 mL of water, the aqueous layer was extracted with ether, and the combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The oil was purified by flash chromatography on silica gel. Elution with 3:1 hexane–ether afforded 3.0 mg of starting diol **15** and 10.8 mg (82% based on recovered starting material) of acetonide **18**: IR (film) ν 2980, 2950, 2880, 1520, 1470, 1390, 1260, 1235, 1045, 800 cm^{-1}; ^1H NMR (500 MHz, C_6D_6) δ 7.25 (d, 2 H, J = 8.6 Hz, aryl H), 6.80 (d, 2 H, J = 8.6 Hz, aryl H), 4.38, 4.32 (AB q, 2 H, J = 11.5 Hz, benzyl H), 3.77 (dd, 1 H, J = 10.0, 4.3 Hz, carbinyl H), 3.62 (dd, 1 H, J = 2.8, 7.5 Hz, carbinyl

H), 3.53, 3.35 (AB of ABX, J_{AB} = 8.8 Hz, J_{AX} = 7.9 Hz, J_{BX} = 5.9 Hz, CH_2OR), 3.45, 3.41 (AB of ABX, J_{AB} = 9.9 Hz, J_{AX} = 4.1 Hz, J_{BX} = 5.0 Hz, CH_2OR), 3.30 (s, 3 H, OCH_3), 1.97 (m, 2 H, 2 CHCH$_3$), 1.88 (m, 1 H, CHCH$_3$), 1.41 (s, 3 H, CCH$_3$), 1.38 (s, 3 H, CCH$_3$), 1.21 (d, 3 H, J = 6.6 Hz, CHCH_3), 1.11 (d, 3 H, J = 6.9 Hz, CHCH_3), 0.98 (s, 9 H, SiC(CH$_3$)$_3$), 0.94 (d, 3 H, J = 6.6 Hz, CHCH_3), 0.04 (s, 6 H, Si(CH$_3$)$_2$); ^{13}C NMR (75 MHz, CDCl$_3$) δ 159.0, 130.8, 129.2 (2 C), 113.7 (2 C), 100.5, 74.4, 72.8, 72.7, 71.2, 64.7, 55.2, 36.7, 35.4, (2 C), 25.8 (3 C), 24.8, 23.5, 18.2, 14.3, 12.7, 11.1, -5.5 (2 C); $[\alpha]^{23}_D$ +4.85° (c 1.01, EtOH); HRMS calcd for $C_{27}H_{48}O_5Si$ 480.3271, found m/e 480.3275 (M$^+$).

(2*S*,3*S*,4*S*,6*R*)-1,3-(Benzylidenedioxy)-7-[(*tert*-butyldimethylsilyl)oxy]-2,4,5-trimethylheptane (19). To a stirred solution of 8.1 mg (18.5 μmol) of alcohol **16** in 0.20 mL of dimethylformamide under nitrogen were added 11.0 μL (73.9 μmol) of DBU and 17.8 μL (0.295 mmol) of carbon disulfide. The solution was heated to 40 °C for 1.5 h and was then cooled to room temperature. To this solution was added 35.6 μL (0.572 mmol) of iodomethane, and the yellow mixture was stirred for 1 h. The solution was concentrated under reduced pressure, 2 mL of water was added, and the aqueous layer was extracted with ether. The combined extracts were dried over sodium sulfate and concentrated under reduced pressure. The yellow oil, xanthate **17**, was used directly in the next step: ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.43 (d, 2 H, J = 8.6 Hz, aryl H), 6.85 (d, 2 H, J = 8.8 Hz, aryl H), 6.23 (d, 1 H, J = 8.6 Hz, CHOCS$_2$Me), 5.30 (s, 1 H, benzylidene H), 3.98 (br s, 2 H, CH$_2$OR), 3.78 (s, 3 H, OCH$_3$), 3.58 (m, 2 H, CH$_2$OR), 3.49 (m, 1 H, carbinyl H), 2.56 (s, 3 H, SCH$_3$), 2.12 (m, 2 H, 2 CHCH$_3$), 1.54 (m, 1 H, CHCH$_3$), 1.13 (d, 3 H, J = 6.9 Hz, CHCH_3), 0.94 (d, 3 H, J = 6.8 Hz, CHCH_3), 0.92 (d, 3 H, J = 7.0 Hz, CHCH_3), 0.81 (s, 9 H, SiC(CH$_3$)$_3$), -0.3 (d, 6 H, J = 3.5 Hz, Si(CH$_3$)$_2$).

To a stirred solution of 9.8 mg (18.5 μmol) of xanthate **17** in 0.2 mL of dry benzene under argon were added 8.1 μL (29.5 μmol) of tri-*n*-butyltin hydride and a catalytic amount of AIBN.[20] After refluxing for 0.5 h, the mixture was cooled to room temperature and concentrated under reduced pressure. The clear oil was purified by flash chromatography on silica gel. Elution with 6:1 hexane–ether afforded 6.3 mg (81%) of acetal **19**: IR (film) ν 2940, 2920, 2840, 1610, 1510, 1455, 1245, 1110, 1030, 820, 770 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.41 (d, 2 H, J = 8.5 Hz, aryl H), 6.86 (d, 2 H, J = 8.8 Hz, aryl H), 5.40 (s, 1 H, benzylidene H), 4.00 (m, 2 H, CHCH_2), 3.79 (s, 3 H, OCH$_3$), 3.48, 3.26 (AB of ABX, J_{AB} = 9.9 Hz, J_{AX} = 4.7 Hz, J_{BX} = 6.6 Hz, CHCH_2), 3.39 (dd, 1 H, J = 2.1, 9.7 Hz, carbinyl), 1.76 (m, 2 H, 2 CHCH$_3$), 1.64 (m, 1 H, CHCH$_3$), 1.13 (d, 3 H, J = 6.9 Hz, CHCH_3), 0.90 (d, 3 H, J = 6.4 Hz, CHCH_3), 0.86 (s; 9 H, SiC(CH$_3$)$_3$), 0.85 (m, 2 H, CHCH_2CH), 0.83 (d, 3 H, J = 6.7 Hz, CHCH_3), -0.003 (s, 6 H, Si(CH$_3$)$_2$); ^{13}C NMR (75 MHz, CDCl$_3$) δ 131.8, 127.3 (2 C), 113.4 (2 C), 101.6, 85.0, 74.1, 68.1, 55.3, 37.7, 33.3, 32.4, 30.1, 29.7, 26.0 (3 C), 18.8, 18.3, 14.9, 11.0, -5.4 (2 C); $[\alpha]^{20}_D$ -19.8° (c 1.01, CHCl$_3$). Anal. Calcd for $C_{24}H_{42}O_4Si$: C, 68.20; H, 10.01. Found, C, 68.26; H, 10.05.

(2*S*,3*S*,4*S*,6*R*)-1,3-[(*p*-Methoxybenzylidene)dioxy]-2,4,5-trimethylheptan-7-ol (20). To a stirred solution of 8.4 mg (19.9 μmol) of acetal **19** in 0.20 mL of tetrahydrofuran at 0 °C under nitrogen was added 0.100 mL (99.4 μmol) of 1.1 M tetrabutylammonium fluoride in tetrahydrofuran. The mixture was stirred for 5 h and quenched with water. The aqueous layer was extracted with ether, and the combined extracts were dried over magnesium sulfate and concentrated under reduced pressure. The yellow oil was purified by flash chromatography on silica gel. Elution with 1:1 ether–hexane afforded 5.1 mg (84%) of alcohol **20**: IR (film) ν 3410, 2950, 2920, 2840, 1615, 1515, 1460, 1380, 1300, 1245, 1005, 930, 825 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.38 (d, 2 H, J = 8.5 Hz, aryl H), 6.87 (d, 2 H, J = 8.8 Hz, aryl H), 5.41 (s, 1 H, benzylidene H), 4.00 (br s, 2 H, ROCH$_2$), 3.78 (s, 3 H, OCH$_3$), 3.42 (m, 2 H, ROCH$_2$), 1.60 (m, 3 H, 3 CHCH$_3$), 1.14 (d, 3 H, J = 6.9 Hz, CHCH_3), 0.91 (d, 3 H, J = 6.5 Hz, CHCH_3), 0.85 (d, 3 H, J = 6.8 Hz, CHCH_3); ^{13}C NMR (75 MHz, CDCl$_3$) δ 160.3, 131.7, 127.6 (2 C), 114.0 (2 C), 102.2, 85.5, 74.3, 67.5, 55.6, 37.8, 33.9, 32.7, 30.5, 19.0, 15.9, 11.2; $[\alpha]^{22}_D$ -26.5° (c 1.28, CHCl$_3$). Anal. Calcd for $C_{18}H_{28}O_4$: C, 70.10; H, 9.15. Found: C, 70.03; H, 9.21.

Methyl (*E*)-(4*S*,5*S*,6*S*,8*R*)-5-(Benzyloxy)-9-[(*p*-methoxybenzyl)oxy]-4,6,8-trimethyl-2-nonenoate (22). To a solution of 6 μL (0.07 mmol) of oxalyl chloride in 0.232 mL of dry methylene chloride under argon at -78 °C was added 0.01 mL (0.139 mmol) of dimethyl sulfoxide.[9] The mixture was allowed to stir for 25 min, and then 20 mg (0.0465 mmol) of alcohol **13** in 0.5 mL of dry methylene chloride was added and stirring was continued for 1.5 h, after which 0.033 mL (0.232 mmol) of triethylamine was added and the mixture was warmed to 0 °C with stirring. The thick mixture was diluted with 2 mL of water, and the phases were separated. The organic phase was washed with water, dried over sodium sulfate, and concentrated under reduced pressure.

The resulting oil was diluted with 0.3 mL of dry methylene chloride. To the solution was added 48 mg (0.139 mmol) of (carbomethoxymethylene)triphenylphosphorane, and the mixture was stirred overnight. The reaction was diluted with 1:1 ether–hexane, and the solution was placed directly on a column of silica gel for purification by flash chromatography. Elution with 1:1 ether–hexane afforded 18.7 mg (82%) of ester **22**: IR (film) ν 2970, 2880, 1725, 1615, 1215, 1460, 1250, 1100, 1040, 825, 710 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.32 (m, 5 H, phenyl H), 7.23 (d, 2 H, J = 8.6 Hz, aryl H), 6.98 (dd, 1 H, J = 8.3, 15.7 Hz, vinyl H), 6.85 (d, 2 H, J = 8.7 Hz, aryl H), 5.83 (d, 1 H, J = 15.7 Hz, vinyl H), 4.55, 4.50 (AB q, 2 H, J = 11.3 Hz, benzyl H), 4.41, 4.36 (AB q, 2 H, J = 11.7 Hz, benzyl H), 3.78 (s, 3 H, OCH$_3$), 3.71 (s, 3 H, CO$_2$Me), 3.30, 3.11 (AB of ABX, J_{AB} = 9.0 Hz, J_{AX} = 4.7 Hz, J_{BX} = 4.8 Hz, CHCH_2OR), 3.12 (m, 1 H, CHOR), 2.64 (m, 1 H, CHCH$_3$), 1.80 (m, 2 H, 2 CHCH$_3$), 1.11 (d, 3 H, J = 6.7 Hz, CHCH_3), 1.02 (m, 2 H, CHCH_2CH), 0.96 (d, 3 H, J = 6.8 Hz, CHCH_3), 0.95 (d, 3 H, J = 6.6 Hz, CHCH_3); ^{13}C NMR (75 MHz, CDCl$_3$) δ 167.1, 159.7, 152.7, 138.7, 130.9, 129.0 (2 C), 128.3 (2 C), 127.7 (2 C), 127.5, 120.2, 113.7 (2 C), 87.4, 75.1, 74.8, 72.7, 55.3, 51.5, 39.6, 36.4, 34.0, 31.2, 19.2, 17.6, 15.1; $[\alpha]^{20}_D$ -2.38° (c 1.01, CHCl$_3$); HRMS calcd for $C_{28}H_{38}O_5$ 454.2719, found m/e 454.2711 (M$^+$). Anal. Calcd for $C_{28}H_{38}O_5$: C, 73.98; H, 8.42. Found: C, 73.88; H, 8.47.

(*E*)-(4*S*,5*S*,6*S*,8*R*)-5-(Benzyloxy)-9-[(*p*-methoxybenzyl)oxy]-4,6,8-trimethyl-2-nonen-1-ol (23). To a solution of 50.7 mg (0.11 mmol) of ester **22** in 0.6 mL of dry methylene chloride under argon at -78 °C was added 0.280 mL (0.280 mmol) of 1.0 M DIBAH[6] in hexanes. The mixture was allowed to stir for 1 h, and the product was isolated as described for alcohol **4**. The resulting oil was purified by flash chromatography on silica gel. Elution with 1:1 ether–hexane afforded 43.2 mg (91%) of alcohol **23**: IR (film) ν 3440, 2980, 2940, 2880, 1615, 1515, 1350, 1090, 755, 710 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.32 (m, 5 H, phenyl H), 7.23 (d, 2 H, J = 8.6 Hz, aryl H), 6.85 (d, 2 H, J = 8.6 Hz, aryl H), 5.61 (br s, 1 H, vinyl H), 5.60 (br s, 1 H, vinyl H), 4.57, 4.51 (AB q, 2 H, J = 11.3 Hz, benzyl H), 4.40 (s, 2 H, benzyl H), 4.0 (br s, 2 H, CH_2OH), 3.78 (s, 3 H, OCH$_3$), 3.26, 3.15 (AB of ABX, 2 H, J_{AB} = 9.2 Hz, J_{AX} = 5.7 Hz, J_{BX} = 6.4 Hz, CH_2OPMB), 3.04 (dd, 1 H, J = 4.1, 6.9 Hz, CHOBn), 2.49 (m, 1 H, CHCH$_3$), 1.84 (m, 1 H, CHCH$_3$), 1.80 (m, 1 H, OH), 1.63 (m, 1 H, CHCH$_3$), 1.06 (d, 3 H, J = 6.7 Hz, CHCH_3), 0.97 (d, 3 H, J = 6.8 Hz, CHCH_3), 0.96 (m, 2 H, CHCH_2CH), 0.92 (d, 3 H, J = 6.6 Hz, CHCH_3); ^{13}C NMR (75 MHz, CDCl$_3$) δ 159.0, 139.0, 135.9, 130.6, 129.2 (2 C), 128.4, 128.3 (2 C), 127.6 (2 C), 127.4, 113.7 (2 C), 87.7, 75.5, 74.5, 72.6, 63.6, 55.2, 39.3, 36.4, 33.4, 30.9, 18.7, 17.7, 16.7; $[\alpha]^{20}_D$ -0.52° (c 3.48, CHCl$_3$). Anal. Calcd for $C_{27}H_{38}O_4$: C, 76.02; H, 8.98. Found: C, 75.93; H, 9.01.

(*E*)-(4*S*,5*S*,6*S*,8*R*)-1,5-Bis(benzyloxy)-9-[(*p*-methoxybenzyl)oxy]-4,6,8-trimethyl-2-nonene (24). To a stirred solution of 43.2 mg (0.101 mmol) of alcohol **23** in 1 mL of benzene at room temperature were added 5 mL (0.010 mmol) of tris[2-(2-methoxyethoxy)ethyl]amine, 11.4 mg (0.202 mmol) of crushed potassium hydroxide, and 48 mL (0.405 mmol) of benzyl bromide, and the slurry was stirred overnight. The reaction was quenched with 4 mL of 1:1 water–ether, and the aqueous layer was extracted with ether. The combined extracts were dried over magnesium sulfate and concentrated under reduced pressure. The resulting oil was purified by flash chromatography on silica gel. Elution with 9:1 hexane–ether afforded 47.7 mg (91%) of ether **24**: IR (film) ν 2970, 2940, 2870, 1515, 1455, 1250, 1095, 740, 700 cm^{-1}; ^{1}H NMR (300 MHz, CDCl$_3$) δ 7.33 (m, 10 H, phenyl H), 7.22 (d, 2 H, J = 7.9 Hz, aryl H), 6.84 (d, 2 H, J = 7.9 Hz, aryl H), 5.70 (dd, 1 H, J = 7.6, 15.5 Hz, vinyl H), 5.60 (dt, 1 H, J = 5.5, 15.5 Hz, vinyl H), 4.56 (s, 2 H, benzyl H), 4.48 (s, 2 H, benzyl H), 4.40, 4.34 (AB q, 2 H, J = 11.7 Hz, benzyl H), 3.95 (d, 2 H, J = 5.5 Hz, CH$_2$OBn),

3.78 (s, 3 H, OCH_3), 3.34, 3.10 (AB of ABX, J_{AB} = 9.1 Hz, J_{AX} = 4.7 Hz, J_{BX} = 7.5 Hz, CH_2OPMB), 3.05 (dd, 1 H, J = 4.8, 6.4 Hz, CHOBn), 2.51 (m, 1 H, $CHCH_3$), 1.82 (m, 2 H, 2 $CHCH_3$), 1.09 (d, 3 H, J = 6.7 Hz, $CHCH_3$), 1.01 (m, 2 H, $CHCH_2CH$), 0.97 (d, 3 H, J = 7.6 Hz, $CHCH_3$), 0.97 (d, 3 H, J = 6.6 Hz, $CHCH_3$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 158.9, 139.0, 138.4, 138.0, 130.9, 128.9 (2 C), 128.3 (2 C), 128.2 (2 C), 127.7 (2 C), 127.5 (3 C), 127.3, 125.7, 113.6 (2 C), 88.3, 75.2, 74.8, 72.6, 71.9, 70.9, 55.2, 39.4, 36.6, 33.6, 31.2, 19.2, 17.6, 16.1; $[\alpha]^{20}_D$ −3.85° (*c* 1.56, $CHCl_3$). Anal. Calcd for $C_{34}H_{44}O_4$: C, 79.03; H, 8.58. Found: C, 79.10; H, 8.61.

(*E*)-(4*S*,5*S*,6*S*,8*R*)-1,5-Bis(benzyloxy)-4,6,8-trimethyl-2-nonen-9-ol (25). To a stirred solution of 13.3 mg (0.025 mmol) of ether **24** in 0.270 mL of 18:1 methylene chloride–water at room temperature was added 8.7 mg (38.5 μmol) of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone.[12] After stirring for 5 min the dark mixture turned reddish in color. The reaction was quenched with saturated sodium bicarbonate. The organic layer was washed with water, dried over magnesium sulfate, and concentrated under reduced pressure. The resulting oil was purified by flash chromatography on silica gel. Elution with 3:1 hexane–ether afforded 8.2 mg (80%) of alcohol **25**: IR (film) ν 3420, 2965, 2930, 2870, 1450, 1360, 1065, 975, 735, 700 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.33 (m, 10 H, phenyl H), 5.65 (m, 2 H, vinyl H), 4.57 (s, 2 H, benzyl H), 4.50 (s, 2 H, benzyl H), 3.94 (d, 2 H, J = 6.1 Hz, CH_2OBn), 3.37 (m, 2 H, CH_2OH), 3.06 (dd, 1 H, J = 6.7, 4.6 Hz, CHOBn), 2.52 (m, 1 H, $CHCH_3$), 1.82 (m, 1 H, $CHCH_3$), 1.67 (m, 1 H, $CHCH_3$), 1.60 (m, 1 H, OH), 1.08 (d, 3 H, J = 6.7 Hz, $CHCH_3$), 1.00 (m, 2 H, $CHCH_2CH$), 0.97 (d, 3 H, J = 6.8 Hz, $CHCH_3$), 0.92 (d, 3 H, J = 6.4 Hz, $CHCH_3$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 138.8, 138.2, 138.1, 128.4 (2 C), 128.3 (2 C), 127.8 (2 C), 127.7, 127.6 (2 C), 127.5, 125.7, 88.4, 75.2, 72.3, 70.9, 66.8, 39.8, 35.0, 33.6, 33.0, 18.5, 18.0, 16.4; $[\alpha]^{20}_D$ −2.98° (*c* 0.90, $CHCl_3$). Anal. Calcd for $C_{26}H_{36}O_3$: C, 78.75; H, 9.15. Found: C, 78.66; H, 9.19.

(*E*)-(2*R*,4*S*,5*S*,6*S*)-5,9-Dihydroxy-2,4,6-trimethyl-7-nonenecarboxylic Acid δ-Lactone (27). To a stirred solution of 10.4 mg (0.026 mmol) of alcohol **25** in 0.26 mL of dry dimethylformamide under nitrogen was added 49 mg (0.132 mmol) of pyridinium dichromate. The dark mixture was stirred overnight, filtered through Florisil, and concentrated under reduced pressure. The residue was filtered through silica gel with 1% acetic acid in ether, and the filtrate was concentrated under reduced pressure.

The crude acid **26** was diluted with 2 mL of dry THF, and the mixture was cooled to −78 °C. Into this solution was condensed 2 mL of dry ammonia, and then 12 mg (0.316 mmol) of sodium was added. The yellow solution was stirred until it became deep blue, whereupon the excess sodium was quenched with solid ammonium chloride. The mixture was warmed to room temperature, and the ammonia was evaporated. The residue was diluted with 4 mL of ether and acidified with 10% HCl. The aqueous layer was extracted with ether, and the combined extracts were dried over magnesium sulfate and concentrated under reduced pressure. The resulting oil was purified by flash chromatography on silica gel. Elution with 3:1 ether–hexane afforded 2.4 mg (45%) of lactone **27**: IR (film) ν 3410, 2970, 2935, 2880, 1725, 1460, 1370, 1200, 1110, 1040, 990, 975 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 5.85 (dd, 1 H, J = 7.5, 15.5 Hz, vinyl H), 5.68 (dt, 1 H, J = 5.6, 16.4 Hz, vinyl H), 4.10 (d, 2 H, J = 5.5 Hz, $HOCH_2$), 3.95 (dd, 1 H, J = 2.3, 10.0 Hz, CO_2CH), 2.47 (m, 2 H, 2 $CHCH_3$), 1.91 (m, 1 H, $CHCH_3$), 1.61 (br s, 1 H, OH), 1.34 (m, 2 H, $CHCH_2CH$), 1.25 (d, 3 H, J = 7.1 Hz, $CHCH_3$), 1.01 (d, 3 H, J = 6.9 Hz, $CHCH_3$), 0.98 (d, 3 H, J = 6.4 Hz, $CHCH_3$); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.6, 135.0, 129.4, 89.8, 63.6, 38.0, 37.5, 36.2, 30.9, 17.3, 17.2, 12.5; $[\alpha]^{23}_D$ +59.3 (*c* 0.30, $CHCl_3$).

(*E*)-(2*R*,4*S*,5*S*,6*S*)-9-(1-Ethoxyethoxy)-5-hydroxy-2,4,6-trimethyl-7-nonenecarboxylic Acid δ-Lactone (28). To a stirred solution of 3.3 mg (15.5 μmol) of alcohol **27** in 0.150 mL of dry methylene chloride under nitrogen was added 13 μL (93.3 μmol) of ethyl vinyl ether and a catalytic amount of pyridinium *p*-toluenesulfonate. The mixture was stirred for 5 h at room temperature and was quenched with 2 mL of water. The aqueous layer was extracted with methylene chloride, and the combined extracts were dried over magnesium sulfate and concentrated under reduced pressure. The clear oil was purified by flash chromatography on silica gel. Elution with 1:1 ether–hexane afforded 4.1 mg (93%) of lactone **28**: IR (film) ν 2990, 2950, 2890, 1730, 1465, 1385, 1195, 1135, 1110, 980, 800 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 5.86 (dd, 1 H, J = 7.9, 15.4 Hz, vinyl H), 5.61 (dt, 1 H, J = 6.2, 15.4 Hz, vinyl H), 4.70 (q, 1 H, J = 5.3 Hz, acetal H), 4.05 (m, 2 H, $ROCH_2$), 3.95 (m, 1 H, carbinyl H), 3.50 (m, 2 H, CH_2CH_3), 2.46 (m, 2 H, 2 $CHCH_3$), 1.90 (m, 1 H, $CHCH_3$), 1.30 (d, 3 H, J = 5.3 Hz, $CH_3CH(OR)_2$), 1.25 (d, 3 H, J = 7.1 Hz, $CHCH_3$), 1.19 (t, 3 H, J = 7.0 Hz, CH_3CH_2), 1.01 (d, 3 H, J = 7.0 Hz, $CHCH_3$), 0.97 (d, 3 H, J = 6.4 Hz, $CHCH_3$); $[\alpha]^{20}_D$ +20.7° (*c* 0.41, $CHCl_3$); HRMS calcd for $C_{15}H_{25}O_4$ 269.1753, found *m/e* 269.1753 (M − CH_3).

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Supplementary Material Available: Calculated energies for i and ii and ^1H NMR spectra for **15–17**, **27**, and **28** (8 pages). Ordering information is given on any current masthead page.