Synthesis of a Vitamin D_3 Hydrindan Ring−Side-Chain Building Block, Involving Tandem Conjugate Addition and Alkylation Reactions

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Abstract: Vitamin D_3 hydrindan ring−side-chain building block **4** (racemic) has been synthesized from ketene acetal **12** (derived from 6-methylheptanoic acid), 2-methylcyclopent-2-en-1-one (**13**), allyl methyl carbonate, and dimethyl methylphosphonate. The Mukaiyama−Michael conjugate addition of **12** and **13** yielded the adduct **11** (*lk*) accompanied by ca. 10% of its diastereomer. Allylation of **11** with allyl methyl carbonate in the presence of palladium catalyst afforded **10**. The latter was transformed into enol lactone **26**, which on treatment with 2 equiv of lithium dimethyl methylphosphonate and then 1 equiv of acetic acid provided **4**.

Introduction

Recent discoveries of important new biological properties of vitamin D_3 metabolites and analogs[1] have given a fresh impetus to the longstanding interest in the synthesis of these compounds.[2] The classical approach[3] using cholesterol or related readily available sterols as starting materials embraces several low-yield steps (including photochemical rearrangement) and imposes significant limitations on the availability of analogues. Owing to advances in the methodology of stereoselective transformations, the total synthesis appears to provide the most versatile and efficient strategy for the small-scale synthesis of 1α,25-dihydroxyvitamin D_3 (**1**, Scheme 1) and the congeners fuctionalized, both in ring A and in the side chain. The convergent synthesis of vitamin D pioneered by Lythgoe and co-workers[4] consists of the separate preparation of the CD ring-side-chain fragments **2** or **3** and the appropriate ring A fragments (not shown) and in combining these fragments in the due course. The synthesis of C/D ring−side-chain fragments **2** or **3**, which comprise the *trans*-hydrinadan structure of steroids[5] and several terpenoids, have received a great deal of attention.[6] It occurred to us that some progress in the diastereoselective approach to **2** and/or **3** could be attained by using the Mukaiyama−Michael conjugate addition[7] as the strategic reaction. Our retro-synthetic considerations are illustrated in Scheme 1.

It was assumed that compound **2** will be secured from the precursor **4** by one of the methods that have been well documented.[2] It was considered that sulfone **3** will likewise be accessible by the reduction either of the double bond in α,β-unsaturated ketone **6** and then the removal of the oxo group or of the double bond in vinyl sulfone **5** (devoid of the oxo group).[8] In principle, the reduction of **5** (or **6**) to yield **3** should be technically simpler than the transformation of **4** into **2**, since in the latter case the reduction of a double bond and oxygen function transposition are involved.

Ring C in the intermediates **4**, **5**, or **6** was thought to be constructed by annulation of the suitable precursors **7**, **8**, and **9**. The vinyl derivative **10** could also serve as an attractive precursor of **4**, as a similar compound has already been used in vitamin D synthesis.[9] Preparation of compounds **4**, **5**, and **6** from their respective precursors **7**−**10** would additionally require a reduction of the thioester group at C_{21} (steroid numbering), which should not pose any difficulty.

Intermediates **7**−**10** were expected to be attained by the diastereoselective reactions of silyl enol ether **11** with

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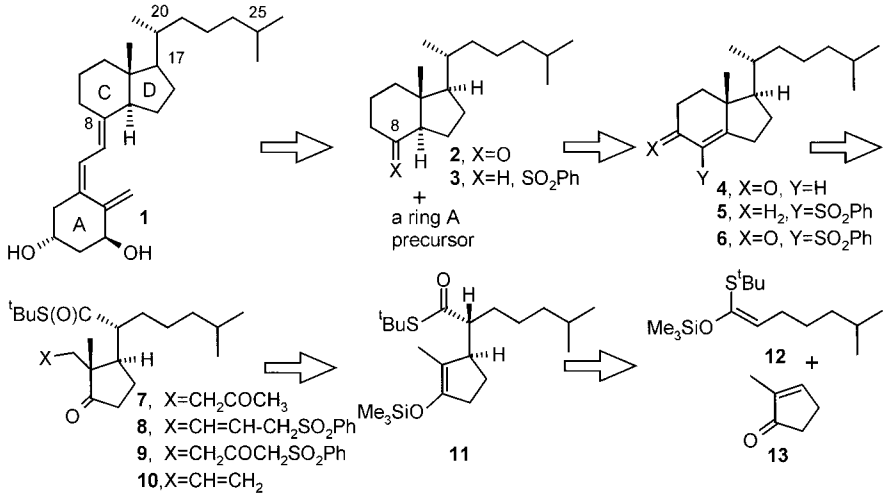
Scheme 1

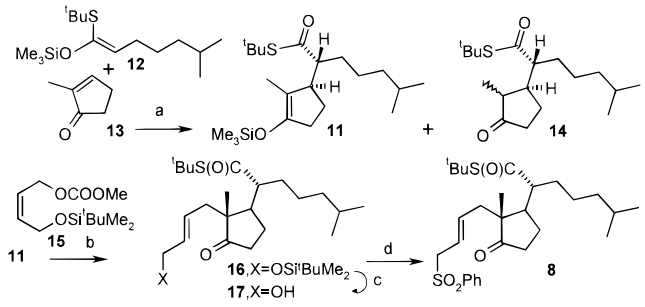


the respective electrophiles, such as methyl vinyl ketone (to generate **7**) or allyl carbonates in the presence of palladium catalyst.[10] It has been shown that in alkylation of cyclopentanone enolates similar to **11** formation of the new C−C bond occurs on the side opposite (*trans*) to the γ-substitutent.[11]

The intermediate **11** will play the crucial role in the planned synthesis. It bears two chiral centers (C_{17} and C_{20}) in the *lk* configuration. It was envisioned that this intermediate will be prepared by the conjugate addition of ketene acetal **12** (derived from *tert*-butylthio 6-methylheptanoate) to unsaturated ketone **13**. Mukaiyama and co-workers have reported[10c] that ketene acetals generated from *tert*-butylthio propionate and trialkyl(aryl)silyl chloride react with **13** to give the respective adducts with high *lk* diastereoselectivity. There were legitimate reasons to assume that elongation of the ketene acetal side chain will not affect the reaction yield or the stereoselectivity. It should be noted that the synthesis of each of the compounds **7**−**10** entails two consecutive reactions generated by the silyl enol ether moiety. Because of the similarity in the reaction conditions, it was expected that these two reactions could be carried out in tandem in one synthetic operation.

With this general plan allowing for some options with respect to the character of ring C precursors, we have chosen to first examine[12] routes leading *via* intermediate **8** or **10**. Preparation of these two compounds from **11** consists of allylation of the silyl enol ether moiety, for which some precedents have been recorded.[10] In this paper, we describe a diastereoselective synthesis of **4** utilizing the reaction of **12** and **13**, followed by allylation of **11** to yield **10**. The attempted synthesis of **3** *via* **8** will also be discussed.

Scheme 2[a]



[a] Key: (a) 3 mol % $TrSbCl_6/CH_2Cl_2$, −78 °C; (b) 2 mol % $Pd_2(dba)_3{\cdot}CHCl_3$−dppe/THF, 60 °C, 87% from **13**; (c) $Bu_4NF{\cdot}3H_2O$, 86%; (d) $TsCl/Et_3N$−DMPA/CH_2Cl_2 then $PhSO_2Na$/DMSO.

Results and Discussion

The reaction of ketene acetal **12** with 2-methylcyclopent-2-en-1-one[13] (**13**) (Scheme 2) in the presence of trityl hexachloroantimonate gave a mixture of *O*-(trimethylsilyl) enol ether **11** and the corresponding ketone **14**. Labile trimethylsilyl enol ether **11** (contaminated with its diastereomer, ca. 10%, by ^{1}H NMR) could be isolated in 40−50% yield, along with ketone **14**, 12−18%, by flash chromatography on silica gel deactivated with Et_3N. Some **14** was always formed in parallel with the main reaction product (even under rigorously anhydrous conditions), most likely by the proton−trimethylsilyl group exchange[14] involving **11** and **13**. The treatment of crude **11** with *cis*-allyl carbonate **15** and palladium dibenzylideneacetone complex $Pd_2(dba)_3{\cdot}CHCl_3$, according to the procedure of Tsuji and co-workers,[10] smoothly afforded the product **16** in 87% overall yield from **13**. In the ^{1}H NMR spectrum of **16**, vinylic protons signals occurred as a multiplet at δ 5.64−5.36 ppm. The presence of a contaminant (ca. 10%) could be detected, being most likely that of the isomer with respect to the double-bond configuration. The configuration of the double bond in **16** became evident after the *tert*-butyldimethylsilyl group had been removed. In the ^{1}H NMR spectrum of **17**

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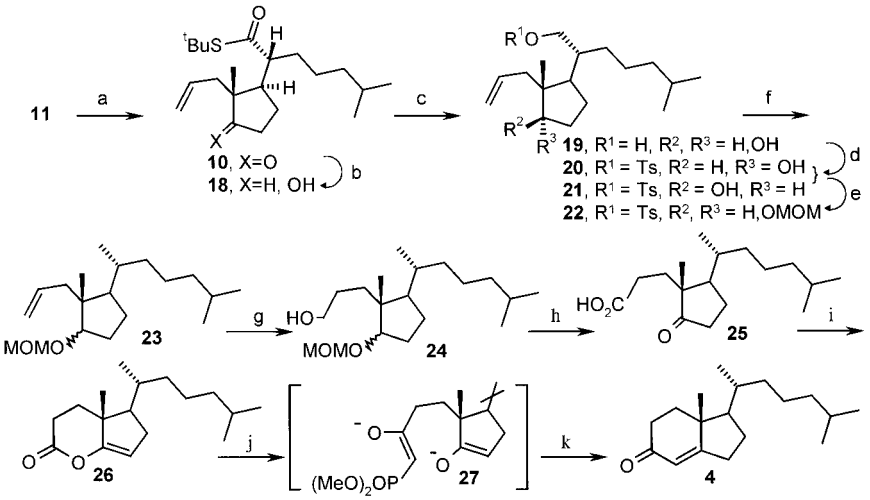
(11) For an example, see: Duhamel, P.; Dujardin, G.; Hennequin, L.; Poirier, J.-M. *J. Chem. Soc., Perkin Trans. 1* **1992**, 387−396. Cf. ref 10a,c.

(12) A preliminary communication from this work has been published: Marczak, S.; Wicha, J. *Tetrahedron Lett.* **1993**, *34*, 6627−6630. For relevant work from this laboratory, see: Marczak, S.; Michalak, K.; Wicha, J. *Tetrahedron Lett.* **1995**, *36*, 5425−5428. Michalak, K.; Stepanenko, W.; Wicha, J. *Tetrahedron Lett.* **1996**, *37*, 7657−7658.

(13) For a simple procedure for preparation of this compound, see: Marczak, S.; Michalak, K.; Wicha, J. *Pol. J. Chem.* **1994**, *68*, 321−322.

(14) For mechanism of the Mukaiyama reaction, see: (a) Hollis, T. K.; Bosnich, B. *J. Am. Chem. Soc.* **1995**, *117*, 4570−4581. (b) Otera, J.; Fujita, Y.; Sakuta, N.; Fujita, M.; Fukuzumi, S. *J. Org. Chem.* **1996**, *61*, 2951−2962.

Scheme 3[a]



[a] Key: (a) allyl methyl carbonate, 5 mol % $Pd_2(dba)_3$·$CHCl_3$, 63% overall from **13**; (b) $NaBH_4$/EtOH, 0 °C, 96%, 1:2 isomer ratio; (c) $LiAlH_4$; (d) TsCl−Et_3N/CH_2Cl_2, 95% in two steps; (e) MOMCl; (f) $LiAlH_4$, 89% in two steps; (g) BH_3·Me_2S and then H_2O_2−NaOH; (h) Jones' reagent−H_2SO_4, 61% in two steps; (i) Ac_2O−AcONa, 76%; (j) 2 equiv of $(MeO)_2POCH_2Li$/THF; (k) 1 equiv of AcOH, 64%.

(obtained in 86% yield), vinylic proton resonance occurred at δ 5.64 (1H) as a doublet of triplets, J = 5.6, 15.4 Hz, and at δ 5.45, 1H, dt, J = 6.8, 15.4 Hz, with the large coupling constant typical of *trans*-oriented protons. The isomerization of the double bond in the allylic carbonate moiety in the course of the reaction involving a π-allylpalladium complex was not entirely surprising, although in certain cases complete retention of the double bond *cis*-configuration has been reported.[15]

The next objective was to synthesize oxo sulfone **8** and to affect the closure of ring C. Accordingly, **17** was treated with TsCl in the presence of Et_3N, and the crude product consisting of the tosylate and the respective chloride was reacted with sodium phenylsulfinate to give **8**. Cyclization of **8** was examined using protic and aprotic solvents and a variety of bases. However, the required product could not be obtained. A reluctance of **8** to generate the *cis*-double bond isomer, which was the necessary intermediate in the ring closure, was considered responsible for this failure. To remove the obstacle to intramolecular reaction, hydrogenation of the double bond in **8** (and in **17**) over palladium catalyst was attempted. However, poisoning of the catalyst was observed.

Next, we examined an alternative approach to the CD ring-side-chain fragment of vitamin D, involving **10** as the key intermediate. The reaction of ketene acetal **12** and enone **13** in the presence of $TrSbCl_6$ afforded silyl enol ether **11**, which, in the crude form, was treated with allyl methyl carbonate and palladium catalyst, as described above. The expected product **10** (Scheme 3) was obtained in 63% yield from **12**, along with its diastereomer (7% yield) and ketone **14** (9% yield). Reduction of **10** with $LiAlH_4$ afforded a mixture of diols **19** that was selectively tosylated at the primary hydroxy group. At this stage, the mixture of isomers was easily separated by chromatography on a silica gel column into pure components **20** and **21** (in a ratio of 1:2).

Since reduction of the carbonyl group flanked by the methyl and allyl groups occurred with marked selectivity, we pursued the isomer structure determination. The measurement of the nuclear Overhauser effect between C_{14}-H and the protons of the angular methyl group (C_{18}) in both isomers unequivocally indicated structure **20** with the hydroxy group in the α-orientation for the minor product (for details of COSY and NOE experiments, see the Supporting Information). This means that addition of the hydride anion to the carbonyl group occurred predominantly on the side of the allyl group. Interestingly, on irradiation of C_{18}-H, a significant enhancement of the signals corresponding to C_{20}-H was also recorded (6.5% for **20** and 3.6% for **21**), which indicates proximity in space of respective protons.

Coming back to the synthesis, the secondary hydroxy group in a crude mixture of **20** and **21** was protected with the methoxymethyl group, and the derivative **22** was treated with $LiAlH_4$ to give **23**. Hydroboration of **23** with the BH_3·Me_2S complex followed by oxidation afforded **24**, which was then treated with Jones' reagent containing some additional sulfuric acid. Under these conditions, oxidation of the primary hydroxy group and deprotection, and oxidation of the secondary hydroxy group, occurred to provide keto acid **25**. Crude **25** was dehydrated with acetic anhydride essentially according to the described procedure[9] to give **26**. The ^1H NMR spectrum of this compound was identical with that of the authentic sample.[16]

It is noteworthy that treatment of **10** with sodium borohydride resulted in regioselective reduction of the keto group in the presence of the thioester group to give a mixture of isomeric alcohols **18** (ca. 1:2, no stereochemical assignments was made) in an excellent yield. This regioselective reduction may be useful in the future utilization of the intermediate **10**.

To complete the synthesis, lactone **26** was transformed into the AB-des-cholestane derivative **4**. A two-step procedure for this transformation was reported previously.[9,17] It involves exposure of **26** to 1 equiv of methylmagnesium bromide, in order to add the methyl group

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to the lactone carbonyl, and then annulation of the resultant 1,5-dione. It was tempting to make use of a procedure invented by the Syntex workers[18] and then improved by Aristoff[19] for steroid ring A lactone elaboration. According to this procedure, **26** was subjected to reaction with 2 equiv of lithium dimethyl methylphosphonate (THF, −78 °C), whereupon dianion **27** was quenched with 1 equiv of acetic acid. The intermediate monoanions underwent intramolecular cyclization (at 55 °C) to give the target compound[20] **4** as the sole product.

In conclusion, a new concise synthesis of vitamin D and sterol building block **4** from ketene acetal **12** and methylcyclopentenone **13** was developed. It has been shown that the Mukaiyama−Michael conjugate addition of **12** and **13** affords intermediate **11** in a highly diastereoselective manner. Further transformations of **11** involve palladium-catalyzed reaction with allyl methyl carbonate to yield **10** and, after elaboration of **10** into lactone **26**, addition of lithium dimethyl methylphosphonate as the carbon C_8 precursor. Attempted cyclization of the oxo sulfone **8** failed.

Experimental Section

Melting points were determined on a hot-stage apparatus and are uncorrected. NMR spectra were recorded for $CDCl_3$ solutions with the resonance of residual chloroform at δ_H 7.26 and δ_C 77.00 as internal references. ^{13}C DEPT experiments are reported as quaternary (0), tertiary (1), secondary (2), and primary (3). Mass spectra were determined at an ionizing voltage of 70 eV. Anhydrous solvents were obtained by distillation from potassium−sodium/benzophenone (diethyl ether, THF) or calcium hydride (dichloromethane, benzene, toluene). Air-sensitive reactions were performed in oven- or flame-dried glassware under argon. Organic extracts were dried over anhydrous Na_2SO_4, and solvents were evaporated on a rotary evaporator. Column chromatography was performed on Merck silica gel 60, 230−400 mesh, and TLC on Merck aluminum sheets, silica gel 60 S_{254}. Optical rotations were measured with a Perkin-Elmer Model 141 polarimeter using a 8 mL capacity cell (10 cm path length) for $CHCl_3$ solutions, unless otherwise stated. Microanalyses were performed at our analytical laboratory.

1-(*tert*-Butylsulfanyl)-1-[(trimethylsilyl)oxy]-6-methylhept-1-ene[21] (12). To a solution of LDA, prepared from diisopropylamine (8.9 mL, 0.068 mol) and *n*-BuLi (1.2 M, 60 mL), was added 6-methylheptanethioic acid *S*-*tert*-butyl ester (13.35 g, 0.062 mol) (for preparation of this compound from 1-bromo-3-methylbutane and methyl acrylate see the Supporting Information) dropwise at −78 °C. The mixture was stirred at −78 °C for 1 h, Me_3SiCl (20.5 mL, 0.163 mol) was added, and the cooling bath was removed. After 4 h, the solution was decanted, and the solvent was evaporated. The residue was distilled at 123 °C/8 Torr to give **12** (14.1−16.5 g, 79−92%): ^1H NMR (200 MHz) δ 5.21 (1H, t, J = 7.5 Hz), 2.15 (2H, dt, J = 7.3 Hz, 7.3 Hz), 1.69−1.04 (5H, m), 1.36 (9H, s), 0.86 (6H, d, J = 6.6 Hz), 0.21 (9H, s); ^{13}C NMR and DEPT (50 MHz) δ 145.01 (0), 121.08 (1), 46.29 (0), 38.53 (2), 31.75 (3), 29.39 (1), 27.85 (2), 27.78 (2), 22.63 (3), 0.32 (3). The minor isomer: ^1H NMR δ 1.33 ($SCCH_3$) (isomer ratio ca. 10:1); ^{13}C NMR δ 31.37.

(2*R,1′*R**)-6-Methyl-2-[2′-methyl-3′-[(trimethylsilyl)oxy]cyclopent-2-enyl]heptanethioic Acid *S*-*tert*-Butyl Ester (11) and (2*R**,1′*S**,2′*ξ*)-6-Methyl-2-(2′-methyl-3′-oxocyclopentyl)heptanethioic Acid *S*-*tert*-Butyl Ester (14).** To a solution of **13** (623 mg, 6.5 mmol) and $TrSbCl_6$ (114 mg, 0.2 mmol, 3 mol %) in CH_2Cl_2 (35 mL), stirred at −78 °C, was added a solution of **12** (2.06 g, 7.14 mmol) in CH_2Cl_2 (5 mL) dropwise. Stirring at −78 °C was continued for 30 min, the reaction was quenched with pyridinemethanol (0.13 mL, 1.3 mmol), and the mixture was diluted with hexane (120 mL). The precipitate was filtered off, and the solvent was evaporated. The residue was chromatographed on SiO_2 (30 g, deactivated with 1% Et_3N in hexane, elution with hexane) to give **11** (1.00−1.25 g, 40−50% yield) and **14** (244−366 mg, 12−18%). **11**: ^1H NMR (500 MHz) δ 2.87 (1H, m), 2.57 (1H, ddd, J = 2.5, 4.4, 10.9 Hz), 2.26−2.14 (2H, m), 1.82−1.60 (3H, m), 1.55−1.47 (1H, m), 1.48 (3H, m), 1.45 (9H, s), 1.38−1.29 (1H, m), 1.22−1.10 (4H, m), 0.84 (6H, d, J = 6.6 Hz), 0.17 (9H, s); ^{13}C NMR and DEPT (125 MHz) δ 203.69 (0), 148.66 (0), 113.88 (0), 56.83 (1), 48.40 (1), 47.65 (0), 39.05 (2), 32.81 (2), 29.81 (3), 27.76 (1), 26.25 (2), 25.61 (2), 22.66 (3), 22.45 (3), 21.99 (2), 10.46 (3), 0.55 (3). **14**: ^1H NMR (500 MHz) δ 2.46 (1H, ddd, J = 3.4, 7.5, 10.8 Hz), 2.36−2.30 (1H, m), 2.16−2.10 (2H, m), 2.10−1.90 (2H, m), 1.71−1.64 (1H, m), 1.56−1.10 (7H, m), 1.46 (9H, s), 1.08 (3H, d, J = 6.8 Hz), 0.85 (6H, br d, J = 6.6 Hz); ^{13}C NMR (125 MHz) δ 220.16, 203.01, 58.57, 48.35, 46.80, 38.82, 36.90, 30.07, 29.64, 27.76, 25.17, 24.83, 22.64, 22.37, 14.21; MS EI 312 (6); HRMS calcd for $C_{18}H_{32}O_2S$ 312.212 30, found 312.212 03. The diastereomer of **14**: ^1H NMR 1.45 (s) δ 1.03 (d, J = 7.6 Hz); ^{13}C NMR 55.10, 48.14, 45.10, 42.43, 38.92, 36.81, 31.19, 29.71, 24.35, 23.94, 10.61.

(*Z*)-4-[(*tert*-Butyldimethylsilyl)oxy]but-2-enyl Methyl Carbonate (15). A solution of (*Z*)-4-hydroxybut-2-enyl methyl carbonate[22] (920 mg, 6.3 mmol), TBSCl (1.24 g, 8.2 mmol), imidazole (560 mg, 8.2 mmol), and DMAP (50 mg) in CH_2Cl_2 (20 mL) was stirred at rt for 1 h, and then the reaction was quenched with ice-cold water. The product was extracted with hexane. The extract was washed with 1 M aqueous HCl and then with aqueous $NaHCO_3$. The solvent was evaporated. The residue (2.3 g) was chromatographed on SiO_2 (50 g, hexane whereupon 1% EtOAc in hexane) to give **15** (985 mg, 378 mmol, 60%): ^1H NMR (200 MHz) δ 5.75 (1H, dtt, J = 1.3, 5.7, 11.2 Hz), 5.58 (1H, dtt, J = 1.6, 6.5, 11.2 Hz), 4.72 (2H, dd, J = 1.1, 6.4 Hz), 4.28 (2H, br dd, J = 1.5, 5.7 Hz), 3.78 (3H, s), 0.89 (9H, s), 0.07 (6H, s).

(2*R,1′*R**,2′*R**)-2-[2′-[(*E*)-4-[(*tert*-Butyldimethylsilyl)oxy]but-2-enyl]-2′-methyl-3-oxocyclopentyl]-6-methylheptanethioic Acid *S*-*tert*-Butyl Ester (16).** To a solution of **13** (140 mg, 1.46 mmol) and $TrSbCl_6$ (24 mg, 0.044 mmol, 3 mol %) in CH_2Cl_2 (7 mL), stirred at −78 °C, was added a solution of **12** (460 mg, 1.6 mmol) in CH_2Cl_2 (2 mL) dropwise. After 30 min at −78 °C, the reaction was quenched with pyridinemethanol (0.03 mL, 0.3 mmol) in hexane (30 mL), and the mixture was allowed to warm to rt. The precipitate was filtered off, and the solvent was evaporated to give crude **11**, which was dissolved in THF (10 mL) and treated consecutively with bis(diphenylphosphino)ethane (dppe, 80 mg, 0.2 mmol), $Pd_2(dba)_3{\cdot}CHCl_3$ (43 mg, 0.04 mol, 3 mol %), and allyl carbonate **15** (500 mg, 1.9 mmol). The mixture was heated at 60 °C until **11** was consumed (TLC, 3−6 h) and then was cooled to rt and poured into 1 M aqueous HCl. The product was extracted with CH_2Cl_2, and the extract was washed with aqueous $NaHCO_3$. The solvent was evaporated. The residue (850 mg) was chromatographed on SiO_2 (45 g, 3.5% EtOAc in hexane) to give **16** (631 mg, 1.27 mmol, 87%) and **14** (41 mg, 0.13 mmol, 9%). **16**: ^1H NMR (200 MHz) δ 5.64−5.36 (2H, m), 4.08 (2H, d, J = 4.0 Hz), 2.60−2.20 (4H, m), 2.15−1.85 (3H, m), 1.55−1.02 (8H, m), 1.47 (9H, s), 0.99 (3H, s), 0.88 (9H, s), 0.85 (6H, d, J = 6.6 Hz), 0.04 (6H, s); ^{13}C NMR and DEPT (50 MHz) δ 222.22 (0), 203.24 (0), 133.81 (1), 125.97 (1), 63.99 (2), 54.86 (1), 52.64 (0), 48.65 (0), 43.37 (1), 39.20 (2), 38.47 (2), 37.68 (2), 31.96 (2), 29.87 (3), 28.02 (1), 26.16 (3), 24.61 (2), 23.62 (2), 22.84 (3), 22.63 (3), 18.97 (3), 18.58 (0), −4.92 (3) (additional signals appeared at 31.77 (2) and 14.29 (3) which reflects ca. 10% contamination, most likely with the *cis*

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isomer of **16**); MS EI 481 (0.5%); HR MS calcd for $C_{27}H_{49}O_3SiS$ 481.3172, found 481.3174; $(M - C_4H_9)^+$ calcd for $C_{24}H_{43}O_3SiS$ 439.2702, found 439.2704.

(2*R,1′*R**,2′*R**)-2-[2′-((*E*)-4-Hydroxybut-2-enyl)-2′-methyl-3-oxocyclopentyl]-6-methylheptanethioic Acid *S*-*tert*-Butyl Ester (17).** A solution of **16** (500 mg, 1.0 mmol) and tetrabutylammonium fluoride trihydrate (TBAF·$3H_2O$, 785 mg, 3 mmol) in THF (10 mL) was stirred at rt for 3 h, and then it was diluted with CH_2Cl_2 and washed with aqueous $NaHCO_3$. The solvent was evaporated, and the residue (500 mg) was chromatographed on SiO_2 (20 g, 5% EtOAc in hexane) to give **17** (330 mg, 0.86 mmol, 86%): ^{1}H NMR (200 MHz) δ 5.64 (1H, dt, J = 5.6, 15.4 Hz), 5.45 (1H, dt, J = 6.8, 15.4 Hz), 4.04 (2H, d, J = 5.4 Hz), 2.63−2.24 (4H, m), 2.13−1.80 (3H, m), 1.70−1.10 (8H, m), 1.47 (9H, s), 0.99 (3H, s), 0.85 (6H, d, J = 6.6 Hz); ^{13}C NMR and DEPT δ 222.27 (0), 203.57 (0), 133.50 (1), 127.72 (1), 63.73 (2), 54.74 (1), 52.56 (0), 48.76 (0), 43.43 (1), 39.14 (2), 38.37 (2), 37.58 (2), 32.00 (2), 29.84 (3), 27.98 (1), 24.60 (2), 23.56 (2), 22.81 (3), 22.61 (3), 18.86 (3).

(2*R,1′*R**,2′*R**)-2-[2′-Methyl-3-oxo-2′-[(*E*)-4-(phenylsulfonyl)but-2-enyl]cyclopentyl]-6-methylheptanethioic Acid *S*-*tert*-Butyl Ester (8).** To a solution of **17** (300 mg, 0.78 mmol) in CH_2Cl_2 (20 mL) were added Et_3N (0.22 mL, 1.58 mmol), DMAP (20 mg, 0.16 mmol), and TsCl (230 mg, 1.18 mmol) consecutively at rt. The mixture was stirred for 12 h, and then the reaction was quenched with 1 M aqueous HCl. The products (TLC showed two main products; it was assumed that tosylate and the corresponding chloride were formed) were extracted with CH_2Cl_2. The extract was washed with aqueous $NaHCO_3$ and evaporated. The residue was dissolved in dry DMSO (10 mL), $PhSO_2Na$ (380 mg, 2.34 mmol) was added, and the mixture was stirred at 60 °C for 10 h. After cooling, the mixture was poured into water. The product was isolated with ether and purified by chromatography on SiO_2 (9 g, 20% EtOAc in hexane) to give **8** (160 mg, 0.31 mmol, 40%): ^{1}H NMR (200 MHz) δ 7.92−7.80 (2H, m), 7.70−7.48 (3H, m), 5.50−5.28 (2H, m), 3.71 (2H, d, J = 6.2 Hz), 2.60−1.75 (7H, m), 1.65−1.10 (8H, m), 1.45 (9H, s), 0.95 (3H, s), 0.86 (6H, d, J = 6.6 Hz); ^{13}C NMR δ 221.90, 203.56, 138.87, 136.89, 133.61, 129.17, 128.70, 120.34, 60.44, 54.84, 52.42, 48.80, 43.37, 39.14, 38.47, 37.35, 32.17, 29.81, 27.98, 24.54, 23.70, 22.82, 22.60, 18.81.

(2*R,1′*R**,2′*R**)-2-(2′-Allyl-2′-methyl-3′-oxocyclopentyl)-6-methylheptanethioic Acid *S*-*tert*-Butyl Ester (10).** To a solution of crude **11**, prepared as described above (starting from **13**, 620 mg), in THF (60 mL), were added dppe (260 mg, 0.65 mmol), $Pd_2(dba)_3$·$CHCl_3$ (120 mg, 0.12 mmol, 2 mol %), and allyl methyl carbonate (1.6 mL, 13.5 mmol) consecutively. The mixture was heated at 60 °C until **11** was consumed (TLC, 3−6 h) and then was cooled and poured into 1 M aqueous HCl. The product was extracted with CH_2Cl_2, the extract was washed with aqueous $NaHCO_3$, and the solvent was evaporated. The oily residue (3.2 g) was chromatographed on SiO_2 (100 g, 5% EtOAc in hexane) to give (1) **10** (1.38 g, 3.92 mmol, 60%), (2) a mixture of **10** and its diastereomer (420 mg, in a ratio of 1.2:1, by NMR), and (3) ketone **14** (187 mg, 0.6 mmol, 9%). **10**: IR (film) 1742, 1677 cm^{-1}; ^{1}H NMR (200 MHz) δ 5.72−5.48 (1H, m), 5.10−4.95 (2H, m), 2.62−2.25 (4H, m), 2.12−1.90 (3H, m), 1.60−1.08 (8H, m), 1.49 (9H, s), 1.02 (3H, s), 0.87 (6H, d, J = 6.6 Hz). ^{13}C NMR and DEPT (50 MHz) δ 222.16 (0), 203.37 (0), 133.95 (2), 118.75 (1), 54.62 (1), 52.38 (0), 48.59 (0), 43.22 (1), 39.86 (2), 39.02 (2), 37.57 (2), 31.87 (2), 29.70 (3), 27.85 (1), 24.45 (2), 23.47 (2), 22.70 (3), 22.48 (3), 18.79 (3); MS EI 352 (30); HRMS calcd for $C_{21}H_{36}O_2S$ 352.243 50, found 352.243 46. The diastereomer of **10**: ^{1}H NMR (200 MHz) δ 1.04 (3H, s); ^{13}C NMR (50 MHz) δ 220.99, 133.92, 117.96, 54.22, 51.80, 49.67, 39.06, 36.89, 35.95, 31.93, 24.52, 23.12, 22.14.

(2*R,1′*R**,2′*R**,3′ξ)-2-(2′-Allyl-3′-hydroxy-2′-methylcyclopentyl)-6-methylheptanethioic Acid *S*-*tert*-Butyl Ester (18).** To a solution of **10** (66 mg, 0.187 mmol) in ethanol (5 mL), stirred at 0 °C, was added $NaBH_4$ (15 mg, 0.4 mmol). The mixture was stirred at rt for 3 h, and then the reaction was quenched with 1 M aqueous HCl (2 mL) and $CHCl_3$ (30 mL) was added. The solution was washed with aqueous $NaHCO_3$. The solvent was removed, and the residue was chromatographed on SiO_2 (8 g, 5% EtOAc in hexane) to give **18** (64 mg, 0.18 mmol, 96%): IR (film) 3425, 1679 cm^{-1}; ^{1}H NMR (500 MHz) δ 6.01−5.90 (1H, m), 5.11−5.01 (2H, m), 3.84 (1H, dd, J = 8.8 Hz, 8.8 Hz), 2.50−2.20 (3H, m), 2.05−1.85 (3H, m), 1.75−1.00 (10H, m) overlapping 1.46 (9H, s), 0.90 (3H, s), 0.86 (6H, d, J = 6.6 Hz); ^{13}C NMR and DEPT (50 MHz) δ 204.01 (0), 136.02 (1), 117.34 (2), 77.61 (1), 55.23 (1), 48.16 (0), 46.25 (0), 45.59 (1), 43.09 (2), 38.92 (2), 32.36 (2), 29.53 (3), 28.25 (2), 27.76 (1), 24.35 (2), 24.08 (2), 22.63 (3), 22.40 (3), 12.90 (3). The minor isomer: ^{1}H NMR δ 3.76 (1H, d, J = 5.2 Hz), 1.47 (9H, s), 0.86 (6H, d, J = 6.6 Hz), 0.85 (3H, s) (isomer ratio ca. 2:1); ^{13}C NMR and DEPT (50 MHz) δ 136.49 (1), 116.43 (2), 80.84 (1), 55.13 (1), 48.50 (0), 48.05 (0), 46.99 (1), 41.00 (2), 33.36 (2), 29.75 (2), 26.68 (2), 24.47 (2), 17.39 (3); MS EI 354 (1, M^+); HRMS calcd for $C_{21}H_{38}O_2S$ 354.259 25, found 354.259 82.

(2*R,1′*R**,2′*R**,3′*R*)-2-(2′-Allyl-3′-hydroxy-2′-methylcyclopentyl)-6-methylheptan-1-ol 1-Tosylate (20) and (2*R**,1′*R**,2′*R**,3′*S*)-2-(2′-Allyl-3′-hydroxy-2′-methylcyclopentyl)-6-methylheptan-1-ol 1-Tosylate (21).** To a stirred suspension of $LiAlH_4$ (340 mg, 9 mmol) in THF (45 mL) was added a solution of **10** (1.06 g, 3 mmol) in THF (20 mL) dropwise at 0 °C. The mixture was stirred at rt for 15 h, and then wet THF (10 mL), 1 M aqueous NaOH (2 mL), and water (4 mL) were consecutively added. The mixture was filtered through a pad of Celite. The filtrate was evaporated. The residue (**19**, 1 g) was dissolved in CH_2Cl_2 (50 mL) and treated with Et_3N (1 mL), DMAP (100 mg), and TsCl (600 mg, 3.1 mmol). The mixture was stirred at rt for 18 h, and then it was poured into 1 M aqueous HCl. The product was extracted with CH_2Cl_2. The extract was washed with water and then with aqueous $NaHCO_3$. The solvent was removed to give a crude mixture of **20** and **21** (1.2 g, 95%). In order to determine the relative configuration of alcohols **20** and **21** a sample of crude product (300 mg) was chromatographed on SiO_2 (30 g, hexane−EtOAc, 9:1) to give **20** (97 mg) and then **21** (195 mg). **20**: ^{1}H NMR (500 MHz) δ 7.79−7.75 (2H, m), 7.34−7.30 (2H, m), 5.93−5.83 (1H, m), 5.06−5.00 (2H, m), 3.97 (2H, part AB of ABX system, δ_A = 4.00, δ_B = 3.94, J_{AB} = 9.6 Hz, J_{AX} = 4.9 Hz, J_{BX} = 4.8 Hz), 3.70 (1H, dd, J = 2.4, 2.4 Hz), 2.42 (3H, s), 2.18 (1H, dd, J = 13.9, 7.9 Hz), 1.95 (1H, dd, J = 13.9, 6.5 Hz) overlapping 1.94−1.85 (1H, m), 1.85−1.75 (1H, m), 1.64−0.95 (11H, m) overlapping 1.65 (1H, m, part X of the ABX system), 0.80 (3H, d, J = 6.6 Hz), 0.79 (3H, d, J = 6.6 Hz), 0.71 (3H, s); ^{13}C NMR (50 MHz) δ 144.61, 135.97, 132.90, 129.70, 127.86, 116.82, 80.84, 71.89, 48.02, 44.98, 41.35, 39.08, 37.79, 30.56, 29.00, 27.77, 25.07, 24.38, 22.56, 22.39, 21.52, 18.04; HRMS calcd for $C_{24}H_{38}O_4S$ 422.2491, found 422.2487. H, H COSY and NOE data for **20** are given in the Supporting Information. **21**: mp 61−62 °C (acetone−hexane); ^{1}H NMR (500 MHz) δ 7.72−7.68 (2H, m), 7.28−7.24 (2H, m), 5.84−5.74 (1H, m), 5.00−4.95 (2H, m), 3.89 (2H, AB part of ABX system, δ_A = 3.90, δ_B = 3.87, J_{AB} = 9.6 Hz, J_{AX} = 5.0 Hz, J_{BX} = 4.5 Hz), 3.70 (1H, dd, J = 8.3, 8.3 Hz), 2.36 (3H, s), 2.05 (1H, ddd, J = 13.9, 7.0, 1.2 Hz), 1.85−1.69 (3H, m), 1.56 (1H, m) overlapping 1.59−0.91 (11H, m), 0.74 (3H, d, J = 6.6 Hz), 0.73 (3H, d, J = 6.6 Hz), 0.67 (3H, s); ^{13}C NMR (50 MHz) δ 144.71, 135.43, 132.95, 129.75, 127.92, 117.77, 78.22, 71.75, 46.32, 44.18, 44.08, 39.09, 38.00, 29.09, 28.23, 27.83, 24.55, 22.59, 22.44, 21.59, 13.37. Anal. Calcd for $C_{24}H_{38}O_4S$ (422.2491): C, 68.21; H, 9.06. Found: C, 68.28; H, 9.05. COSY and NOE data for **21** are given in the Supporting Information.

(2*R,1′*R**,2′*R**,3′ξ)-2-[2′-Allyl-3′-[(methoxymethyl)oxy]-2′-methylcyclopentyl]-6-methylheptan-1-ol 1-Tosylate (22).** A crude mixture of **20** and **21** (1.34 g, 3.2 mmol), ^{i}Pr_2EtN (1.3 mL, 8.0 mmol), MOMCl (0.4 mL, 4.8 mmol), and CH_2Cl_2 (50 mL) was stirred at rt for 18 h and then poured into 1 M aqueous HCl (50 mL). The organic layer was separated. The aqueous layer was extracted with CH_2Cl_2. The combined organic extracts were washed with water and then with aqueous $NaHCO_3$, and the solvent was evaporated. The residue (1.57 g) was chromatographed on SiO_2 (50 g, 3% EtOAc in hexane) to give **22** (1.33 g, 89%): ^{1}H NMR (200 MHz) δ 7.84−7.74 (2H, m), 7.38−7.30 (2H, m), 5.92−5.66 (1H, m), 5.07−4.87 (2H, m), 4.61 (1H, A part of AB quartet, J = 6.6 Hz), 4.56 (1H, part B of AB quartet, J = 6.6 Hz), 4.04−3.88

(2H, part AB of ABX system), 3.65−3.51 (1H, m), 3.32 (3H, s), 2.43 (3H, s), 2.35−0.90 (15H, m), 0.80 (6H, d, J = 6.6 Hz), 0.74 (3H, s); ^{13}C NMR and DEPT (50 MHz) δ 144.58 (0), 134.45 (1), 132.89 (0), 129.65 (1), 127.84 (1), 117.57 (2), 95.93 (2), 81.97 (1), 71.85 (2), 55.28 (3), 46.26 (0), 42.51 (2), 41.97 (1), 39.06 (2), 37.69 (1), 28.06 (2), 27.76 (1), 27.15 (2), 24.43 (2), 22.92 (2), 22.53 (3), 22.41 (3), 21.50 (3), 15.04 (3). The minor isomer: ^{1}H NMR (200 MHz) δ 4.64 (1H, A part of AB quartet, J = 6.8 Hz), 4.55 (1H, part B of AB quartet, J = 6.8 Hz), 3.35 (3H, s), 0.80 (6H, d, J = 6.6 Hz), 0.72 (3H, s); ^{13}C NMR and DEPT (50 MHz) δ 136.00 (1), 116.61 (2), 95.68 (2), 86.51 (1), 72.25 (2), 55.62 (3), 47.33 (0), 45.13 (1), 41.02 (2), 37.80 (1), 28.78 (2), 28.14 (2), 24.52 (2), 18.97 (3); MS EI 435 (10); HRMS calcd for $C_{25}H_{39}O_4S$ (M − OMe)$^+$ 435.2569, found 435.255 42.

(2*R,1′*R**,2′*R**,3′*ξ*)-1-[2′-Allyl-2′-methyl-3′-(methoxymethyl)cyclopentyl]-1,5-dimethylhexane (23).** To a suspension of $LiAlH_4$ (100 mg, 2.6 mmol) in THF (20 mL), stirred at rt, was added a solution of **22** (540 mg, 1.16 mmol) in THF (10 mL). After 4 h, the reaction was terminated and the product recovered as described above. The colorless oil (570 mg) was chromatographed on SiO_2 (15 g, 2% of EtOAc in hexane) to give **23** (276 mg, 80%). An analogous $LiAlH_4$ reduction of crude **22** gave **23** in 89% overall yield from the tosylates. **23**: ^{1}H NMR (200 MHz) δ 6.00−5.78 (1H, m), 5.15−4.90 (2H, m), 4.67 (1H, A part of AB quartet J = 6.6 Hz), 4.56 (1H, B part of AB quartet, J = 6.6 Hz), 3.72−3.57 (1H, m), 3.35 (3H, s), 2.50−1.00 (15H, m), 0.96 (3H, d, J = 6.0 Hz), 0.86 (6H, d, J = 6.6 Hz), 0.83 (3H, s); ^{13}C NMR and DEPT (50 MHz) δ 135.42 (1), 117.45 (2), 96.30 (2), 82.27 (1), 55.56 (3), 46.45 (0), 45.99 (1), 42.61 (2), 39.67 (2), 35.35 (2), 35.02 (1), 28.18 (1), 27.13 (2), 25.08 (2), 24.46 (2), 22.99 (3), 22.75 (3), 19.02 (3), 14.94 (3). The minor isomer: ^{1}H NMR (200 MHz) δ 4.66 (1H, A part of AB quartet, J = 6.7 Hz), 4.58 (1H, B part of AB quartet, J = 6.7 Hz), 3.37 (3H, s), 0.94 (3H, d, J = 6.6 Hz), 0.80 (3H, s); ^{13}C NMR and DEPT (50 MHz) δ 137.16 (1), 116.38 (2), 96.16 (2), 87.84 (1), 55.93 (3), 50.67 (1), 47.81 (0), 41.91 (2), 35.94 (2), 34.49 (1), 28.30 (2), 26.52 (2), 24.76 (2), 20.01 (3), 18.98 (3); MS EI 296 (1); HRMS calcd for $C_{19}H_{36}O_2$ 296.2715, found 296.2714.

(2*R,1′*R**,2′*R**,3′*ξ*)-1,6-Dimethyl-1-[2′-(hydroxypropyl)-3′-[(methoxymethyl)oxy]-2′-methylcyclopentyl]hexane (24).** To a solution of **23** (900 mg, 3.04 mmol) in THF (30 mL), stirred at 0 °C, was added BH_3·Me_2S (10 M in THF, 0.45 mL, 4.5 mmol). The mixture was allowed to warm to rt (in ca. 30 min) and stirred for and additional 2 h, and then the reaction was quenched with 3 M aqueous NaOH (3 mL) followed by H_2O_2 (30%, 2.5 mL). The mixture was diluted with $CHCl_3$ and washed with aqueous $FeSO_4$ and then with water, and the solvent was evaporated. The residue (1.05 g) was chromatographed on SiO_2 (30 g, 10% and then 20% of EtOAc in hexane) to give unreacted **23** (60 mg, 7%) and **24** (843 mg, 2.68 mmol, 88%). **24**: ^{1}H NMR (200 MHz) δ 4.59 (2H, br q, J = 6.6 Hz), 3.75−3.50 (3H, m), 3.34 (3H, s), 2.00−1.00 (17H, m), 0.92 (3H, d, J = 6.6 Hz), 0.84 (6H, d, J = 6.6 Hz), 0.80 (3H, s); ^{13}C NMR and DEPT (50 MHz) δ 95.97 (2), 82.37 (1), 63.57 (2), 55.28 (3), 46.10 (1), 45.41 (0), 39.41 (2), 35.12 (2), 34.66 (1), 34.16 (2), 27.92 (1), 26.89 (2), 24.86 (2), 24.16 (2), 22.74 (3), 22.50 (3), 18.64 (3), 14.95 (3). Signals of the minor isomer: ^{1}H NMR (200 MHz) δ 3.36 (3H, s); ^{13}C NMR and DEPT (50 MHz) δ 95.54 (2), 87.27 (1), 63.82 (2), 55.63 (3), 50.85 (1), 47.42 (0), 35.73 (2), 32.59 (2), 28.20 (2), 27.80 (2), 26.25 (2), 24.51 (2), 19.93 (3); MS EI 314 (1); HRMS calcd for $C_{19}H_{38}O_3$ 314.2821, found 314.2823.

(2*R,1′*R**,2′*R**)-1-[2′-(Carboxyethyl)-2′-methyl-3′-oxocyclopentyl]-1,5-dimethylhexane (25).** To a solution of **23** (1.3 g, 4.4 mmol) in THF (40 mL) was added BH_3·Me_2S in THF (10 M, 0.66 mL, 6.6 mmol) at 0 °C, and the mixture was allowed to warm to rt (in ca. 30 min). After **23** was consumed (TLC, ca. 2 h), 3 M aqueous NaOH (4 mL) and H_2O_2 (30%, 5 mL) were added consecutively. The mixture was diluted with $CHCl_3$ and washed with aqueous $FeSO_4$. The solvent was removed to give **24** (1.43 g), which was dissolved in acetone (50 mL). Concentrated H_2SO_4 (2 mL) was added, and then Jones' reagent was added dropwise until the brown color persisted (ca. 23 mL). The mixture was stirred until **24** was consumed (TLC, ca. 3 h), and then water was added and the product isolated with CH_2Cl_2. The solvent was evaporated, and the residue was chromatographed on SiO_2 (100 g, 50% EtOAc in hexane) to give **25** (0.76 g, 61%): IR (film) 1738, 1711 cm^{-1}; ^{1}NMR (200 MHz) δ 2.5−2.3 (2H, m), 2.3−1.95 (4H, m), 1.9−1.7 (2H, m), 1.65−1.00 (9H, m), 0.99 (3H, d, J = 6.6 Hz), 0.94 (3H, s), 0.88 (6H, d, J = 6.6 Hz); ^{13}C NMR and DEPT (50 MHz) δ 223.34 (0), 179.28 (0), 51.09 (0), 47.66 (1), 39.28 (2), 37.09 (2), 34.27 (2), 33.84 (1), 31.84 (2), 29.42 (2), 27.90 (1), 23.93 (2), 23.15 (2), 22.70 (3), 22.46 (3), 18.44 (3), 17.55 (3); MS EI 267 (14); HRMS calcd for $C_{16}H_{27}O_3$ (M − CH_3)$^+$ 267.196 02, found 267.194 59.

(1*R,1′*R**,7a*R**)-1-(1,5-Dimethylhexyl)-2,3,4,5,6,7-hexahydro-7a*β*-methyl-4-oxaindan-5-one (26).** A solution of **25** (104 mg) in acetic anhydride (10 mL) containing anhydrous sodium acetate (220 mg) was heated under reflux for 14 h. The solvent was evaporated under reduced pressure. The residue was taken up in ether and washed with water and then aqueous $NaHCO_3$. The solvent was removed, and the residue (184 mg) was chromatographed on SiO_2 (20 g, 10% EtOAc in hexane) to give **26** (74 mg, 76%): IR (film) 1769 cm^{-1}; ^{1}H NMR (500 MHz) δ 5.02 (1H, dd, J = 1.7, 3.4 Hz), 2.64 (1H, A part of ABMX system, J_{ab} = −18.0 Hz, J_{ax} = 10.9 Hz, J_{am} = 6.8 Hz), 2.60 (1H, B part of ABMX system, J_{ba} = −18.0 Hz, J_{bx} = 6.6 Hz, J_{bm} = 4.1 Hz), 2.32 (1H, ddd, J = 15.1, 7.1, 3.4 Hz), 1.98 (1H, M part of ABMX system, J_{ma} = 6.8 Hz, J_{mb} = 4.1 Hz, J_{mx} = −13.4 Hz), 1.84 (1H, X part of ABMX system, J_{xm} = −13.4, J_{xa} = 10.9, J_{xb} = 6.6 Hz), 1.75−1.62 (2H, m), 1.53 (1H, septet, J = 6.6 Hz), 1.44−1.32 (2H, m), 1.24−1.00 (4H, m), 1.10 (3H, s), 0.93 (3H, d, J = 6.2 Hz), 0.88 (3H, d, J = 6.6 Hz), 0.87 (3H, d, J = 6.6 Hz) (this ^{1}H NMR spectrum is identical with that of the original sample[9] (by a direct comparison); ^{13}C NMR and DEPT (50 MHz) δ 168.24 (0), 157.63 (0), 102.61 (1), 55.55 (1), 41.21 (0), 39.30 (2), 34.80 (2), 33.50 (1), 33.07 (2), 31.20 (2), 27.92 (1), 27.17 (2), 23.64 (2), 22.73 (3), 22.46 (3), 18.66 (3), 15.88 (3); MS EI 264 (22); HRMS calcd for $C_{17}H_{28}O_2$ 264.2089, found 264.2087.

(1*R,1′*R**,7a*R**)-1-(1,5-Dimethylhexyl)-7a*β*-methyl-2,3,5,6,7,7a-hexahydro-1*H*-inden-5-one (4).** To a stirred mixture of $MePO(OMe)_2$ (0.43 mL, 4 mmol) and THF (60 mL) was added *n*-BuLi (1.4 M in hexane, 2.9 mL, 4.1 mmol) at −78 °C followed, after 1 h, by **26** (0.53 g, 2 mmol) in THF (8 mL). Stirring at −78 °C was continued for 30 min, and then the mixture was allowed to warm to −20 °C over 2.5 h, and AcOH (0.11 mL, 1.92 mmol) was added dropwise. The mixture was heated for 3 h at 55 °C, cooled to 0 °C, and neutralized with 1 M aqueous HCl. Water was added, and the product was isolated with EtOAc. The organic extract was washed with brine, and the solvent was removed. The residue was chromatographed on SiO_2 (30 g, 3% EtOAc in hexane) to give **4** (335 mg, 64%): IR (film) 1672, 1639 cm^{-1}; ^{1}H NMR (200 MHz) δ 5.72 (1H, br s), 2.75−0.75 (17H, m), 1.07 (3H, s), 0.95 (3H, d, J = 6.4 Hz), 0.86 (6H, d, J = 6.6 Hz); ^{13}C NMR and DEPT (50 MHz) δ 199.19 (0), 180.05 (0), 121.35 (1), 55.75 (1), 44.99 (0), 39.39 (2), 37.03 (2), 35.74 (2), 34.34 (1), 33.52 (2), 28.86 (2), 27.97 (1), 26.77 (2), 23.67 (2), 22.76 (3), 22.52 (3), 18.71 (3), 16.14 (3); MS EI 262 (43, M$^+$); HRMS calcd for $C_{18}H_{30}O$: 262.229 66, found 262.229 51. The ^{1}H NMR spectrum is in compliance with that described.[20]

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Supporting Information Available: Experimental procedure for preparation of 6-methylheptanethioic acid *S*-*tert*-butyl ester, ^{1}H and ^{13}C NMR spectra of new compounds **4**, **8**, **10**−**12**, **14**, **15**, **17**, **18**, and **20**−**26** and of some acyclic intermediates, and H,H COSY and NOE data for compounds **20** and **21** (36 pages). This material is contained in 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.

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