by reacting **18** (R^1 = PH, R^2 = R^3 = R^4 = H, n = 2) (1.67 g, 10 mmol), acetic anhydride (3 g, 30 mmol), and $CoCl_2$ (~20 mg) at 80 °C for 3 h. The crude product upon column chromatography yielded **18b** (1.9 g, 79%): IR (thin film) 1733, 1729 cm^{-1}; ^1H NMR ($CDCl_3$) 6.95–7.59 (m, 5 H), 5.41 (t, 1 H, J = 6.9 Hz), 4.52 (t, 2 H, J = 7 Hz), 1.89 (s, 3 H), 1.97 (s, 3 H), 1.43–1.83 (m, 4 H). Anal. Calcd for $C_{14}H_{18}O_4$: C, 67.20; H, 7.20. Found: C, 67.29; H, 7.31.

1′,1′-Dimethylbenzyl 3-Oxobutanoate (22). The reaction was carried out as described above with **19** (2.72 g, 20 mmol), acetic anhydride (4 g, 40 mmol), and $CoCl_2$ (30 mg) at 25 °C for 8 h. The crude product upon column chromatography yielded **22** (0.44 g, 10%). The ^1H NMR of this product was compared with an authentic sample prepared according to ref 13.

1′-Methylcyclohexyl 3-Oxobutanoate (33). The reaction was carried out as described above with **30** (1.70 g, 15 mmol), acetic anhydride (3 g, 30 mmol), and $CoCl_2$ (35 mg). The crude product upon flash column chromatography yielded **33** (0.55 g, 19%). This product was compared with an authentic sample[13] as described above.

1′-Phenylcyclohexyl 3-Oxobutanoate (39). The reaction was carried out as described above with **36** (2.1 g, 12 mmol), acetic anhydride (2.5 g, 25 mmol), and $CoCl_2$ (40 mg). The crude product upon flash column chromatography yielded **39** (0.37 g, 12%) as a semisolid: IR (CH_2Cl_2) 1733, 1727 cm^{-1}; ^1H NMR ($CDCl_3$) 6.97–7.52 (m, 5 H), 3.48 (s, 2 H), 2.08 (s, 3 H), 1.27–1.89 (m, 10 H). Anal. Calcd for $C_{16}H_{20}O_3$: C, 73.84; H, 7.69. Found: C, 73.71; H, 7.55.

1′-Methylcyclopentyl 3-Oxobutanoate (46). The reaction was carried out as described above with **44** (1.5 g, 15 mmol), acetic anhydride (3 g, 30 mmol), and $CoCl_2$ (30 mg). The crude product upon flash chromatography yielded **46** (0.46 g, 17%): IR (CH_2Cl_2) 1735, 1727 cm^{-1}; ^1H NMR (CCl_4) 3.37 (s, 2 H), 2.09 (s, 3 H), 1.39–1.92 (m, 8 H), 1.21 (s, 3 H). Anal. Calcd for $C_{10}H_{16}O_3$: C, 65.22; H, 8.69. Found: C, 65.30; H, 8.73.

Two New Approaches to the 25-Hydroxy-vitamin D_2 Side Chain

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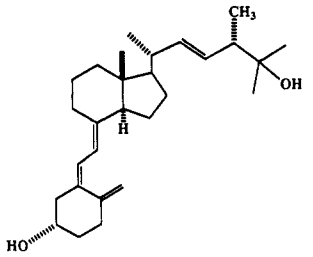
Two approaches to the 25-hydroxy-vitamin D_2 side chain have been developed based on the solvolysis of cyclopropylcarbinyl precursors. The first involves addition of trimethylcyclopropyllithium reagent **4** to a suitably protected C/D system **9**. This reaction leads directly to cyclopropylcarbinols **10a,b** which can be solvolyzed to the vitamin D_2 side chain directly. The second approach uses an intermediate C/D system with a side chain allylic alcohol. Cyclopropanation of the allylic alcohol using Et_2Zn/CH_3CHI_2 produces the same type of cyclopropylcarbinols **10a,b** but in differing isomer ratios. Model studies and stereochemical differences in the two approaches are discussed.

The biological significance and possible uses of 25-hydroxy-vitamin D_2 (**1**) and its metabolites continues to expand.[1] Recent discoveries of the role of vitamin D metabolites in cell differentiation, cell proliferation, and the immune system have prompted renewed interest in synthetic routes.[2] While a classic[3] synthesis of the vitamin D_2 side chain appeared some years ago, several new approaches have recently been reported[4] for the synthesis of 25-OH-D_2 or 1,25-$(OH)_2$-D_2. Nonetheless, good methods for the production of 25-hydroxy side chain isomers are still needed.



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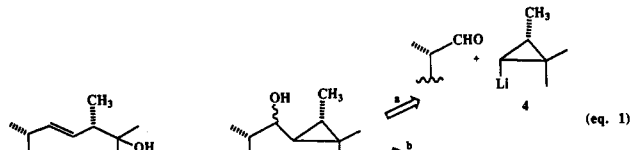
Our own examination of the 25-hydroxy-vitamin D_2 side chain revealed the following retrosynthetic transformations (eq 1). The solvolysis of a cyclopropane such as **3** would produce in one step the vitamin D_2 side chain. The stereocenter at C-24 is created during the cyclopropanation



(eq. 1)

(1) (a) DeLuca, H. F.; Schnoes, H. K. *Ann. Rev. Biochem.* **1983**, *52*, 411. (b) Pardo, R.; Santelli, M. *Bull. Soc. Chim. Fr.* **1985**, 98. (c) Smith, E. L.; Walworth, N. C.; Holick, M. F. *J. Invest. Dermatol.* **1986**, *86*, 709. (d) *Calcium Regulation and Bone Metabolism: Basic and Chemical Aspects*, Cohn, D. V., Ed.; Elsevier Science: New York, 1987. (e) Ikekawa, N.; Eguchi, T.; Hara, N.; Takatsuto, S.; Honda, A.; Mori, Y.; Otomon, S. *Chem. Pharm. Bull* **1987**, *35*, 4362. (f) Calverley, M. J. *Tetrahedron* **1987**, *43*, 4609. (g) *Proceedings of the Seventh Workshop on Vitamin D*: Norman, A. W., Schaefar, K., Grigolief, H. G., Herrath, D. V., Eds.; Walter de Gruyter: Berlin, 1988. (h) Kutner, A.; Perlman, K. L.; Lago, A.; Sicinski, R. R.; Schnoes, H. K.; DeLuca, H. F. *J. Org. Chem.* **1988**, *53*, 3450 and references cited therein. (i) de Costa, B. R.; Holick, S. A.; Holick, M. F. *J. Chem. Soc., Chem. Commun.* **1989**, 325. (j) *Proceedings of the Eighth Workshop on Vitamin D*; Norman, A. W., Ed.; Walter de Gruyter: Berlin, 1991.

(2) For a recent review of vitamin D methods see: Wilson, S. R.; Yasmin, A. In *Topics in Natural Products Chemistry*; Ur-Raman, A., Ed.; Elsevier Science: New York, in press.

(3) Lythgoe, B.; Roberts, D. A.; Waterhouse, I.; *J. Chem. Soc., Perkin Trans. 1* **1977**, 2608.

(4) (a) Salmond, W. G.; Sobala, M. C. *Tetrahedron Lett.* **1977**, 1695. (b) Salmond, W. G.; Barta, M. A.; Haress, J. L. *J. Org. Chem.* **1978**, *43* 790. (c) Sardina, F. J.; Mourino, A.; Castedo, L. *Tetrahedron Lett.* **1983**, 4477. (d) Yamada, S.; Shiraishi, M.; Ohmori, M.; Takayama, H. *Tetrahedron Lett.* **1984**, 3347. (e) Wovkulich, P. M.; Barcelos, F.; Batcho, A. D.; Sereno, J. F.; Baggiolini, E. G.; Hennessy, B. M.; Uskokovic, M. R. *Tetrahedron* **1984**, *40*, 2283. (f) Baggiolini, E. G.; Iacobelli, J. A.; Hennessy, B. M.; Batcho, A. D.; Sereno, J. F.; Uskokovic, M. R. *J. Org. Chem.* **1986**, *51*, 3098. (g) Castedo, L.; Mourino, A.; Mascarenas, J. L. *J. Org. Chem.* **1986**, *51*, 1269. (h) Castedo, L.; Granja, J.; Maestro, M. A.; Mourino, A. *Tetrahedron Lett.* **1987**, 4589. (i) Perlman, K. L.; Schnoes, H. K.; DeLuca, H. F. *J. Chem. Soc., Chem Commun.* **1989**, 1113.

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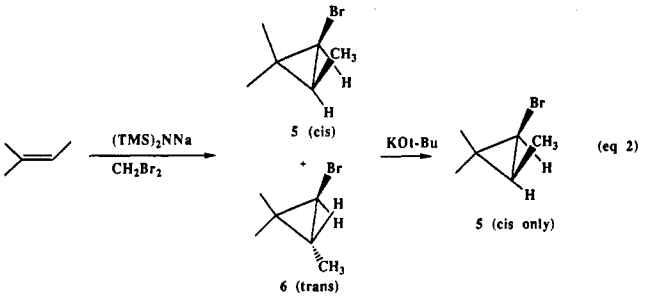
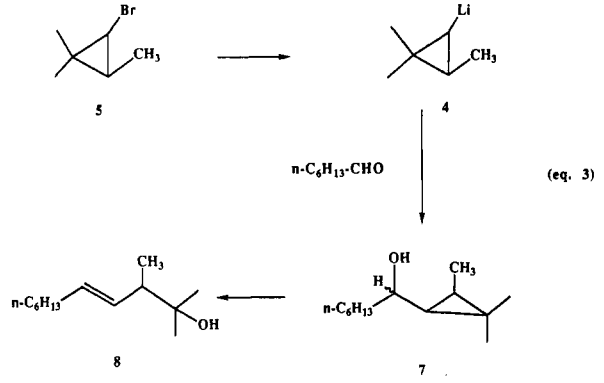
in pathway b, whereas the chiral center at C-24 maintains its configuration during the sequence in pathway a. Because of the biological interest in vitamin D epimers,[5] we have carried out the synthesis and separation of both diastereomers at C-24.

The Cyclopropyllithium Approach (Pathway a). The racemic cyclopropyllithium reagent 4 can be obtained by halogen–metal exchange of the corresponding 1-bromo-2,2,3-trimethylcyclopropane prepared as outlined in eq 2.[6] We obtained a 63% yield of a mixture of cis and



trans isomers **5** and **6** (a ratio of 73/27 by ^{1}H NMR). The trans isomer **6** could be selectively dehydrohalogenated with potassium *tert*-butoxide in dimethyl sulfoxide. Presumably, syn elimination of HBr from *trans*-**6** forms 1,3,3-trimethylcyclopropene which polymerizes while the cis isomer **5** remains untouched. All the work described herein was carried out with *cis*-bromocyclopropane **5** to make the identification of products easier. In principle, however (vide infra), the methodology could as well be carried out with the cis–trans mixture.

Lithium–halogen exchange at −78 °C in THF with 2 equiv of *tert*-butyllithium was carried out as reported by Seebach.[7] Formation of the *cis*-lithium reagent **4** was monitored by GC analysis of aliquots (disappearance of starting bromide **5**) and was complete in 0.5 h (eq 3).

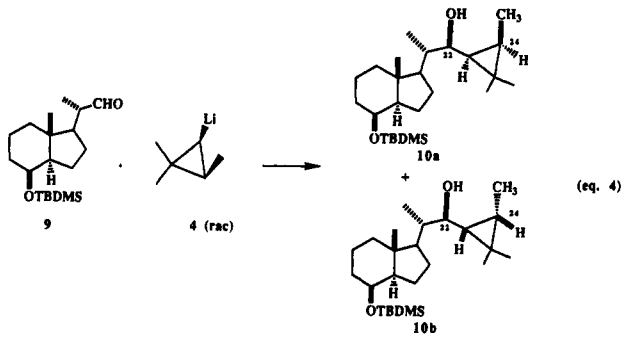


Addition of the heptaldehyde to the cyclopropyllithium reagent **4** gave cyclopropylcarbinyl alcohol **7** in 36% overall yield. Product **7** was obtained as a mixture of two diastereomers in a ratio 1:1 (determined by capillary GC analysis of the acetates). The epimeric alcohols can be separated by radial chromatography eluting with 7% ethyl acetate in hexane. To corroborate the cis relationship of the vicinal protons in the cyclopropane, the ^{1}H NMR spectrum was recorded with decoupling at 3.4 ppm (*CH*-OH), wherein the resonance at 0.57 ppm corresponding to the adjacent cyclopropyl methine hydrogen collapses to a doublet (J = 8.71 Hz). If the cyclopropane hydrogens had been trans, the coupling constant should have been 3–5 Hz.[8]

Solvolysis of compound **7** in 75% dioxane in water containing a catalytic amount of *p*-toluenesulfonic acid gave an 85% isolated yield of (*E*)-2,3-dimethyl-4-undecen-2-ol (**8**). The stereoselective production of *trans*-olefin (J = 15.2 Hz) from the mixture of cyclopropylcarbinyl alcohols was expected and is a consequence of the stability of the cation whose lifetime is long enough to allow isomerization to the more stable trans geometry.

In another experiment heptaldehyde reacted with a cyclopropyl lithium reagent derived from the cis/trans mixture of bromides to produce four isomers. Capillary GC of their acetates showed a ratio of 15:15:35:35. The two first peaks correspond to the *trans*-(2,2,3-trimethylcyclopropyl)-1-heptanols (1*S*,1*R*,3*S* and 1*R*,1*R*,3*S*) and the other two correspond to the cis diastereomers. Solvolysis of this mixture, however, again gives only compound **8**.

Preparation of the 25-Hydroxy D_2 Side Chain. A suitably protected C/D aldehyde substrate **9** was prepared as described in ref 4e. Aldehyde **9** is evidently fairly hindered, since it did not react cleanly with reagent **4** under our usual conditions (i.e., eq 3). However, if 25 mol % TMEDA is added to the reaction mixture to increase the nucleophilicity of reagent **4**, then cyclopropylcarbinols **10a** and **10b** were formed in 49% yield (eq 4).[9] Alcohols **10a**



and **10b** were formed as a separable mixture of diastereomers at C23 and C24 (steroidal numbering). The isomers are the result of Cram addition of reagent **4** to aldehyde **9** and therefore have the 22*R* configuration. Thin-layer chromatography (Analtech reversed-phase F, 7% ethyl acetate in hexane) shows two major spots (R_f 0.34 and 0.31). The compound at R_f 0.34 was identified as **10a** and the compound at R_f = 0.31 as **10b** by the transformations which follow.[12] Thus, a resolution of the side chain stereochemistry for (24*R* and -*S*)-25-hydroxy-vitamin D_2 has been achieved chromatographically. Solvolysis (75% dioxane–water/pTsOH) of compound **10a** gave **11a** in 98% yield (eq 6). Under the same conditions compound

(5) (a) For the synthesis and properties of C24-epimers of vitamin D see: Sicinski, R. R.; Tanaka, Y.; Schnoes, H. K.; DeLuca, H. F. *Bioorganic Chem.* **1985**, *13*, 158. (b) For the remarkable activities of C20-epimers of vitamin D see: Calverley, M. J.; Binderup, E.; Binderup, L. In *Proceedings of the Eighth Workshop on Vitamin D*; Bouillon, R., Norman, A. W., Thomasset, M., Eds.; Walter de Gruyter: Berlin, 1991.

(6) Martel, B.; Hiriart, J. M. *Synthesis* **1972**, 201.

(7) Seebach, D.; Newmann, H. *Chem. Ber.* **1978**, *111*, 2785.

(8) Wiberg, K. B.; Barth, D. E.; Schertler, P. H. *J. Org. Chem.* **1973**, *38*, 378.

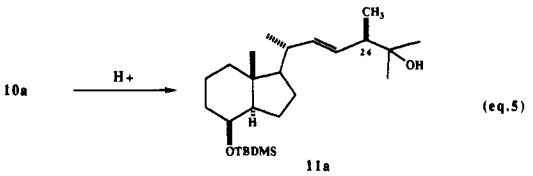
(9) The 20*S* stereochemistry of the series **10a,b**–**13a,b** was established by the characteristic ^{1}H NMR shifts of the C21 methyl group.[10] The 20*S* isomers show a signal 0.1 ppm downfield from the corresponding 20*R* isomers. A comparison was made with authentic **13b**.[11] Expansion of the 400-MHz methyl region of our **13a,b** and authentic **13b** is shown in the supplementary material.

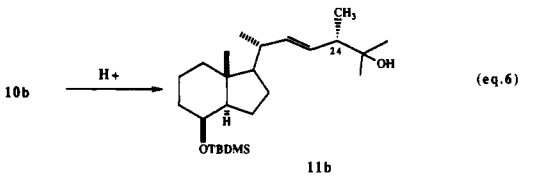
(10) For a discussion of the assignment of C20 configuration by the chemical shift of the C21 methyl group see: Narwid, T. A.; Cooney, K. E.; Uskokovich, M. R. *Helv. Chim. Acta* **1974**, *57*, 771.

(11) We gratefully acknowledge the late Enrico G. Baggiolini, Hoffmann-LaRoche Inc., for a sample of compound **12b**.

(12) Minor products (>8%) isomeric with compounds **10a,b** could be observed at R_f = 0.43 and 0.38 and were isolated (see Experimental Section) but their stereochemistry was not unequivocally determined.

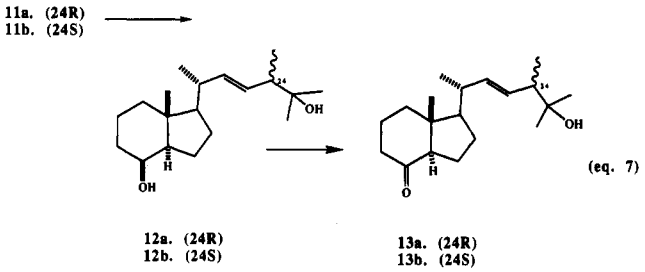
10b gave **11b** in 94% yield (eq 5). Stereoisomers **11a** and



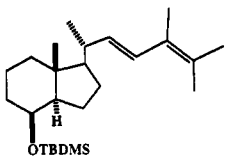


11b have very similar properties. The ^1H NMR spectra of the alcohols **11a** and **11b** at 300 MHz are virtually identical except for the shape of the multiplet of the olefinic protons at 5.3 ppm (400-MHz NMR resolution of the 24-methyl groups is described later for **13a,b**). The ^{13}C spectrum of a mixture of **11a** and **11b** shows two sets of olefinic signals at 129.04, 129.23, and 139.36, 139.74 ppm revealing in this way the existence of diastereomers.

To complete the synthesis of the vitamin D_2 Windaus–Grundman ketones **13a** and **13b**, alcohols **11a** and **11b** were deprotected and oxidized as shown in eq 7. Hydrolysis



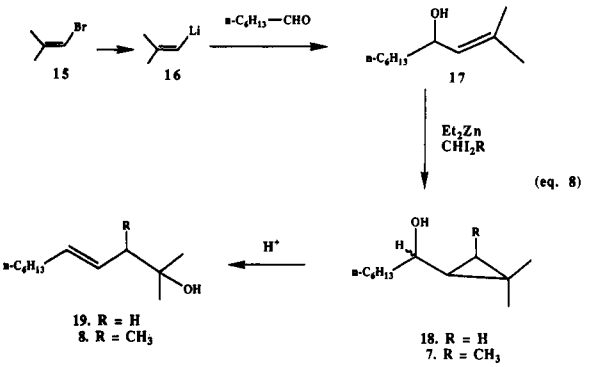
of the dimethyl-*tert*-butylsilyl protecting group in **11b** with 48% aqueous hydrofluoric acid in acetonitrile (5:95) gave **12b** in 95% yield. When the reaction was carried out on **11a**, however, an 8% yield of the dehydration product **14**



was obtained as a side product. The ^1H NMR spectrum of **14** shows distinct chemical shifts for the olefinic protons: a doublet of doublets at 5.39 ppm (H_1, J = 15.2, 8.7 Hz) and a doublet at 6.42 ppm (H_2, J = 15.3 Hz).

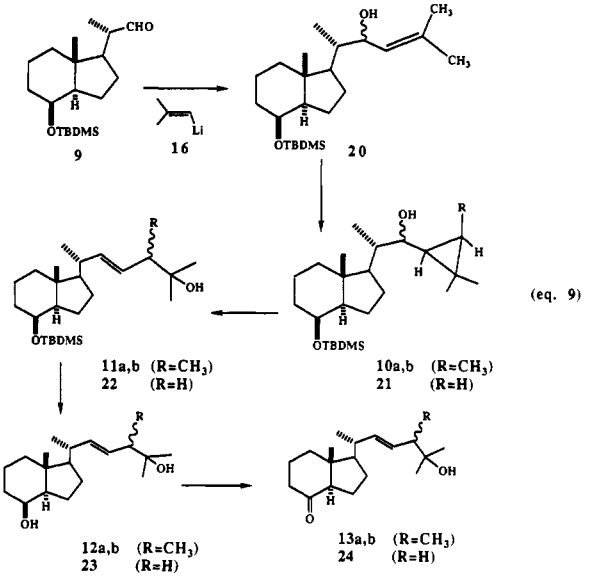
Oxidation of alcohols **12a** or **12b** with PCC in methylene chloride gave ketones **13a** or **13b**, respectively, in high yield. The ^1H NMR spectrum of one isomer has a doublet at 1.086 ppm (J = 6.48 Hz), and the spectrum of the other isomer has a doublet at 1.092 ppm (J = 6.47 Hz). To make the configurational assignments of the two series, we synthesized **13b** from an authentic sample of **12b**.[11] TLC, GC, and NMR comparison proved the identity of our compound **13b** with the authentic sample. The ^1H NMR spectrum of **13b** presents two doublets at 1.092 ppm (J = 6.47 Hz) and 1.02 ppm (J = 6.86 Hz, C-21 methyl), while the isomer **13a** shows doubletts at 1.086 ppm and 1.02 ppm (J = 6.86 Hz, C-21 methyl). Expansion of the 400-MHz spectra of these isomers and their comparison with known **13b** are shown in the supplementary material.

An Alternative Approach (Pathway b). An alternative approach to the same type of cyclopropyl carbinol precursors involves cyclopropanation of an allylic alcohol (eq 8). A model study for such a strategy was carried out



by conversion of the commercially available 1-bromo-2-methylpropene (**15**) to vinyllithium (**16**) followed by addition to heptaldehyde to give allylic alcohol **17** in 72% yield. Cyclopropanation of **17** was accomplished with diethylzinc and methylene iodide or 1,1-diiodoethane[13] to produce **18** or **7**, respectively. (Compound **7** consists of a different diastereomeric mixture from **7** represented in eq 2 which employed *cis*-cyclopropyllithium reagent **4** and thus was a mixture of only two of the possible epimeric alcohols.) Solvolysis of **18** (75% dioxane/water–*p*TsOH) gave 2-methyl-4*E*-undecen-2-ol (**19**) in 76% yield, whereas similar treatment of **7** gave **8**, identical to that prepared previously.

The reaction of the dimethylvinyllithium (**16**) with freshly prepared aldehyde **9** (eq 9) gave **20** in 77% yield as a 7:3 mixture of 22*RS*-diastereomers.



While the epimers could be separated (see Experimental Section), cyclopropanation of the mixture with diethylzinc/methylene iodide gave compound **21** which was converted to **22** without prior purification. Tertiary alcohol **22** was obtained in 38% yield overall from **20**. Desilylation of **22** with 48% HF–acetonitrile (5:95) gave **23** in 93% yield. PCC oxidation led to the 22-dehydro-vitamin D_3 Windaus–Grundmann ketone **24** in 57% yield. Cyclopropanation of allylic alcohol **20** with 1,1-diiodoethane led to compounds **10a,b** and their trans isomers (a different diastereomeric mixture than before, cf. eq 4). Conversion of **10a,b** to **11a,b** by solvolysis led to the 24*RS* D_2 series.

(13) Furukawa, J.; Kawabata, N.; Nishimura, J. *Tetrahedron* **1968**, *24*, 53.

Conclusion

The 25-hydroxy Windaus–Grundmann ketones for vitamin D_3 and D_2 are accessible from the Lythgoe–Inhoffen diol derived synthon **9** using a new methodology involving cyclopropylcarbinol solvolysis. Two approaches to the synthesis of solvolytic precursors to the side chain are reported. The first involves a new cyclopropyllithium reagent. The second explores cyclopropanation of an allylic alcohol.[14] Since methods for hormone total synthesis generally couple ring A onto a preformed C/D unit, this approach has considerable practical value.

Experimental Section[15]

***cis*- and *trans*-1-Bromo-2,2,3-trimethylcyclopropane (5 and 6):** Following the procedure reported by Martel,[6] CH_2Br_2 (2.9 mL, 39.7 mmol) was added dropwise with stirring to a mixture of sodium bis[trimethylsilyl]amide (7.41 g, 40.3 mmol), 2-methyl-2-butene (12.8 mL, 120 mmol), and dry pentane (50 mL) under N_2. The reaction mixture was stirred for 3 h at rt (water bath). It was then quenched with 5 mL of water, and ether and water were added. The aqueous layer was extracted with ether, and the ethereal layer was dried ($MgSO_4$) and concentrated at atmospheric pressure. The residue contains hexamethyldisilazane and the bromocyclopropane isomers. Methanol (5 mL) was added, and the mixture was refluxed for 2 h and then extracted with water and pentane. The organic layer was dried ($MgSO_4$), and the pentane was distilled at atmospheric pressure (bath temperature 80 °C). Kugelrohr distillation at 93 °C (760 mm) of the residue gave 4.14 g (63%) of a 73:27 mixture of bromocyclopropanes **5** (cis) and **6** (trans): GC (program rate: 40 °C (2 min)/20 °C per min/320 °C): t_R = 1.27 min (trans) and 1.42 min (cis). ^1H NMR ($CDCl_3$): δ 0.75–0.87 (m, 1 H), 1.06 (d, J = 8.7, 3 H), 1.08 (superimposed, s, 3 H), 1.13 (s, 3 H), 2.52 (d, J = 3.92, 1 H, *trans*), 2.97 (d, J = 7.6, 1 H, *cis*). GC–MS (relative abundance): 84.1 (6.9), 83.1 (M^+ – Br, 0.0), 67.2 (12.5), 55.1 (84.1), 53.1 (7.7), 43.1 (15.8), 41.1 (50.0).

The *trans*-bromocyclopropane **6** was removed by reaction with potassium *tert*-butoxide in DMSO. A solution of of potassium *tert*-butoxide (224 mg, 2 mmol) in 8 mL of DMSO was stirred for 15 min at rt under N_2. To this solution was added 168 mg (1.03 mmol) of the bromocyclopropane mixture from the previous experiment in 2 mL of DMSO dropwise. The reaction mixture was heated at 75 °C (bath temperature) for 20 min and then cooled to rt and quenched with 2 mL of water. The mixture was extracted with pentane and dried ($MgSO_4$). The pentane was distilled from the solution at atmospheric pressure. ^1H NMR analysis of the residue shows this product to be 100% *cis*-cyclopropane **5** (116 mg, 69%): bp: 93 °C (Kugelrohr distillation, 760 mmHg). GC (program: 40 °C (2 min)/20 °C per min/320 °C): t_R = 1.42 min. ^1H NMR ($CDCl_3$): δ 0.75–0.87 (m, 1 H), 1.06 (d, J = 6.68, 3 H), 1.08 (s, 3 H), 1.12 (s, 3 H), 2.96 (d, J = 7.56, 1 H). When the decoupler is set at 0.85 ppm, the doublet at 2.96 ppm collapses into a broad singlet. GC–MS (relative abundance): 84.1 (7.5), 83.1 (M^+ – Br, 100.0), 67.1 (14.2), 55.1 (89.5), 53.1 (8.5), 43.1 (16.7), 41.1 (51.9). ^{13}C NMR: δ 10.72, 16.99, 21.36, 27.12, 38.27.

1-(*cis*-2,2,3-Trimethylcyclopropyl)-1-heptanol (7). Method A (via eq 3). A solution of of bromide **5** (0.209 g, 1.3 mmol) in dry THF (8 mL) under N_2 was stirred and cooled at −78 °C (dry ice/acetone) and *tert*-butyllithium (1.5 mL of a 1.6 M solution in pentane) was added. After 0.5 h of stirring at −78 °C, heptaldehyde (0.123 in 2 mL of THF) was added. The solution was stirred for an additional 0.5 h at −78 °C and then was quenched with 1 mL of saturated aqueous NH_4Cl. The mixture was then extracted with ether, and the ether extracts were dried (MgSO4) and concentrated under vacuum to give 0.317 g of crude product. Purification by radial chromatography (7% ethyl acetate/hexane) gave 0.209 g of a mixture of alcohol **7** (36%) and 2,2-dimethyl-1-nonanol (64%, the *tert*-butyllithium/heptaldehyde adduct).

Method B (via eq 8). Allylic alcohol **17** (143 mg, 0.84 mmol) in dry ether (1 mL) was added dropwise to a stirred solution of diethylzinc (15% wt in toluene, 1.1 M, 0.84 mL, 0.92 mmol, 1.1 equiv) in ether (1 mL) under N_2 at rt. After the evolution of gas had ceased (1–2 min), 1,1-diiodoethane[17] (355 mg, 1.26 mmol, 1.5 equv) in ether (1 mL) was added and the mixture was stirred for 30 h when more diethylzinc (0.84 mL, 0.92 mmol, 1.1 equiv) and 1,1-diiodoethane (355 mg, 1.26 mmol, 1.5 equiv) in ether (1 mL) were added and stirring continued for a further 12 h. The reaction mixture was poured into saturated aqueous NH_4Cl (60 mL) and extracted with ether (3 × 20 mL). The combined organic phase was washed with water, dried ($MgSO_4$), filtered, and concentrated to give compound **7** as an oil (164 mg, 99% crude yield, 90–95% pure mixture of isomers by NMR analysis). The ^1H NMR spectrum showed a 1:2 mixture of isomers A:B of the cyclopropyl alcohol **7**. Anal. Calcd for $C_{13}H_{26}O$: C, 78.78; H, 13.13. Found: C, 78.51; H, 13.26. ^1H NMR ($CDCl_3$) isomer A (*trans*-cyclopropyl isomer): δ 0.25 (dd, J = 9.2, 5.4, 1 H), 0.48–0.60 (hidden m, 1 H), 0.89 (br s, 3 H), 1.00 (s, 3 H), 1.02 (hidden s, 3 H), 1.06 (d, J = 6.0, 3 H), 1.29 (br m, 10 H), 3.15–3.24 (m, 1 H). Isomer B (*cis*-cyclopropyl isomer): δ 0.48–0.60 (m, 1 H), 0.63–0.73 (m, 1 H), 0.89 (br s, 3 H), 0.94 (s, 3 H), 1.02 (s, 3 H), 1.07 (d, J = 6.6 Hz, 3 H), 1.29 (br m, 10 H), 3.34–3.35 (m, 1 H). Assignment was aided by COSY decoupling experiments. Isomer A corresponds to the slower moving isomer of the mixture of *cis*-cyclopropylheptanols **7** described earlier. Isomer B, which does not correspond to the faster moving isomer, is a *trans*-cyclopropyl heptanol. The stereochemistry of the hydroxyl carbon remains unassigned in both isomers A and B. IR ν_{max} (neat): 3350 cm^{-1}.

Capillary GC and GC–MS analyses of an acetylated sample of this mixture of alcohols showed a similar 1:2 mixture of acetates. GC (25 M capillary, OV-101, 60 °C/20 °C per min/210 °C): t_R = 8.64 min and 8.96 min in a 1:2 ratio (possible evidence of other minor isomers at 8.08 and 9.28 min.). GC–MS (100 °C (1 min)/16 °C per min/220 °C): t_R = 4.9 and 5.2 min (1:2); m/e 240 (M^+), 182 (M – C_4H_{10}), 180 (M – AcOH), 110, 95, 81.

(*E*)-2,3-Dimethyl-4-undecen-2-ol (8). A solution of the cyclopropyl alcohol **7** (100 mg, 0.51 mmol) in 10 mL of 75% dioxane/water and *p*-toluenesulfonic acid (10 mg) was stirred at rt for 16 h after which time the product was extracted with ether and the ethereal solution dried ($MgSO_4$) and concentrated under vacuum to give 99 mg (99%) of **8**. Further purification by radial, chromatography gave 85 mg of product (85%). GC (6- × $^1/_4$-in. OV-101): t_R = 8.40 min. TLC: silica gel, 20% ethyl acetate in hexane, R_f = 0.54. ^1H NMR ($CDCl_3$): δ 0.91 (br s, 3 H), 1.03 (d, J = 6.93, 3 H), 1.16 (s, 3 H), 1.20 (s, 3 H), 1.30 (br s, 8 H), 2.05 (q, J = 6.5, 2 H, CH_2C=), 2.11–2.22 (m, 1 H, CHC=), 5.37 (dd, J = 15.26, 7.7, H_2, 1 H), 5.48–5.60 (m, H_1, 1 H). With the decoupler set at 2.0 ppm, the multiplet at 5.48–5.60 ppm collapses into a doublet at 5.52 ppm with J = 15.25 Hz indicative of the trans geometry of the double bond. If the decoupler is set at 2.145 ppm, the doublet of doublets at 5.37 ppm turns into a doublet at the same chemical shift with J = 15.26 Hz. ^{13}C NMR: δ 14.3, 16.4, 22.9, 26.4, 27.8, 29.2, 30.0, 32.1, 32.8, 48.5, 66.4, 132.1, 132.8. GC–MS (relative abundance): 183 (M^+ – 15, 4), 140.1 (24.3), 97.1 (12.4), 70.1 (14.8), 69.1 (16.1), 59.1 (100.0), 56.1 (13.9), 55.1 (19.4), 43.1 (25.4), 41.0 (19.5). Anal. Calcd for $C_{13}H_{26}O$: C, 78.78; H, 13.13. Found: C, 78.94; H, 12.86.

Cyclopropyl Alcohols 10a,b. To a solution of 211 mg (1.29 mmol) of cyclopropane **5** in 10 mL of dry THF at −78 °C (dry ice/acetone) and under N_2 was added 1.5 mL (2.55 mmol) of *tert*-butyllithium (1.7 M) in pentane. The mixture was stirred for 0.5 h at −78 °C, and then 37 mg (25 mol %) of dry *N,N,N,N*-tetramethylethylenediamine was added, followed by the addition of a solution of 273.6 mg (0.84 mmol) of [1*R*-[1β,[β,-S*],3aα,4β,7aβ]]-octahydro-β,7a-dimethyl-4-[[(1,1-dimethyl-

(14) During the course of this work, a similar approach for the construction of the 25-hydroxycholesterol side chain was reported: Moiseenkov, A. M.; Cheskis, B. A.; Semenovskii, A. V.; Bogoslovskii, N. A.; Litvinova, G. E.; Samokhvalov, G. I.; Segal, G. M.; Torgov, I. V. *Bioorg. Khim.* **1983**, *9*, 118; *Chem. Abstr.* **1985**, *98*, 198577h.

(15) GC analysis was performed on a Varian 3700 equipped with a 3 ft × $^1/_4$-in. OV-101 column (program: 60°/min–16°/min to 300°) unless otherwise indicated. Radial chromatography refers to the use of a chromatron. I values are given in Hz. Other general experimental details may be found in ref 16.

(16) Wilson, S. R.; Digrandi, M. J. *J. Org. Chem.* **1991**, *56*, 4766.

(17) Letsinger, R. L.; Kanmeyer, C. W. *J. Am. Chem. Soc.* **1951**, *73*, 4476.

ethyl)dimethylsilyl]oxy]-1*H*-indene-1-acetaldehyde (**9**)[46] in 3 mL of dry THF. The mixture was allowed to warm to rt and then was quenched with saturated aqueous NH_4Cl and extracted with ether. The combined extracts were dried (Na_2SO_4) and concentrated under vacuum to give 353.5 mg of crude product. Purification by flash chromatography (7% ethyl acetate in ligroin) gave 83 mg (24%) of **10a** and 84 mg (24%) of **10b**. Minor diastereomers (20 mg, ~8%) were also isolated. GC: t_R = 11.56 min. TLC: silica gel, 10% ethyl acetate in ligroin, R_f = 0.38, 0.45 (major components), 0.53 (minor components). TLC: Analtech reversed-phase, F, 7% ethyl acetate in hexane, R_f = 0.31, 0.34 (major components), 0.38, 0.43 (minor components). MS: 391 (M^+ – OH), 351 ($M^+ - C_4H_9$), 333, 209, 164, 135, 113, 95, 75. Faster moving major isomer **10a** (R_f = 0.34). ^1H NMR ($CDCl_3$): 0.018 (s, 3 H, CH_3Si), 0.034 (s, 3 H, CH_3Si), 0.65 and 0.75 (2m, 2H) (cyclopropyl H), 0.91 (s, 9 H, *tert*-butyl), 0.94 (s, 3 H, $CH_3C(18)$), 0.98 (d, J = 6.50, 3 H), 1.02 (d, J = 5.82, 3 H), 1.10 (s, 6 H), 3.50 (m, 1 H, *CH*OH), 4.02 (br s, 1 H, *CH*OTBDMS). ^{13}C NMR: δ –5.00, –4.66, 9.25, 12.00, 13.67, 14.85, 17.82, 21.42, 23.06, 25.96, 26.07, 26.91, 29.45, 30.26, 34.60, 40.17, 40.91, 53.17, 53.67, 69.66, 71.19. Slower moving major isomer **10b** (R_f = 0.31). ^1H NMR: δ 0.02 (s, 3 H, CH_3Si), 0.03 (s, 3 H, CH_3Si), 0.75 (m, 1 H, cyclopropyl H), 0.91 (s, 9 H, *t*-Bu), 0.95 (s, 3 H), 0.97 (s, 3 H), 1.02 (d, J = 6, 3 H), 1.04 (s, 3 H), 1.08 (d, J = 6, 3 H), 3.50 (m, 1 H, *CH*OH), 4.03 (br s, 1 H, *CH*OTBDMS). ^{13}C NMR: δ –5.00 –4.66, 8.69, 12.03, 13.70, 15.47, 17.83, 20.75, 23.06, 25.97, 26.89, 29.26, 29.80, 30.34, 34.60, 40.56, 40.93, 53.17, 53.71, 69.66, 70.54. HRMS for mixture **10a/10b** (neg CI, M – H): calcd for $C_{25}H_{47}O_2Si$ 407.3343, obsd 407.3403; Anal. Calcd for $C_{25}H_{48}O_2Si$: C, 73.53; H, 11.76. Found: C, 73.14; H, 11.88.

[1*R*-[1β(*R,*E*,*R**),3aα,4β,7aβ]]- and [1*R*-[1β(*R**,*E*,-*S**),3aα,4β,7aβ]]-6-(Octahydro-4-[[(1,1-dimethylethyl)dimethylsilyl]oxy]-7a-methyl-1*H*-inden-1-yl)-2,3-dimethyl-4-hepten-2-ol (11a and 11b).** The procedure for the solvolysis of compound **7** was followed. Cyclopropyl alcohol mixture **10a,b** (45 mg, 0.11 mmol) was reacted in 5 mL of 75% dioxane in water with 20 mg of *p*-toluenesulfonic acid. The yield of products **11a,b** was 37 mg (81%).

Solvolysis of 15.2 mg of the faster moving cyclopropyl alcohol diastereomer **10a** (24-*R*) in 4 mL of solvent gave 14.9 mg of product **11a** (98%).

Solvolysis of about 10 mg of the slower moving cyclopropyl alcohol **10b** (24-*S*) in 4 mL of solvent gave 9 mg of product **11b** (93%). GC: t_R = 11.92 min. TLC: 10% ethyl acetate in ligroin, R_f = 0.43. ^1H NMR ($CDCl_3$): (on the mixture of diastereomers) δ 0.010 (s, 3 H, CH_3Si), 0.026 (s, 3 H, CH_3Si), 0.907 (s, 9 H, *t*-Bu), 0.950 (s, 3 H, $CH_3C(18)$), 1.147 (s, 3 H, CH_3COH), 1.188 (s, 3 H, CH_3COH), 4.016 (br s, 1 H, *CH*OTBDMS), 5.335 (m, 2 H, CH=CH).

The ^1H NMR spectra of the pure 24-*R* (**11a**) and 24-*S* (**11b**) isomers are virtually the same. The major difference is the shape of the vinyl proton multiplet at 5.3 ppm. ^{13}C NMR ($CDCl_3$): δ –5.03, –4.67, 14.09, 15.69, 15.99, 17.58, 17.81, 20.77, 23.24, 23.30, 25.96, 26.38, 26.57, 27.00, 27.09, 27.89, 28.33, 29.45, 34.59, 39.89, 40.14, 40.84, 42.26, 48.24, 48.53, 53.17, 53.32, 56.55, 56.70, 71.18, 72.45, 129.04, 129.23, 139.36, 139.74. The ^{13}C spectrum shows two sets of olefinic signals, revealing the presence of two isomers. Some other signals also seem to be doubled.

[1*R*-[1β(*R,*E*,*R**),3aα,4β,7aβ]]- and [1*R*-[1β(*R**,*E*,-*S**),3aα,4β,7aβ]]-6-(Octahydro-4-hydroxy-7a-methyl-1*H*-inden-1-yl)-2,3-dimethyl-4-hepten-2-ol (12a and 12b).** To a solution of 25.4 mg (0.062 mmol) of silyl ether mixture **11a,b** in 9.5 mL of acetonitrile was added 0.5 mL of 48% aqueous HF. The mixture was stirred for 2.5 h and then poured into 20 mL of $CHCl_3$ and 2 mL of water. The aqueous phase was then extracted twice with 10 mL of $CHCl_3$. The combined organic layers were washed with 3 mL of saturated aqueous $NaHCO_3$ and 5 mL of brine, dried (Na_2SO_4), and concentrated under vacuum to yield 18.8 mg of a yellow oil. Purification by TLC (25% ethyl acetate in ligroin) gave 17.3 mg of the product (**12a,b**) as a colorless oil (95%). Desilylation of a pure sample of **11a** gave expected diol **12a** plus 8% yield of dehydration product **14**. Desilylation of a pure sample of **11b** gave diol **12b** with ^1H NMR spectra and TLC identical to an authentic sample of 24-*S* diol **12b** provided by Baggiolini.[11] TLC: silica gel, 25% ethyl acetate in ligroin, R_f = 0.40 (The two diastereomers **12a** and **12b** do not separate). ^1H NMR (mixture of diastereomers): δ 0.98 (s, 3 H), 1.15 (s, 3 H), 1.20 (s, 3 H), 4.10 (br s, 1 H), 5.35 (m, 2 H). The ^1H NMR spectra of the mixture of diastereomers and of pure 24-*R* (**12a**) and pure 24-*S* (**11b**) are quite similar but can be distinguished at 400 MHz (see supplementary material). ^{13}C NMR (24-*S* isomer): δ 13.89, 15.74, 17.58, 20.78, 22.67, 26.60, 27.12, 27.74, 33.78, 39.90, 40.48, 48.27, 52.86, 56.53, 69.49, 76.96, 129.27, 139.11. ^{13}C NMR of the mixture of diastereomers shows two sets of olefinic signals, revealing the presence of the two isomers. IR: 3580 (w), 2970 (s), 2920 (s), 2870 (s), 1450 (m), 1370 (m), 1120 (s), 950 (w) cm^{-1}.

[1*R*-[1β(*R,*E*,*R*),3aα,7aβ]]- and [1*R*-[1β(*R**,*E*,-*S*),3aα,7aβ]]-6-(Octahydro-7a-methyl-1*H*-4-oxoinden-1-yl)-2,3-dimethyl-4-hepten-2-ol (13a and 13b).** A solution of 9.43 mg (0.032 mmol) of diol **12a,b** in 0.5 mL of CH_2Cl_2 was added to a suspension of 21 mg (0.097 mmol) of pyridinium chlorochromate in 2 mL of CH_2Cl_2, and the reaction mixture was stirred at rt. CH_2Cl_2 was then evaporated, and ether was added. The solution was filtered through Florisil, dried (Na_2SO_4), and evaporated to give 9.34 mg (0.032 mmol) of a **13a,b** mixture (100%). Reaction of 10 mg of **12a** gave **13a** (91%) and 10 mg of **12b** gave **13b** (94%), respectively, using the same method. GC: t_R = 10.64 min (the isomers do not separate). TLC: silica gel, 25% ethyl acetate in ligroin, R_f = 0.35 (The isomers do not separate). ^1H NMR ($CDCl_3$) (mixture of diastereomers): δ 0.68 (s, 3 H, CH_3C-18), 1.02 (d, J = 6.86, CH_3C-21), 1.085 (d, J = 6.55, $^3/_2$ H, CH_3C(24R)), 1.090 (superimposed d, J = 6.42, $^3/_2$ H, CH_3C (24-*S*)), 1.16 (s, 3 H, CH_3COH), 1.19 (s, 3 H, CH_3COH), 5.35 (m, 2 H, CH=CH). ^{13}C NMR: δ 12.86, 14.22, 15.71, 15.87, 19.23, 19.29, 20.94, 21.04, 24.04, 24.17, 26.55, 26.67, 27.10, 27.87, 28.32, 29.45, 29.81, 39.03, 39.99, 40.19, 41.06, 48.27, 48.60, 56.46, 62.15, 130.00, 130.1, 138.2, 138.50 (the carbonyl carbon could not be seen). ^{13}C NMR spectrum of the mixture of isomers shows two sets of olefinic signals revealing the presence of the two isomers. Other signals are also doubled. IR: 2965 (s), 2934 (m), 2875 (m), 2857 (w), 1717 (s), 1459 (m), 1374 (m), 1262 (s), 1099 (s), 1020 (s), 1013 (s) cm^{-1}.

The only difference in the ^1H NMR spectra of pure 24-*R* (**13a**) and pure 24-*S* (**13b**), besides the chemical shift of the methyl doublet at C-24, is the shape of the vinyl proton multiplet at 5.3 ppm. TLC: silica gel, 10% ethyl acetate in ligroin, R_f = 0.27. GC–MS (relative abundance): 170 (M^+, 1), 155.2 (5.1), 85.1 (100.0), 57.1 (8.4), 43.1 (14.7), 41.1 (26.3). ^1H NMR: δ 0.90 (br s, 3 H), 1.31 (br s, 10 H), 1.71 (s, 3 H), 1.75, (s, 3 H), 4.36 (m, 1 H), 5.18 (d, J = 8.69, 1 H). ^{13}C NMR: δ 14.12, 18.29, 22.69, 25.53, 25.83, 29.40, 31.95, 37.92, 68.88, 114.02, 128.52. IR ($CHCl_3$): 3500 (s), 3000 (s) with shoulder at 2900, 1470 (m), 1370 (w) cm^{-1}. Anal. Calcd for $C_{19}H_{34}O_2$: C, 77.49; H, 11.64. Found: C, 77.85; H, 11.48. Comparison of **13a** and **13b** with authentic **13b** was carried out as described below.

Authentic Windaus–Grundmann Ketone (13b). Oxidation of 16.8 mg (0.06 mmol) of diol **12b**[11] with PCC gave 9.5 mg (57%) of ketone **13b**. GC (program 110° to 320° at 20°/min): t_R = 7.69 min. TLC: silica gel, 25% ethyl acetate in ligroin, R_f = 0.25. ^1H NMR ($CDCl_3$): δ 0.68 (s, 3 H, CH_3CH-18), 1.02 (d, J = 6.86, CH_3-C21), 1.090 (J = 6.42, 3 H, CH_3-C (24)), 1.16 (s, 3 H, CH_3-C-OH), 1.19 (s, 3 H, CH_3COH), 5.35 (m, 2 H, CH/dbdCH). IR: 2960 (s), 2920 (s), 2850 (s), 1680 (m), 1600 (m), 1450 (m), 1260 (s), 1100 (s), 1020 (s) cm^{-1}. TLC, GC, and ^1H NMR comparisons were also made with **13b** prepared above. Expansion of the methyl region is shown in supplemental data.

2-Methyldec-2-en-4-ol (17). To a stirred solution of 1-bromo-2-methylpropene **15** (326 mg, 248 μL, 2.42 mmol, 4.1 equiv) in dry THF (2 mL) at –78 °C was added *t*-BuLi (1.42 M solution in pentane, 3.32 mL, 4.72 mmol, 8.0 equiv) and the mixture allowed to warm with stirring to approximately 5 °C over 90 min. After the mixture was recooled to –78 °C, heptaldehyde (67 mg, 79 μL, 0.59 mmol) was added in THF (1 mL), and the mixture was allowed to warm to rt and stirred for 15 h. The reaction mixture was then diluted with ether (50 mL), added to saturated aqueous NH_4Cl solution (100 mL), partitioned, and extracted with two further portions of ether (50 mL), and the organic extracts were combined, washed (brine), dried ($MgSO_4$), filtered, and concentrated to an oil (202 mg). Chromatography (ether–pentane (15:85)) of this crude product yielded a mixed forerun, then 1-heptanol (23 mg, 34%), and finally compound **17** (51 mg, 51%) as a colorless oil. TLC: silica gel, ether–pentane (1:4), R_f 0.30. GC: t_R = 2.04

min. GC–MS *m/e*: 155 (6%, M – CH_3), 152 (6, M – H_2O), 113 (8, M – C_4H_9), 95 (15), 85 (100, $C_6H_{13}^+$ or M – C_6H_{13}). ^1H NMR ($CDCl_3$): δ 0.88 (t, *J* = 6.6 Hz, 3 H, CH_3), 1.28 (br s, 10 H, CH_2), 1.68, 1.72 (2s, 6 H, allylic CH_3), 4.33 (dt, *J* = 6.9 and 8.4 Hz, 1 H, C*H*OH), 5.16 (d, *J* = 8.6 Hz, 1 H, H-C=). IR (neat): 3450 (OH) cm^{-1}.

1-(2,2-Dimethylcyclopropyl)-1-heptanol (18). To a stirred mixture of 130 mg (0.76 mmol) of 2-methyl-2-decen-4-ol **17** and 1.2 mL (1.5 mmol) of diethylzinc (15% solution in toluene) in 5 mL of dry pentane under N_2 was added 0.46 mL (5.7 mmol) of CH_2Cl_2 (Aldrich, 99%). The reaction was exothermic, and a white precipitate formed. After 20 min, the cooled reaction mixture was quenched with 2 mL of water and extracted with diethyl ether. The organic extracts were dried (Na_2SO_4) and concentrated under vacuum. The crude product was purified by flash chromatography, eluting first with CH_2Cl_2 to separate the excess CH_2Cl_2 and then with ether to elute the product. The ether layer was concentrated under reduced pressure to yield 0.137 g of **18** as a yellowish oil (98.1%). GC: t_R = 4.8 min. TLC: silica gel, 10% ethyl acetate in ligroin, R_f = 0.28. GC–MS (relative abundance): 141.3 (6.7), 126.3 (17.1), 99.2 (19.9), 97.3 (12.7), 82.3 (10.4), 81.3 (28.0), 71.3 (13.2), 70.3 (28.8), 69.3 (15.3), 67.2 (11.1), 59.2 (100.0), 58.3 (14.8), 57.2 (28.2), 55.2 (58.5), 43.3 (69.9), 41.3 (44.3). ^1H NMR: δ 0.25 (t, *J* = 4.76, H_3), 0.51 (dd, *J* = 8.34, 4.16, H_2), 0.69 (m, H1), 0.91 (br s, 5 H), 1.07 (s, 3 H), 1.08 (s, 3 H), 1.32 (br s, 8 H), 3.20 (m, *CH*OH). ^{13}C NMR: δ 14.19, 18.28, 20.88, 22.75, 25.63, 27.47, 29.54, 29.82, 31.97, 32.16, 38.34, 73.37.

(*E*)-2-Methyl-4-undecen-2-ol (19). To a solution of cyclopropyl alcohol **18** (29 mg, 0.16 mmol) in 3 mL of 75% dioxane in water was added *p*-toluenesulfonic acid (3 mg, 0.017 mmol). The resulting solution was stirred at rt for 16 h under N_2. The mixture was then diluted with water and extracted with ether. The organic extracts were dried (Na_2SO_4) and evaporated under vacuum. The residue was purified by preparative TLC (10% ethyl acetate in ligroin) to give the homoallylic alcohol **19** (22 mg, 76%) as an oil. GC: t_R = 6.56 min. TLC: silica gel, 10% ethyl acetate in ligroin, R_f = 0.30. ^1H NMR: δ 0.91 (br t, *J* = 6.6, 3 H), 1.23 (s, 3 H), 1.30 (br d, *J* = 6.37, 8 H), 2.05 (q, *J* = 6, 2 H), 2.18 (d, *J* = 6.43, 2 H), 5.52 (m, 2 H). GC–MS (rel abundance): 169 (M^+ – CH_3, 3), 166 (M^+ – H_2O, 1), 126.2 (13.4), 97.2 (11.8), 70.1 (12.4), 69.1 (11.5), 59.2 (100.0), 56.2 (13.4), 55.2 (14.6), 43.1 (28.7), 41.1 (17.5).

[1*R*-[1β,[α*S,β*S**],3aα,4aβ,7aβ]]-Octahydro-β,7a-dimethyl-4-[[(1,1-dimethylethyl)dimethylsilyl]oxy]-α-(2′,2′-dimethyl-1-ethenyl)-1*H*-indene-1-ethanol (20).** To a stirred solution of 1-bromo-2-methylpropene (326 mg, 248 μL, 2.42 mmol, 4.1 equiv) in dry THF (2 mL) at −78 °C was added a pentane solution of *t*-BuLi (1.42 M, 3.32 mL, 4.72 mmol, 8.0 equiv), and the mixture was allowed to warm to 0 °C over 1.5 h. The solution was then cooled to −78 °C, and a solution of the aldehyde **9** (0.91 mg, 0.59 mmol) in dry THF (3 mL) was added dropwise. This mixture was allowed once more to reach room temperature, and stirring was continued for 15 h. The mixture was partitioned between aqueous NH_4Cl and ether and extracted with two further portions of ether. The combined organic phases were washed with water, dried ($MgSO_4$), filtered, and concentrated to an oil (334 mg) which, upon chromatography (ether–pentane (1:3)) gave alcohol **20** (172 mg, 77%) as a colorless oil. This was isolated as a diastereomeric mixture of Cram and anti-Cram products in a ratio of 7:3, respectively, which could be separated by flash chromatography, eluting with ether–pentane (1:4). GC: t_R = 9.35 min. TLC: silica gel, ether–pentane (1:4), R_f = 0.28 (Cram product) and 0.23 (anti-Cram product). ^1H NMR (Cram product, 22-*R*): δ 0.02 (s, 3 H, CH_3Si), 0.03 (s, 3 H, CH_3Si), 0.91 (s, 9 H, *t*-Bu *H*), 0.94 (s, 3 H, CH_3C-18), 1.68 (s, 3 H, CH_3C=), 1.75 (s, 3 H, CH_3C=), 4.01 (br s, 1 H, C*H*OSi), 4.48 (d, *J* = 8.1 Hz, 1 H, C*H*OH), 5.35 (d, *J* = 8.1 Hz, 1 H, *H*C=). ^1H NMR (anti-Cram product, 22-S): δ 0.02 (s, 3 H), 0.03 (s, 3 H), 0.91 (s, 9 H), 0.96 (s, 3 H), 1.00 (d, *J* = 6.7 Hz, 3 H, CH_3C-21), 1.75 (s, 3 H), 1.78 (s, 3 H), 4.06 (br s, 1 H), 4.43 (dd, *J* = 9.3 Hz, 3.6 Hz, 1 H, C*H*OH), 5.29 (d, *J* = 9.3 Hz, 1H, *H*C=). IR (neat): 3400 (OH), 3000 (CH)cm^{-1}.

Cyclopropyl Alcohol 21. The method B procedure reported earlier for **7** was applied to 155.7 mg (0.41 mmol) of allylic alcohol **20** to give 166 mg (~100% yield) of compound **21**. TLC: silica gel, 10% ethyl acetate in ligroin, R_f = 0.34 (minor), R_f = 0.28 (major). ^1H NMR: δ 0.02 (s, 3 H, CH_3Si), 0.03 (s, 3 H, CH_3Si), 0.26 (br t, 1 H, H-cyclopropyl), 0.55 (dd, 1 H, H-cyclopropyl), 0.92 (s, 9 H, *t*-Bu), 0.96 (s, 3 H, CH_3C-18), 1.03 (d, 3 H, CH_3-C(21)), 1.06 (s, 3 H, CH_3-cyclopropyl), 1.10 (s, 3 H, CH_3-cyclopropyl). Anal. Calcd for $C_{24}H_{46}O_2Si$: C, 72.63; H, 11.57. Found: C, 72.72; H, 11.82.

[1*R*-[1β(*R,*E*),3aα,4β,7aβ]]-6-(Octahydro-4-[[(1,1-dimethylethyl)dimethylsilyl]oxy]-7a-methyl-1*H*-inden-1-yl)-2-methyl-4-hepten-2-ol (22).** The solvolysis of about 150 mg of the crude cyclopropyl alcohol **21** was carried out as usual to produce 61 mg of compound **22**. A sample for ^1H NMR was purified by preparative TLC. TLC: silica gel, 10% ethyl acetate in ligroin, R_f = 0.28. ^1H NMR: δ 0.02 (s, 3 H), 0.03 (s, 3 H), 0.91 (s, 9 H), 0.96 (s, 3 H), 1.03 (d, *J* = 6.59, 3 H), 1.22 (s, 3 H), 1.28 (s, 3 H), 2.14 (m, 2 H, CH_2, C-24), 4.02 (br s, 1 H), 5.40 (m, 2 H, CH=CH). When the decoupler is set at 2.142 ppm, the multiplet at 5.40 ppm collapses into a broad singlet.

[1*R*-[1β(*R,*E*,*R**),3aα,4β,7aβ]]- and [1*R*-[1β(*R**,*E*,-*S**),3aα,4β,7aβ]]-6-(Octahydro-4-hydroxy-7a-methyl-1*H*-inden-1-yl)-2,3-dimethyl-4-hepten-2-ol (12a and 12b).** The desilylation with 48% HF in acetonitrile (5:95) of **11a,b** (61 mg, 0.15 mmol, prepared from **20** via eq 9) gave 55 mg of alcohol **12a,b**. Purification by radial chromatography on a 1-mm silica gel plate (30% ethyl acetate in ligroin) afforded 39 mg of pure diol **12a** (93.5%). TLC: silica gel, 30% ethyl acetate in ligroin, R_f = 0.29. ^1H NMR: δ 0.98 (s, 3 H), 1.04 (d, *J* = 6.58, 3 H), 1.22 (s, 6 H), 2.17 (br d, 2 H, CH_2C=), 4.11 (br s, 1 H), 5.41 (m, 2 H). Comparison was made to previously prepared samples of **12a**.

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Supplementary Material Available: 300-MHz proton NMR spectra for **17–19, 21,** and **22** (5 pages). Ordering information is given on any current masthead page.