Stereochemistry of the Iodocarbonatation of *cis*- and *trans*-3-Methyl-4-pentene-1,2-diols: The Unusual Formation of Several Anti Iodo Carbonates†

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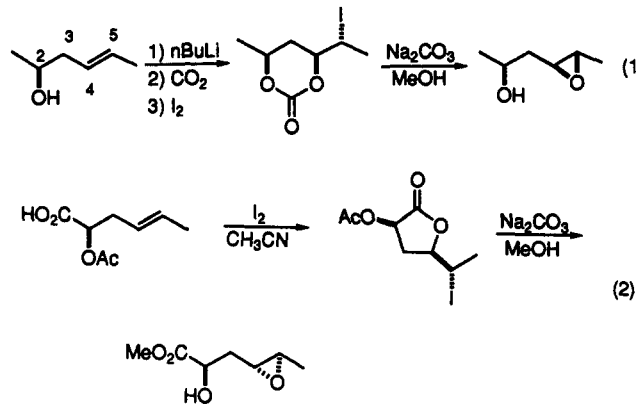
A study on the stereoselective preparation of a series of 3-methyl-4,5-epoxy alcohols as an entry to polypropionates was undertaken. Initially, the opening of cis and trans TIPS-protected 2,3-epoxy butanols by propynyldiethylalane showed an excellent regioselectivity favoring the monoprotected 1,2-diol products. The resulting propargylic alcohols were stereoselectively reduced to the cis and trans 1-[(triisopropylsilyl)oxy]-3-methyl-4-hexen-2-ols. Iodocarbonatation of these four isomeric homoallylic alcohols was carried out and the stereochemistry of the intermediate iodo carbonates established. Interestingly, a complete anti selectivity (>20:1 anti:syn) was observed when both the syn 3-methyl and cis double-bond geometry were present (**3b**, **10**, and **20**). The anti relative configuration for all of the iodo carbonates was established by NMR, and that of **5b** was confirmed by X-ray crystallography. This study demonstrated that the relative stereochemistry of the hydroxyl and C(3) methyl groups in combination with the cis or trans geometry of the alkene exerts a significant effect on the stereochemical outcome of the iodocarbonatation reaction. Methanolysis of the iodo carbonates produced the desired 3-methyl-4,5-epoxy alcohols. The application of this chemistry to the reiterative synthesis of polypropionates was carried out with epoxy alcohol **4a** (anti isomer), producing a new homologated epoxy alcohol, **22**, with six contiguous stereocenters in a highly stereoselective manner.

Introduction

The regio- and stereoselective double-bond halocyclization process has received much attention.[1] Two important strategies, iodocarbonatation[2] and iodolactonization[3] have been used in the stereoselective epoxidation of homoallylic alcohols. These complementary methods produce syn and anti 3,4-epoxy alcohols with high stereoselectivity (eqs. 1 and 2). In both processes, the stereoselectivity results from the 1,3- and 1,2-interactions of the substituents in the cyclic intermediates.[2,3] For the iodocarbonatation reaction, the stereoselectivity has been consistently shown to favor the syn epoxy alcohol regardless of the electrophilic or anionic reaction conditions used.[2a,c]



These double-bond functionalizations have been used as entries to polyacetates and polypropionates via nucleophilic cleavage of the resulting 3,4-epoxy alcohols.[4] Specifically, the iodocarbonatation reaction has been used by Lipshutz[4b,c] and others[5] in a reiterative fashion for the elaboration of 1,3-polyols. These elegant approaches have been limited to the preparation of only the syn 1,3-polyol arrangement.

In connection with an ongoing study related to the development of a general methodology for the synthesis of ansamycin antibiotics,[6] we were working on a procedure for the stereoselective preparation of cis and trans 3,4-epoxy alcohol derivatives. Our approach was based on the use of alkynylalanes as a means of a highly regioselective procedure for oxirane cleavage as illustrated in Scheme I.[7] This methodology allowed the preparation of a series of homoallylic alcohols, **3**, bearing a methyl group at C(3) with high stereoselectivity. Studies on the iodocarbonatation of homoallylic alcohols have usually

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† Taken from the Ph.D. Thesis of R. Tirado, University of Puerto Rico, Río Piedras campus, 1992.

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(1) For related reviews, see: (a) Cardillo, G.; Orena, M. *Tetrahedron* **1990**, *46*, 3321. (b) Bartlett, P. A. In *Asymmetric Synthesis*; Morrison, J. D., Ed.; Academic: Orlando, FL, 1984; Vol. 3, pp 411-454. (c) Bartlett, P. A. *Tetrahedron* **1980**, *36*, 2.

(2) (a) Bongini, A.; Cardillo, G.; Orena, M.; Porzi, G.; Sandri, S. *J. Org. Chem.* **1982**, *47*, 4626. (b) Cardillo, G.; Orena, M.; Porzi, G.; Sandri, S. *J. Chem. Soc., Chem. Commun.* **1981**, 465. (c) Bartlett, P. A.; Meadows, J. D.; Brown, E. G.; Morimoto, A.; Jernstedt, K.K. *J. Org. Chem.* **1982**, *47*, 4013. (d) Bartlett, P. A.; Jernstedt, K. K. *J. Am. Chem. Soc.* **1977**, *99*, 4829. (e) Duan, J. J-W.; Sprengeler, P. A.; Smith, A. B., III. *Tetrahedron Lett.* **1992**, 6439.

(3) (a) Bartlett, P. A.; Myerson, J. *J. Am. Chem. Soc.* **1978**, *100*, 3950. (b) Corey, E. J.; Hase, T. *Tetrahedron Lett.* **1979**, 335.

(4) For some examples, see: (a) Bartlett, P. A.; Holmes, C. P. *J. Org. Chem.* **1989**, *54*, 98 and references cited therein. (b) Lipshutz, B. H.; Barton, J. C. *J. Org. Chem.* **1988**, *53*, 4495. (c) Lipshutz, B. H.; Kozlowski, J. A. *J. Org. Chem.* **1984**, *49*, 1147. (d) Haslanger, M. F.; Ahmed, S. *J. Org. Chem.* **1981**, *46*, 4808. (e) Smith, A. B., III; Duan, J. J-W.; Hull, K. G.; Salvatore, B. A. *Tetrahedron Lett.* **1991**, 4855.

(5) Achmatowicz, B.; Wicha, J. *Tetrahedron: Asymmetry* **1993**, 339 and references cited therein.

(6) For related reviews, see: Ager, D. J.; East, M. B. *Tetrahedron* **1992**, 2803. (b) Oishi, T.; Nakata, T. *Synthesis* **1990**, 635. (c) Hoffmann, R. W. *Angew Chem., Int. Ed. Engl.* **1987**, *6*, 489. (d) Paterson, I.; Mansuri, M. M. *Tetrahedron* **1985**, *41*, 3569.

(7) This approach substitutes the use of organocuprates (ref. 4b) as a means of improving the regioselectivity of the epoxide opening.

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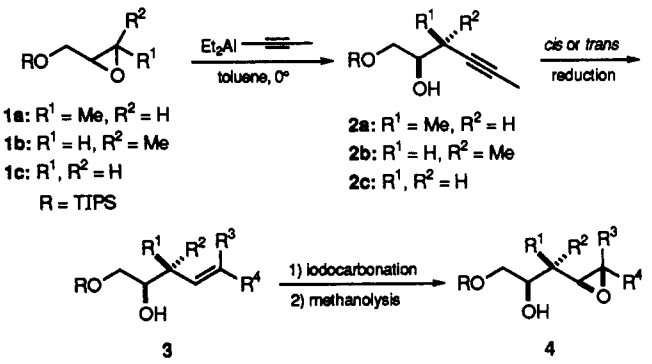
Scheme I



1a: R^1 = Me, R^2 = H
1b: R^1 = H, R^2 = Me
1c: R^1, R^2 = H
R = TIPS

2a: R^1 = Me, R^2 = H
2b: R^1 = H, R^2 = Me
2c: R^1, R^2 = H

3 **4**

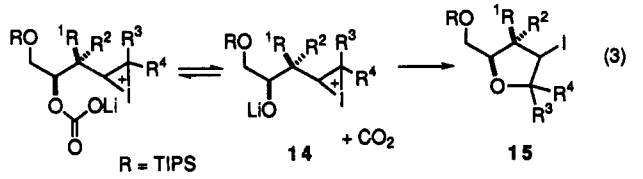
been performed on systems bearing a methyl group at either the C(3) allylic or the C(5) terminal double bond carbons. Since the synthesis of polypropionates would require a methyl group at both positions, the effects of both substitutions on the stereoselectivity of the iodocarbonatation reaction were explored. A systematic study of the iodocarbonatation of various alkenols was undertaken. The results of this study indicated that the syn selectivity which is normally expected for this reaction could be altered and even inverted to an anti selectivity. We were prompted to explore the factors responsible for this intriguing development.

Results and Discussion

The diethylpropynylalane[8] regioselective opening of the protected 2,3-epoxy alcohols **1a** and **1b** produced the propargylic alcohols **2a** and **2b**, respectively, in a highly regioselective manner. The relative syn or anti stereochemistry of the methyl and hydroxyl groups was defined by the geometry of the starting epoxide. In both cases, the monoprotected 1,2-diol was favored over the 1,3-isomer. For the cis epoxide **1b**, only one regioisomer was obtained, while for the trans isomer **1a**, a 15:1 ratio was observed. A semihydrogenation using Pd/C poisoned with quinoline[9] successfully reduced **2a** and **2b** to the cis alkenes **3b** and **3c**, while the trans isomers **3a** and **3d** were obtained by sodium/ammonia reduction.

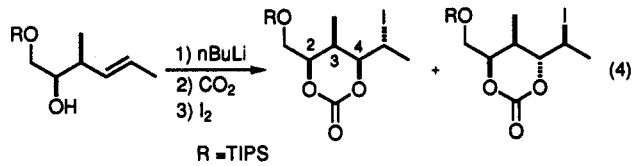
The carbonate extension reaction was applied to **3a–d** for the preparation of the target syn 3,4-epoxy alcohols **4**. The results are summarized in Table I. Some of the iodo carbonates were sensitive to flash chromatography, but pure samples for complete characterization could be isolated by preparative TLC.[10] The relative stereochemistry of the isomeric iodo carbonates was established by means of the corresponding $J_{2,3}$ and $J_{3,4}$ coupling constants.[2a,c,e,4a] The J coupling information for several isolated iodo carbonates is summarized in Table II. As expected, the syn stereoisomer was favored in most cases. Also, a cyclic ether, **15**, was observed in several instances.

This tetrahydrofuran derivative could result from direct cyclization of lithium alkoxide **14** which might form under these reaction conditions (eq 3). Lowering the temperature not only reduced the formation of this secondary product but also increased the stereoselectivity of the reaction.



(3)

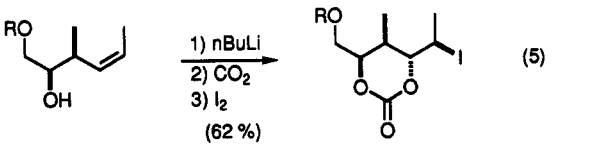
Homoallylic alcohol **3a** (entry 2, Table I) provided a 3:1 syn/anti mixture of carbonates **5a** and **5b** at −78 °C(eq 4). For the syn isomer **5a**, the corresponding $J_{2,3}$ and $J_{3,4}$ of 2.6 Hz are in agreement with the expected axial–equatorial relationship. For the anti isomer **5b**, the $J_{2,3}$ and $J_{3,4}$ of 5.1 and 5.4 Hz, respectively, are near the lower limits of the expected values for an axial–equatorial and/or equatorial–equatorial relationship.



(4)

3a (syn, trans) **5a** (syn) **5b** (anti)

Surprisingly, the iodocarbonatation of the cis homoallylic alcohol **3b** (entry 4) yielded only one detectable stereoisomer (eq 5). This carbonate (**6b**) was isolated as a pure solid in 62% yield. The coupling constants ($J_{2,3}$ = 6.3 Hz and $J_{3,4}$ = 9.9 Hz) for this carbonate were not in agreement with the expected syn configuration and indicated a conformation in which either the 1-iodoethyl or the $TIPSOCH_2$ group was occupying a pseudoaxial position. Such a conformation would require an anti iodo carbonate configuration. X-ray crystallographic analysis confirmed this anti relative configuration.[11] The dioxacyclohexanone ring was found to be in an approximate half-chair or envelope conformation with C(3) out of the main plane of the ring. In this conformation, the bulky $TIPSOCH_2$ group assumes a pseudoaxial position, while the methyl and 1-iodoethyl groups adopt the pseudoequatorial positions. This is, to the best of our knowledge, the first example in which the iodocarbonatation reaction produces an anti iodo carbonate in a highly stereoselective manner.



(5)

3b (syn, cis) **6b** (anti)

The transformation of the analogous TBDMS monoprotected cis homoallylic diol **10** (entry 9) also yielded the anti iodo carbonate **11b**, which was obtained in a 62% yield as a solid product. An increase in reaction temperature to 0 °C did not change the stereoselectivity for **3b**

(8) (a) Fried, J.; Sih, J. C.; Lin, C.; Dalven, P. *J. Am. Chem. Soc.* **1972**, *94*, 4343. (b) Matthews, R. S.; Eickhoff, D. J. *J. Org. Chem.* **1985**, *50*, 3923. (c) Matthews, R. S.; Mihelich, E. D.; McGowan, L. S.; Daniels, K. *J. Org. Chem.* **1983**, *48*, 409.

(9) Isler, O.; Huber, W.; Ronco, A.; Kofler, M. *Helv. Chim. Acta* **1947**, *30*, 1911.

(10) The iodo carbonates were fully characterized by NMR. For example, for carbonate **13a**, the signal at δ 4.45 provided the required information to establish the relative configuration of the system. Coupling constants (obtained by an NMR simulation) of J = 11.5 and 11.6 Hz (AMX part of an ABMX spin system) and J = 2.9 and 2.7 Hz (BMX part) established the syn relative configuration of the major isomer. 2D NMR techniques were used in order to assign the corresponding proton and carbon signals, allowing the unambiguous assignment of the congested area between 3 and 5 ppm in the ^1H NMR spectrum.

(11) Tirado, R.; Prieto, J. A.; Barnes, C. L. *J. Crystallogr. Spectrosc. Res.* **1993**, *23*, 159. Coupling constants $J_{2,3}$ = 4.5 Hz and $J_{3,4}$ = 10.9 Hz were calculated from the X-ray data and are comparable to the solution NMR experimental coupling constants (ref 16).

Table I. Stereoselectivity Studies on the Iodocarbonatation of Alkenols 3a–e, 10, and 12

entry	alkene	R	R^1	R^2	R^3	R^4	t (°C)	carbonate	syn/anti/15 ratio[a]
1	**3a**	TIPS	CH_3	H	H	CH_3	0	**5a, 5b**	1:1:1
2	**3a**	TIPS	CH_3	H	H	CH_3	−78	**5a, 5b**	6:2:1
3	**3b**	TIPS	CH_3	H	CH_3	H	−78	**6a, 6b**[b]	<1:20:2[c]
4	**3c**	TIPS	H	CH_3	CH_3	H	−78	**7a,**[b] **7b**	>20:1[d]
5	**3d**	TIPS	H	CH_3	H	CH_3	0°	**8a, 8b**	10:1:10
6	**3d**	TIPS	H	CH_3	H	CH_3	−78	**8a, 8b**	13:1:3
7	**3e**	TIPS	H	H	CH_3	H	0	**9a, 9b**	7:1[d,e]
8	**3e**	TIPS	H	H	CH_3	H	−78	**9a, 9b**	14:1[d,e]
9	**10**	TBDMS	CH_3	H	CH_3	H	−78	**11a, 11b**[b]	<1:20[c,d]
10	**12**	C_5H_{11}[f]	H	H	CH_3	H	0	**13a, 13b**	6:1[d,e]
11	**12**	C_5H_{11}[f]	H	H	CH_3	H	−78	**13a, 13b**	13:1[d,e]

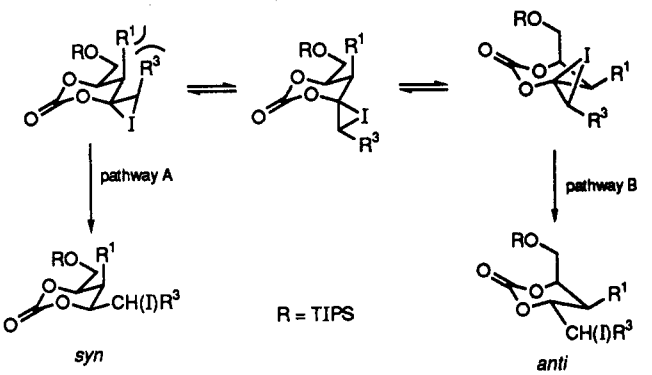
[a] Determined by ^1H NMR of the crude mixture. [b] Only iodocarbonate detected. [c] The same ratio was obtained at 0 °C. [d] The cyclic ether was not observed. [e] Determined by ^{13}C NMR without NOE. [f] *cis*-2-Undecen-5-ol.

Table II. Observed and Calculated Coupling Constants of Selected Iodocarbonates

carbonate	stereo-chemistry	$J_{2,3}$ (Hz) obsd[a]/calcd[b]	$J_{3,4}$ (Hz) obsd[a]/calcd[b]
5a	syn	2.6/2.2	2.6/2.0
5b	anti	5.1/—	5.4/—
6b	anti	6.3/—	9.9/—
7a	syn	10.4/10.9	10.4/9.9
8a	syn	10.2/11.0	10.3/10.6
9a	syn	3.2, 11.5/2.2, 11.6	3.2, 11.6/2.3, 11.6
9b	anti	2.7, 6.6/1.7, 5.8	2.7, 10.8/1.1, 11.4
13a	syn	2.7, 11.5/2.0, 11.6	2.9, 11.6/2.1, 11.6

[a] Verified by an NMR simulation. [b] Obtained from an MMX calculation.

Scheme II



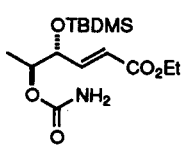
or **10**. Furthermore, compounds lacking the C(3) methyl (entries 7, 8, 10, and 11) resulted in the expected high syn selectivity. This was also the case for compounds having a C(3) methyl in an anti relationship, such as **3c** (entry 4) and **3d** (entries 5 and 6). From these observations, it is clear that the relative configuration of the C(3) methyl group influences the stereochemical outcome of the reaction.[12]

The stereoselectivity of the iodocarbonatation reaction has been explained in terms of the predominance of 1,3- over 1,2-asymmetric induction and the relative stability of the thermodynamic (syn) product.[2a,d] In addition, double-bond geometry has not been demonstrated to be a fundamental factor for the product ratios obtained in this reaction. Consequently, a pseudoequatorial position of the TIPSO and 1-iodoethyl groups (syn isomers **6a** and **11a**) would be expected for **3b** and **10**.[13] The different stereochemistry observed here can be explained as shown in Scheme II. The transition state for the formation of iodo carbonate **6a** is restricted by severe 1,3-repulsive interactions[14] between the C(3) and double bond methyl groups (R^1 and R^3 = Me). Therefore, pathway **B** would be preferred, yielding the anti isomer **6b** exclusively. For **3a**, the syn methyl group and the vinylic hydrogen (R^1 = Me and R^3 = H) exert a less dramatic but still significant effect resulting in a poor 3:1 syn/anti selectivity at −78 °C and even a 1:1 ratio at 0 °C. The high syn selectivity for **3c** and **3d** is expected since when R^1 = H, there would be no steric interactions opposing the formation of a syn isomer (pathway **A**). These results clearly demonstrate that the syn C(3) methyl substituent in combination with the double-bond geometry exerts a powerful influence on the stereochemical outcome of the reaction and that product stability is not the only factor controlling the stereoselectivity of this reaction.

Lipshutz and Barton[4b] in their earlier work on the iodocarbonatation–methanolysis of a series of homoallylic alcohols reported the predominance of the syn products for all of the cases studied. Although their stereochemical assignments were accurate on all other examples, the stereochemical outcome for **3b**, **10**, and **20** (*vide infra*) in our work is opposite from that of a related example used by these authors.[15]

MMX calculations[16] were performed on some iodo carbonates in order to predict the preferred conformations for these highly substituted 2,6-dioxacyclohexanones and to correlate these with the coupling information obtained by NMR. The results are also included in Table II. For all the syn carbonates, the observed and calculated $J_{2,3}$ and $J_{3,4}$ coupling constants were in close agreement.[17] A

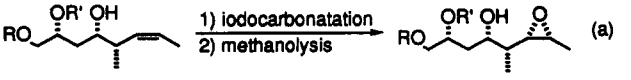
(12) A related finding was obtained on a study on the intramolecular Michael addition of homoallylic carbamates (Hirama, M.; Shigemoto, T.; Ito, S. *Tetrahedron Lett.* **1981**, 4963. Hirama, M.; Nishizaki, I; Shigemoto, T.; Ito, S. *J. Chem. Soc., Chem. Commun.* **1986**, 393). On these systems, the stereoselectivity was influenced by the relative configuration of the OTBDMS group and the cis/trans geometry of the conjugated ester.



(13) (a) Norman, R. O. C. *Principles of Organic Synthesis*; Chapman and Hall, Ltd.: New York, 1978; pp 166–174. (b) Zefirov, N. S.; Gurvich, L. G.; Shaskov, A. S.; Krimer, M. Z.; Vorob'eva, E. A. *Tetrahedron* **1976**, *32*, 1211. (c) Allinger, N. L.; Wertz, D. H. *Ibid.* **1974**, *30*, 1579.

(14) Johnson, F. *Chem. Rev.* **1968**, *68*, 375.

(15) Lipshutz and Barton, basing their stereochemical assignments on an NMR study of a series of corresponding acetonides, did not report a detailed stereochemical analysis for **ii** (eq a). Our findings suggest that **ii** should have an anti hydroxyl/epoxide configuration.



I: R = Bn, R' = TBDMS **II**

(16) PC-Model version 4.0; Serena Software; Bloomington: IN.

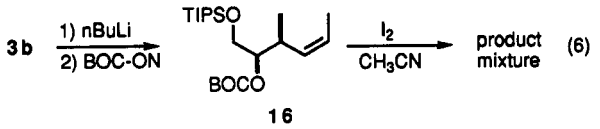
Table III. Preparation of 3,4-Epoxy Alcohols 4a–e

epoxide[a]	R^1	R^2	R^3	R^4	3,4-epoxy	conditions[b]	yield[c] 4/17/18
4a	CH_3	H	H	CH_3	syn	8 h/MeOH	1/55/1
4b	CH_3	H	CH_3	H	anti	18 h/dry MeOH	62/0/0
4c	H	CH_3	CH_3	H	syn	24 h/dry MeOH	51/0/0
4d	H	CH_3	H	CH_3	syn	16 h/dry meOH[d]	43/0/22
4e	H	H	CH_3	H	syn	24 h dry/MeOH	10/45/1
4e	H	H	CH_3	H	syn	24 h/MeOH[d]	46/1/24

[a] Only the major isomer is given. [b] Methanolysis was carried out at 0 °C with 5 equiv of K_2CO_3. [c] Percent from alkene **3**, isolated. [d] 3 equiv of K_2CO_3.

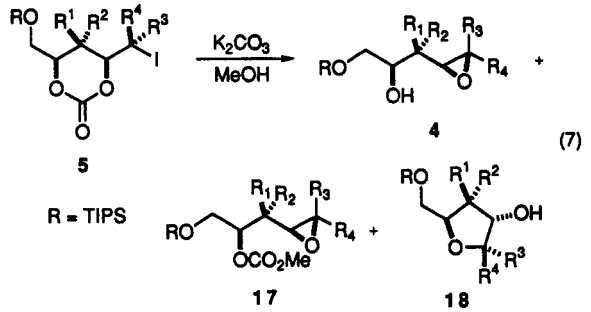
half-chair or envelope conformation, similar to the X-ray structure observed for anti iodo carbonate **6b**, was determined for these iodo carbonates.

Conditions conducive to the formation of the thermodynamically more stable syn product **6a** were unsuccessfully explored. This included the reaction of *tert*-butyl carbonate**16** under electrophilic conditions[2c] at different temperatures (eq 6). An analysis of the crude product showed an untractable mixture with no starting material, iodo carbonate, or epoxide present.



16

The iodo carbonates were submitted to basic methanolysis and transformed into the corresponding 3,4-epoxy alcohols **4** (eq 7). The results are summarized in Table III. In some instances, the acyclic methyl epoxy carbonates **17**, which result from incomplete methanolysis of the cyclic carbonate, were obtained. In some examples, a cyclic side product, **18**, could also be observed. These substituted furans are formed once the epoxy alcohols are produced. The basic reaction conditions can induce the intramolecular oxirane cleavage with a predictable stereochemistry.[18] As shown in Table III, the desired transformation to **4** can be completed by variations in the amount of base and moisture content of the methanol. Some 1,2-silyl migration was observed during the methanolysis of the TBDMS-protected carbonate **11b**, producing a 2:1 mixture of isomeric epoxides. This was not observed for the more hindered TIPS protecting group.



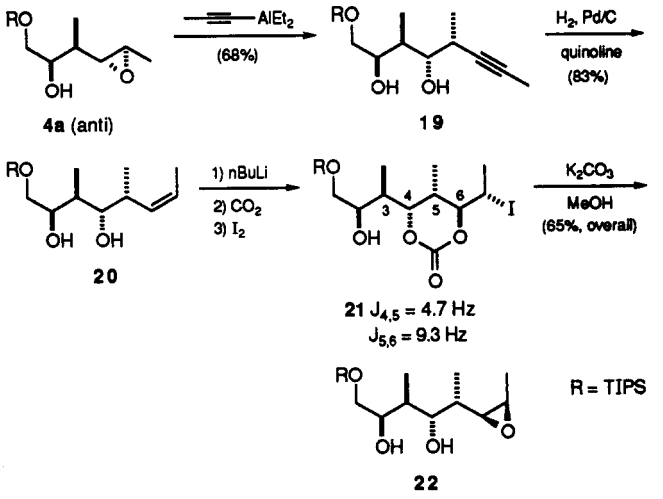
5 **4** **17** **18**

To further extend this approach to polypropionates and to explore the synthetic potential of these findings, the

(17) Inconsistencies are observed for the anti iodo carbonates. The anti carbonate requires a conformation in which the $TIPSOCH_2$ group prefers a pseudoaxial position. Repeatedly, the calculated structure places this group in a pseudoequatorial position. Consequently, no agreement was obtained between the calculated and observed coupling constant for the anti carbonates.

(18) Ireland, R. E.; Wipf, P.; Roper, T. D. *J. Org. Chem.* **1990**, *55*, 2284.

Scheme III



elongation and iodocarbonatation of epoxide **4a** (anti isomer)[19] were undertaken. The transformation is outlined in Scheme III. Alkynediol **19**, obtained from the diethylpropynylalane opening of **4a** (anti), was stereoselectively reduced to the cis isomer **20**. When **20** was subjected to an iodocarbonatation, the anti carbonate **21** was the major stereoisomer observed. The coupling information was obtained with the help of an NMR double-resonance experiment. Irradiation of vicinal proton H(3)at 2.47 ppm in **21** simplified the signal at 4.64 ppm for H(4). This provided the unambiguous measurement of $J_{4,5}$ = 4.7 Hz. The coupling information for this six-membered ring system was in agreement with the anti iodo carbonate configuration. This demonstrated the general tendency for the formation of the anti iodo carbonate when the specific syn configuration of the hydroxyl and methyl groups together with the cis geometry of the alkene is present. Methanolysis of **21** proceeded smoothly yielding epoxide **22** in 65% yield from alkene **20**. Compound **22**, which contains six adjacent stereocenters generated in a highly stereoselective manner, is a potential precursor to the C(22)–C(29) fragment of rifamycin S.[6]

Conclusions

The high regioselectivity of the propynylalane cleavage of disubstituted oxiranes and the subsequent stereoselective reduction of the resulting homopropargylic alcohols provide an efficient route to the cis or trans 2-methyl-3-alken-1-ol moiety. The stereoselectivity of the iodocarbonatation of these system was shown to be dependent on the relative stereochemistry of the homoallylic hydroxyl and C(3) methyl groups joined with the alkene geometry. This methodology, in principle, can be extended to the preparation of polypropionates in a reiterative fashion.

Experimental Section

General. All reactions were carried out on a three-necked, round-bottom flask equipped with a nitrogen inlet, a magnetic bar, a rubber septum, and a dropping funnel. This standard apparatus was flame-dried under a stream of nitrogen and allowed to cool to room temperature. Reactions were monitored by TLC using Sigma Silica Gel 60F (with or without UV indicator) plastic plates (0.25 mm). Components were visualized by ethanolic

(19) Compound **4a** (anti) was also prepared from ethyl 2,3-epoxybutyrate via an iodolactonization sequence (ref 3a) followed by $LiAlH_4$ reduction and silylation (see Experimental Section).

p-anisaldehyde solution, iodine vapor, or long-wave UV light. Flash chromatography was performed with Silica Gel 60 (230–400 mesh) as reported.[20] All solvents were purified before use. Acetonitrile, dichloromethane, DMF, quinoline, and triethylamine were distilled from calcium hydride. THF, hexane, ether, and toluene were distilled from sodium/benzophenone prior to use. Methanol was distilled first from CaO and then from Mg^0 prior to use. Unless otherwise noted, all compounds purified by chromatography were sufficiently pure (by ^1H NMR analysis) for use in subsequent reactions. Melting points are uncorrected. Mass spectra (70 eV) were measured with either an HP 5995 GC-MS or an HP 5971A GC-MS and recorded as *m/z* (relative intensity). The LRFABMS and HRFABMS mass spectra were done by the Midwest Center for Mass Spectroscopy, Lincoln, NE. ^1H NMR (300 MHz) and ^{13}C NMR (75 MHz) were recorded with either a GE QE-300 or a GE GN-300 spectrometer as solutions in deuteriochloroform and recorded in parts per million from tetramethylsilane with the solvent resonance as an internal standard (7.26 and 77.0 ppm, respectively). Analytical GC was carry out using a Varian 3300 capillary gas chromatograph with a flame ionization detector (SE-30, Bonded PSOT, 30 M x 0.25 mm). Elemental analyses were done by Atlantic Microlab Inc., Norcross, GA.

(±)-*trans*-2,3-Epoxy-1-[(triisopropylsilyl)oxy]butane (1a): Procedure A. To a round-bottom flask was added 25.5 g (100 mmol) of TIPS-protected (see 1c below) *trans*-crotyl alcohol diluted in 600 mL of ethanol. After the solution was cooled to 0 °C, 150 g (244 mmol) of MMPP (monoperoxyphthalic acid, magnesium salt, 80%) was added and the reaction mixture stirred for 48 h at rt. Hexane (500 mL) and water (500 mL) were added and the phases separated. The aqueous layer was extracted with hexane (500 mL). The combined organic phase was washed with aqueous 5% H_2SO_4 (300 mL), dried over anhyd $MgSO_4$, and concd under reduced pressure. The crude was distilled to yield 16.4 g (68%) of **1a**: ^1H NMR ($CDCl_3$) δ 3.85 (dd, J = 11.6, 3.7 Hz, 1 H), 3.76 (dd, J = 11.6, 4.5 Hz, 1 H), 2.95 (dq, J = 5.2, 2.2 Hz, 1 H), 2.84 (m, 1 H), 1.32 (d, J = 5.2 Hz, 3 H), 1.10 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 63.6, 59.8, 52.2, 17.9, 17.4, 11.9. Anal. Calcd for $C_{13}H_{28}O_2Si$: C, 63.88; H, 11.54. Found: C, 63.95; H, 11.50.

(±)-*cis*-2,3-Epoxy-1-[(triisopropylsilyl)oxy]butane (1b). Following procedure A, 5.0 g (21.9 mmol) of the TIPS-protected (see 1c below) *cis*-crotyl alcohol and 32.9 g (53.5 mmol) of MMPP provided 4.2 g (74%) of **1b**, bp 74–78 °C/ 0.2 mmHg: ^1H NMR ($CDCl_3$) δ 3.81 (m, 2 H), 3.10 (m, 2 H), 1.28 (d, J = 5.4 Hz, 3 H), 1.07 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 61.5, 57.0, 52.2, 17.9, 13.3, 11.9. Anal. Calcd for $C_{13}H_{28}O_2Si$: C, 63.88; H, 11.54. Found: C, 63.87; H, 11.52.

(±)-2,3-Epoxy-1-[(triisopropylsilyl)oxy]propane (1c). A round-bottom flask was charged with 500 mL of dry DMF, 16.8 mL (120 mmol) of dry TEA, 0.61 g of DMAP, 7.7 g (100 mmol) of glycidol, and 23.1 g (120 mmol) of TIPSCl. After being stirred for 24 h, the reaction mixture, was diluted with 500 mL of ether and 500 mL of aqueous 5% H_2SO_4. The aqueous phase was extracted with ether (3 × 200 mL). The organic phase combination was washed with aqueous saturated NaCl and dried over anhyd MgSO4. The solvent was removed at reduced pressure and distilled providing 17.8 g (77%, bp 72–75 °C/0.1 mmHg) of **1c**: ^1H NMR ($CDCl_3$) δ 3.91 (dd, J = 11.6, 3.2 Hz, 1 H), 3.74 (dd, J = 11.6, 4.7 Hz, 1 H), 3.05 (m, 1 H), 2.76 (dd, J = 5.2, 4.1 Hz, 1 H), 2.66 (dd, J = 5.2, 2.7 Hz, 1 H), 1.07 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 63.8, 52.4, 44.1, 17.7, 11.8. Anal. Calcd for $C_{12}H_{26}O_2Si$: C, 62.55; H, 11.37. Found: C, 62.48; H, 11.32.

(±)-*syn*-3-Methyl-1-[(triisopropylsilyl)oxy]-4-hexyn-2-ol (2a): Procedure B. Following the procedure of Fried[8a] with some modifications, a three-neck round-bottom flask, equipped with a dry ice condenser, was charged with toluene (190 mL) and cooled to 0 °C. Then, 20.6 mL (49.7 mmol) of 2.4 M *n*-BuLi was added, and propyne gas was bubbled through the reaction mixture. The solution became at first yellow and then turned milky white once an excess of propyne had been introduced. After this, 26.4 mL (47.5 mmol) of diethylaluminum chloride (1.8 M in toluene) was added via a syringe and the solution stirred at 0 °C for 4 h. To this solution was added 6.1 g (25 mmol) of epoxide **1a**, and the reaction was stirred for 18 h at 0 °C. Then, aqueous 5% H_2SO_4 (50 mL) was added dropwise at 0 °C. The phases were separated. The aqueous phase was extracted with hexane, and the combined organic phases were dried over anhyd $MgSO_4$. The crude oil was purified by flash chromatography (4:1 hexane/ether) to yield 4.65 g (65%) of **2a**: ^1H NMR ($CDCl_3$) δ 3.90 (dd, J = 9.7, 3.6 Hz, 1 H), 3.76 (dd, J = 9.7, 6.4 Hz, 1 H), 3.47 (m, 1 H), 2.50 (m, 1 H), 2.31 (s, 1 H, variable), 1.77 (d, J = 2.4 Hz, 3 H), 1.22 (d, J = 7.0 Hz, 3 H), 1.10 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 80.4, 77.6, 75.0, 65.4, 29.2, 17.9, 17.4, 11.9, 3.4. Anal. Calcd for $C_{16}H_{32}O_2Si$: C, 67.55; H, 11.34. Found: C, 67.65; H, 11.32.

(±)-*anti*-3-Methyl-1-[(triisopropylsilyl)oxy]-4-hexyn-2-ol (2b). Following procedure B, 15.5 mL (37.0 mmol, 2.4 M) of *n*-BuLi, 19.8 mL (35.6 mmol, 1.8 M) of Et_2AlCl, and 4.55 g (18.6 mmol) of **1b** provided, after flash chromatography (4:1 hexane/ether) 3.4, g (65%) of **2b**: ^1H NMR ($CDCl_3$) δ 3.72 (m, 2 H), 3.54 (ddd, J = 5.9, 5.9, 4.3 Hz, 1 H), 2.75 (m, 1 H), 1.81 (d, J = 2.4 Hz, 3 H), 1.60 (s, 1 H, variable), 1.21 (d, J = 7.1 Hz, 3 H), 1.05 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 79.5, 78.1, 74.4, 65.3, 29.1, 17.9, 17.5, 11.9, 3.5. Anal. Calcd for $C_{16}H_{32}O_2Si$: C, 67.55; H, 11.34. Found: C, 67.58; H, 11.29.

(±)-1-[(Triisopropylsilyl)oxy]-4-hexyn-2-ol (2c). Following procedure B, 105 mL of dry toluene, 11.5 mL (27.5 mmol, 2.39 M) of *n*-BuLi, 14.6 mL (26.3 mmol, 1.8 M in toluene) of Et_2AlCl, and 3.18 g (13.8 mmol) of **1c** provided, after flash chromatography (6:1 hexane/ethyl acetate), 2.3 g (62%) of **2c**: ^1H NMR ($CDCl_3$) δ 3.74 (m, 3 H), 2.38 (dq, J = 5.9, 2.6 Hz, 2 H), 1.78 (t, J = 2.6 Hz, 3 H), 1.10 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 77.5, 74.9, 70.5, 65.9, 23.3, 17.8, 11.8, 3.3. Anal. Calcd for $C_{15}H_{30}O_2Si$: C, 66.61; H, 11.18. Found: C, 66.56; H, 11.16.

(±)-*trans-syn*-3-Methyl-1-[(triisopropylsilyl)oxy]-4-hexen-2-ol (3a): Procedure C. Dry ammonia (30 mL) was added to a round-bottom flask equipped with a dry ice condenser. Then, 1.2 g (52 mmol) of sodium was added followed by the dropwise addition of a solution containing 1.43 g (5 mmol) of **2a** in 13 mL of dry THF and 0.6 mL of *t*-BuOH. The reaction was allowed to reach rt as it was stirred overnight. The excess sodium was destroyed with ethanol, and the solution was diluted with ether (70 mL) and aqueous 5% H_2SO_4 (70 mL). The layers were separated, and the aqueous phase extracted with ether (70 mL). The combined organic portion was dried over anhyd $MgSO_4$ and the solvent removed at reduced pressure to give a yellow oil. After flash chromatography (4:1 hexane/ether), 0.91 g (56%) of **3a** was obtained: ^1H NMR ($CDCl_3$) δ 5.46 (dq, J = 15.3, 6.2 Hz, 1 H), 5.31 (dd, J = 15.3, 8.0 Hz, 1 H), 3.73 (dd, J = 9.7, 3.5 Hz, 1 H), 3.54 (dd, J = 9.7, 7.3 Hz, 1 H), 3.41 (ddd, J = 7.3, 7.3, 3.5 Hz, 1 H), 2.56 (s, 1 H, variable), 2.23 (m, 1 H), 1.65 (d, J = 6.2 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 133.2, 125.2, 75.2, 65.7, 39.9, 17.9, 11.9, 11.6, 11.5. Anal. Calcd for $C_{16}H_{34}O_2Si$: C, 67.07; H, 11.96. Found: C, 67.04; H, 11.96.

(±)-*cis-syn*-3-Methyl-1-[(triisopropylsilyl)oxy]-4-hexen-2-ol (3b): Procedure D. A mixture of 0.05 mL of freshly distilled quinoline, 18 mg of Pd/C (10% Pd), and 0.57 g (2.0 mmol) of **2a** in 5 mL of hexane was exposed to H_2 (1 atm). Stirring was started, causing rapid absorption of hydrogen. When 1.1 equiv of H_2 was consumed (6 h), an abrupt halt on the H_2 consumption was observed. The reaction mixture was filtered and purified by flash chromatography (4:1 hexane/ether) to give 512 mg (90%) of **3b**: ^1H NMR ($CDCl_3$) δ 5.47 (dqd, J = 10.8, 6.8, 0.67 Hz, 1 H), 5.18 (ddq, J = 11.2, 10.8, 1.6 Hz, 1 H), 3.75 (dd, J = 9.5, 3.0 Hz, 1 H), 3.47 (dd, J = 9.5, 7.7 Hz, 1 H), 3.39 (ddd, J = 7.7, 7.7, 3.0 Hz, 1 H), 2.80 (s, 1 H, variable), 2.55 (m, 1 H), 1.61 (dd, J = 6.8, 1.6 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 132.5, 124.3, 75.6, 65.9, 34.5, 17.9, 17.1, 13.1, 11.9. Anal. Calcd for $C_{16}H_{34}O_2Si$: C, 67.07; H, 11.96. Found: C, 67.17; H, 11.92.

(±)-*cis-anti*-3-Methyl-1-[(triisopropylsilyl)oxy]-4-hexen-2-ol (3c). Following procedure D, 0.50 g (1.76 mmol) of **2b** provided 0.47 g (90%) of alkene **3c** after chromatography (4:1 hexane/ether): ^1H NMR ($CDCl_3$) δ 5.52 (dqd, J = 10.9, 6.7, 1.6 Hz, 1 H), 5.35 (m, 1H), 3.72 (dd, J = 8.9, 2.7 Hz, 1 H), 3.55 (m, 2 H), 3.00 (s, 1 H, variable), 2.70 (m, 1 H), 1.61 (dd, J = 6.7, 1.6 Hz, 3 H), 1.10 (m, 21 H), 0.99 (d, J = 6.9 Hz, 3 H); ^{13}C NMR ($CDCl_3$) δ 132.3, 124.5, 75.5, 65.5, 33.6, 17.9, 17.0, 13.0, 11.9. Anal. Calcd for $C_{16}H_{34}O_2Si$: C, 67.07; H, 11.96. Found: C, 66.97; H, 11.91.

(20) Still, C. W.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923.

(±)-*trans-anti*-3-Methyl-1-[(triisopropylsilyl)oxy]-4-hexen-2-ol (3d). Following procedure C, 1.19 g (4.2 mmol) of **2b** provided 0.73 g (61%) of **3d** after flash chromatography (4:1 hexane/ether): ^{1}H NMR ($CDCl_3$) δ 5.47 (m, 2 H), 3.71 (dd, J = 9.6, 3.6 Hz, 1 H), 3.56 (dd, J = 9.6, 7.6 Hz, 1 H), 3.50 (m, 1 H), 2.50 (s, 1 H, variable), 2.27 (m, 1 H), 1.68 (d, J = 4.7 Hz, 3 H), 1.10 (m, 21 H), 1.01 (d, J = 6.9 Hz, 3 H); ^{13}C NMR ($CDCl_3$) δ 132.3, 124.5, 75.3, 65.6, 39.4, 18.0, 17.9, 16.7, 11.9. Anal. Calcd for $C_{16}H_{34}O_2Si$: C, 67.07; H, 11.96. Found: C, 66.97; H, 11.93.

(±)-*cis*-1-[(Triisopropylsilyl)oxy]-4-hexen-2-ol (3e). Following procedure D, 0.27 g (1.0 mmol) of **2c** provided 0.24 g (90%) of alkene **3e** after chromatography (6:1 hexane/ethyl acetate): ^{1}H NMR ($CDCl_3$) δ 5.59 (dqt, J = 10.8, 6.7, 1.4 Hz, 1 H), 5.44 (dtq, J = 10.8, 7.2, 1.7 Hz, 1 H), 3.8–3.6 (m, 2 H), 3.53 (dd, J = 10.6, 8.1 Hz, 1 H), 2.50 (s, 1 H, variable), 2.21 (m, 2 H), 1.62 (m, 3 H), 1.10 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 126.2, 125.7, 71.7, 66.9, 30.5, 17.9, 12.8, 11.8. Anal. Calcd for $C_{15}H_{32}O_2Si$: C, 66.11; H, 11.84. Found: C, 66.03; H, 11.82.

(±)-*cis-syn*-1-[(*tert*-Butyldimethylsilyl)oxy]-3-methyl-4-hexen-2-ol (10). Following procedure D (with Lindlar catalyst, 0.05 g), 1.9 g (7.9 mmol) of **2a** (in the TBDMS-protected form) provided 1.7 g (90%) of alkene **10**: ^{1}H NMR ($CDCl_3$) δ 5.42 (dqd, J = 10.8, 6.8, 1.8 Hz, 1 H), 5.15 (ddq, J = 10.8, 9.8, 1.8 Hz, 1 H), 3.68 (dd, J = 9.4, 2.8 Hz, 1 H), 3.42 (dd, J = 9.4, 6.9 Hz, 1 H), 3.39 (m, 1 H), 2.53 (m, 1 H), 2.51 (m, 1 H, variable), 1.58 (dd, J = 6.8, 1.8 Hz, 3 H), 1.02 (d, J = 6.7 Hz, 3 H), 0.87 (s, 9 H), 0.03 (s, 6 H); ^{13}C NMR ($CDCl_3$) δ 132.7, 124.1, 75.5, 65.5, 34.5, 25.8, 18.2, 17.0, 13.0, -5.48. Anal. Calcd for $C_{13}H_{28}O_2Si$: C, 63.87; H, 11.55. Found: C, 63.94; H, 11.52.

(±)-*cis*-2-Undecen-5-ol (12). Following procedure D, (with Lindlar catalyst, 0.22 g), 3.4 g (20 mmol) of 2-undecyn-1-ol provided 2.42 g (72%) of **12** which was used without further purification: ^{1}H NMR ($CDCl_3$) δ 5.65–5.43 (m, 2 H), 3.61 (m, 1 H), 2.21 (t, J = 6.8 Hz, 2 H), 1.63 (dd, J = 7.2, 0.73 Hz, 3 H), 1.45 (m, 2 H), 1.25 (m, 8 H), 0.85 (m, 3 H); ^{13}C NMR ($CDCl_3$) δ 126.3, 126.2, 71.2, 36.6, 34.7, 31.7, 29.2, 25.5, 22.4, 13.8, 12.7. Anal. Calcd for $C_{11}H_{22}O$: C, 77.58; H, 13.02. Found: C, 77.33; H, 12.89.

(±)-*tert*-Butyl *cis-syn*-2-Methyl-1-[((triisopropylsilyl)oxy)methyl]-3-pentenyl Carbonate (16). Following the procedure of Bartlett[2c] with some modifications, a round-bottom flask containing 0.35 g (1.2 mmol) of **3b** and 3.4 mL of dry THF was cooled to 0 °C. Then, 0.68 mL (1.4 mmol) of 2.1 M *n*-BuLi was added. After 5 min, 0.36 g (1.4 mmol) of 2-(*tert*-butoxycarbonyloxyimino)-2-phenylacetonitrile (BOC-ON) was added and the reaction allowed to reach rt as it was stirred overnight. The reaction mixture was diluted with ether (25 mL) and 0.2 M aqueous NaOH (24 mL). The layers were separated, and the organic phase was washed with aq 0.2 M NaOH (24 mL). The combined aqueous phase was back-extracted with ether (25 mL). The combined organic phase was dried over anhyd $MgSO_4$ and concd under reduced pressure. The crude was purified by flash chromatography (8:1 hexane/ethyl acetate) to give 0.31 g (68%) of **16**: ^{1}H NMR ($CDCl_3$) δ 5.46 (m, 1 H), 5.20 (m, 1 H), 4.56 (m, 1 H), 3.81 (dd, J = 10.9, 3.5 Hz, 1 H), 3.67 (dd, J = 10.9, 6.7 Hz, 1 H), 2.85 (m, 1 H), 1.59 (dd, J = 6.8, 1.6 Hz, 3 H), 1.45 (s, 9 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 153.6, 131.8, 124.8, 81.3, 81.2, 63.4, 32.2, 27.8, 17.9, 16.6, 13.0, 11.9. Anal. Calcd for $C_{21}H_{42}O_4Si$: C, 65.24; H, 10.95. Found: C, 65.27; H, 10.89.

(±)-(3*R,4*R**,5*S**,1′*R**)-5-(1-Iodoethyl)-4-methyl-3-[((triisopropylsilyl)oxy)methyl]-2,6-dioxacyclohexanone (5a): Procedure E.** Following the procedure of Cardillo[2a] with some modifications, in a dry round-bottom flask was placed 0.39 g (1.36 mmol) of **3a** in 14 mL of THF. The solution was cooled to -78 °C, and 0.83 mL (2.04 mmol) of 2.45 M *n*-BuLi was added. After 0.5 h, dry CO_2 was bubbled through the solution for 1 h. Then, 1.38 g (5.44 mmol) of I_2 was added. The reaction mixture was stirred and CO_2 bubbled for an additional 2 h. The reaction mixture was allowed to reach rt as it was stirred overnight. The reaction mixture was diluted with ethyl acetate (20 mL) and washed with aqueous 20% $Na_2S_2O_3$ (20 mL) and 5% $NaHCO_3$ (20 mL). The organic portion was dried over anhyd Na_2SO_4 and concd under reduced pressure to yield 0.59 g of a crude 3:1 mixture of syn/anti isomers. The crude was used without further purification. An analytical sample was obtained by preparative TLC. **Major syn isomer 5a:** ^{1}H NMR ($CDCl_3$) δ 4.54 (ddd, J = 8.3, 5.8, 2.6 Hz, 1 H), 4.47 (dd, J = 10.8, 2.6 Hz, 1 H), 4.01 (dq, J = 10.8, 6.6 Hz, 1 H), 3.94 (dd, J = 10.2, 5.8 Hz, 1 H), 3.76 (dd, J = 10.2, 8.3 Hz, 1 H), 2.89 (qdd, J = 7.2, 2.6, 2.6 Hz, 1 H), 2.10 (d, J = 6.6 Hz, 3 H), 1.17 (m, 21 H), 0.93 (d, J = 7.2 Hz, 3 H); ^{13}C NMR ($CDCl_3$) δ 147.6, 86.5, 81.7, 61.7, 30.7, 24.8, 22.6, 17.9, 11.9, 3.2; EIMS (70 eV) for $C_{17}H_{33}O_4SiI$ (M^+) calcd 456, found 456. **Minor anti isomer 5b:** ^{1}H NMR ($CDCl_3$) δ 4.49 (dd, J = 6.9, 5.4 Hz, 1 H), 4.37 (ddd, J = 6.0, 5.1, 4.2 Hz, 1 H), 4.30 (qd, J = 6.9, 6.9 Hz, 1 H), 3.96 (dd, J = 10.9, 4.2 Hz, 1 H), 3.89 (dd, J = 10.9, 6.0 Hz, 1 H), 2.69 (m, 1 H), 1.99 (d, J = 6.9 Hz, 3 H), 1.14 (d, J = 7.1 Hz, 3 H), 1.10 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 148.1, 87.1, 78.2, 61.7, 30.9, 24.1, 23.1, 17.9, 11.8, 11.8. HRFABMS for $C_{17}H_{34}O_4SiI$ [M + H]$^+$: Calcd 457.127, found 457.127.

(±)-(3*R,4*R**,5*R**,1′*R**)-5-(1-Iodoethyl)-4-methyl-3-[((triisopropylsilyl)oxy)methyl]-2,6-dioxacyclohexanone (6b).** Following procedure E, 0.46 g (1.6 mmol) of **3b** produced a solid which was washed with cold hexane/ether (4:1) to give 0.45 g (62%) of the anti carbonate **6b**, mp 102–104 °C: ^{1}H NMR ($CDCl_3$) δ 4.31 (m, 1 H), 4.24 (dq, J = 7.1, 1.8 Hz, 1 H), 4.08 (dd, J = 11.7, 3.2 Hz, 1 H), 3.98 (dd, J = 11.7, 1.7 Hz, 1 H), 3.86 (dd, J = 9.9, 1.8 Hz, 1 H), 2.41 (dqd, J = 9.9, 6.9, 6.3 Hz, 1 H), 2.03 (d, J = 7.1 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 148.3, 83.0, 79.8, 61.9, 34.8, 28.7, 24.7, 17.7, 11.5, 11.0. Anal. Calcd for $C_{17}H_{33}O_4SiI$: C, 44.73; H, 7.29. Found: C, 44.73; H, 7.33.

(±)-(3*R,4*S**,5*S**,1′*S**)-5-(1-Iodoethyl)-4-methyl-3-[((triisopropylsilyl)oxy)methyl]-2,6-dioxacyclohexanone (7a).** Following procedure E, 0.57 g (2.0 mmol) of **3c** provided 0.82 g of crude **7a**. The crude was used without further purification. An analytical sample was obtained by preparative TLC. **Syn isomer 7a:** ^{1}H NMR ($CDCl_3$) δ 4.29 (dq, J = 7.1, 1.6 Hz, 1 H), 4.17 (dt, J = 10.4, 2.5 Hz, 1 H), 4.02 (dd, J = 11.7, 2.5 Hz, 1 H), 3.90 (dd, J = 11.7, 2.5 Hz, 1 H), 3.14 (dd, J = 10.2, 1.6 Hz, 1 H), 2.51 (m, 1 H), 2.05 (d, J = 7.1 Hz, 3 H), 1.10 (m, 21 H), 0.98 (d, J = 6.7 Hz, 3 H); ^{13}C NMR ($CDCl_3$) δ 148.9, 84.2, 83.1, 62.3, 34.2, 26.6, 25.1, 17.8, 11.8, 11.4; HRFABMS for $C_{17}H_{34}O_4SiI$ [M + H]$^+$ calcd 457.127, found 457.129.

(±)-(3*R,4*S**,5*S**,1′*R**)-5-(1-Iodoethyl)-4-methyl-3-[((triisopropylsilyl)oxy)methyl]-2,6-dioxacyclohexanone (8a).** Following procedure E, 0.14 g (0.5 mmol) of **3d** provided 0.16 g of a 13:1 syn/anti mixture of isomers. The crude was used without further purification. An analytical sample was obtained by preparative TLC. **Major syn isomer 8a:** ^{1}H NMR ($CDCl_3$) δ 4.45 (qd, J = 7.1, 2.3 Hz, 1 H), 4.26 (dd, J = 10.3, 2.3 Hz, 1 H), 4.10–3.85 (m, 3 H), 2.44 (ddq, J = 10.3, 10.2, 6.7 Hz, 1 H), 1.85 (d, J = 7.1 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 149.3, 86.4, 83.2, 62.2, 30.5, 22.0, 20.9, 17.9, 12.6, 11.8. HRFABMS for $C_{17}H_{34}O_4SiI$ [M + H]$^+$ calcd 457.127, found 457.126. **Minor anti isomer 8b:** ^{1}H NMR ($CDCl_3$) δ 4.86 (dd, J = 10.9, 2.7 Hz, 1 H), 4.25 (m, 1 H), 4.05–3.90 (m, 3 H), 2.88 (m, 1 H), 2.08 (d, J = 6.7 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 149.3, 83.8, 82.1, 64.4, 31.1, 24.8, 22.5, 17.9, 11.8, 11.0; LRFABMS for [M + H]$^+$ calcd 457.1, found 457.3.

(±)-(3*R,5*S**,1′*S**)-5-(1-Iodoethyl)-3-[((triisopropylsilyl)oxy)methyl]-2,6-dioxacyclohexanone (9a).** Following procedure E, 0.24 g (0.9 mmol) of **3e** provided 0.33 g of a 14:1 syn/anti mixture of isomers. The crude was used without further purification. An analytical sample was obtained by preparative TLC. **Major syn isomer 9a:** ^{1}H NMR ($CDCl_3$) δ 4.51 (m, 1 H), 4.3–4.1 (m, 2 H), 3.90 (d, J = 4.2 Hz, 2 H), 2.33 (ddd, J = 14.1, 3.2, 3.2 Hz, 1 H), 2.20 (ddd, J = 14.1, 11.6, 11.5, 1 H), 1.95 (d, J = 6.8 Hz, 3 H), 1.10 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 148.5, 80.8, 78.0, 64.3, 27.6, 25.2, 22.7, 17.8, 11.7. **Minor anti isomer 9b:** ^{1}H NMR ($CDCl_3$) δ 4.59 (m, 1 H), 4.53 (m, 1 H), 4.24 (qd, J = 7.1, 3.8 Hz, 1 H), 4.01 (dd, J = 10.9, 3.2 Hz, 2 H), 3.91 (dd, J = 10.9, 5.4 Hz, 1 H), 2.35 (ddd, J = 14.3, 2.7, 2.7 Hz, 1 H), 2.19 (ddd, J = 14.3, 10.8, 6.6 Hz, 1 H), 1.95 (d, J = 7.1 Hz, 3 H), 1.10 (m, 21 H); ^{13}C NMR ($CDCl_3$) δ 148.5, 78.7, 76.3, 64.8, 26.9, 25.5, 22.9, 17.9, 11.8. LRFABMS for [M + 31]$^+$ calcd 473.3, found 473.3. Anal. Calcd for $C_{16}H_{31}O_4SiI$ (**9a**): C, 43.44; H, 7.06. Found: C, 43.22; H, 6.99.

(±)-(3*R,4*R**,5*R**,1′*R**)-3-[(*tert*-Butyldimethylsilyl)oxy]-5-(1-iodoethyl)-4-methyl-2,6-dioxacyclohexanone (11b).** Following procedure E, 1.2 g (5.0 mmol) of **10** provided a crude solid. The solid was washed with cold hexane/ether (4:1) to give 1.28 g (62%) of the anti carbonate **11b**, mp 90–91 °C: ^{1}H NMR ($CDCl_3$) δ 4.30 (m, 1 H), 4.23 (dq, J = 7.1, 1.7 Hz, 1 H), 3.95 (dd, J = 11.9, 2.8 Hz, 1 H), 3.87 (dd, J = 11.9, 1.7 Hz, 1 H), 3.80 (dd, J = 10.0,

1.7 Hz, 1 H), 2.40 (dqd, J = 10.0, 7.1, 6.4 Hz, 1 H), 2.03 (d, J = 7.1 Hz, 3 H), 0.99 (d, J = 7.1 Hz, 3 H), 0.88 (s, 9 H), 0.08 (s, 6 H); ^{13}C NMR ($CDCl_3$) δ 148.5, 83.0, 79.9, 61.6, 35.0, 28.5, 25.7, 25.0, 18.0, 11.2, -5.7. Anal. Calcd for $C_{14}H_{27}O_4SiI$: C, 40.58; H, 6.57. Found: C, 40.49; H, 6.58.

(±)-(3*S,5*S**,1′*S**)-5-Hexyl-3-(1-iodoethyl)-2,6-dioxacyclohexanone (13a).** Following procedure E, 0.34 g (2.0 mmol) of **12** provided 0.41 g of a 13:1 syn/anti mixture of isomers. The crude was used without further purification. An analytical sample was obtained by preparative TLC. **Major syn isomer 13a:** ^{1}H NMR ($CDCl_3$) δ 4.45 (dddd, J = 11.5, 8.2, 4.3, 2.9 Hz, 1 H), 4.3–4.2 (m, 2 H), 2.26 (ddd, J = 14.1, 2.9, 2.9 Hz, 1 H), 1.93 (d, J = 6.8 Hz, 3 H), 1.8–1.1 (m, 11 H), 0.85 (m, 3 H); ^{13}C NMR ($CDCl_3$) δ 148.8, 81.2, 78.2, 35.1, 31.5, 30.9, 28.9, 25.0, 24.4, 22.5, 22.5, 14.0; HRFABMS for $C_{12}H_{23}O_3I$ [M + H]$^+$ calcd 341.063, found 341.061. **Minor anti isomer 13b:** ^{1}H NMR ($CDCl_3$) δ 4.7–4.5 (m, 1 H), 4.4–4.2 (m, 2 H), 2.3–2.1 (m, 2 H), 1.93 (d, J = 6.5 Hz, 3 H), 1.8–1.1 (m, 10 H), 0.85 (m, 3 H); ^{13}C NMR ($CDCl_3$) δ 148.8, 78.3, 77.1, 34.5, 31.5, 29.2, 28.8, 25.5, 25.1, 22.8, 22.5, 13.9; MS (70 eV) for $C_{12}H_{21}O_3I$ (M^+) calcd 340.2, found 340.2.

(±)-(2*R,3*R**,4*S**,5*S**)-4,5-Epoxy-3-methyl-1-[(triisopropylsilyl)-oxy]-2-hexanol (4a) and (+)-Methyl *trans*-3,4-Epoxy-2-methyl-1-[((triisopropylsilyl)oxy)methyl]pentyl carbonate (17a): Procedure F.** Following procedure E, 0.22 g (0.4 mmol) of **3a** produced 0.30 g of a 3:1 isomer mixture of iodo carbonates **5a/5b**. Then, 2.1 mL of dry MeOH was added, and the mixture was cooled to 0 °C followed by the addition of 0.26 g of K_2CO_3. The reaction was followed by TLC. The reaction mixture was diluted with ethyl acetate (20 mL) and water (20 mL), and the aqueous phase was extracted with ethyl acetate (2 x 20 mL). The combined organic layer was washed with saturated aqueous NaCl, dried over anhyd Na_2SO_4, and concd under reduced pressure. The crude showed a 3:1 syn/anti isomer mixture of **17** which was purified by flash chromatography (5:1 hexane/ethyl acetate) to give 0.14 g (51% from **3a**) of **17**. **Major syn methyl carbonate isomer 17a:** ^{1}H NMR ($CDCl_3$) δ 4.78 (dt, J = 5.4, 5.4 Hz, 1 H), 3.83 (d, J = 5.4 Hz, 2 H), 3.77 (s, 3 H), 2.86 (qd, J = 5.2, 2.2 Hz, 1 H), 2.60 (dd, J = 7.0, 2.2 Hz, 1 H), 1.78 (m, 1 H), 1.29 (d, J = 5.2 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 155.6, 79.9, 62.5, 61.1, 54.7, 54.3, 36.7, 17.9, 17.4, 11.9, 11.8. Anal. Calcd for $C_{18}H_{36}O_5Si$: C, 59.96; H, 10.06. Found: C, 60.07; H, 10.07. **Minor anti methyl carbonate isomer 17b:** ^{1}H NMR ($CDCl_3$) δ 4.92 (dt, J = 7.1, 5.4 Hz, 1 H), 3.9–3.8 (m, 5 H), 2.79 (qd, J = 5.4, 2.2 Hz, 1 H), 2.61 (dd, J = 7.3, 2.2 Hz, 1 H), 1.66 (m, 1 H), 1.29 (d, J = 5.4 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 155.6, 79.6, 62.9, 60.6, 54.6, 53.2, 36.3, 17.9, 17.4, 11.9. **Major syn epoxide 4a (syn):** ^{1}H NMR ($CDCl_3$) δ 3.9–3.5 (m, 3 H), 2.86 (qd, J = 5.2, 2.2 Hz, 1 H), 2.60 (m, 1 H), 1.65 (s, 1 H, variable), 1.54 (m, 1 H), 1.29 (d, J = 5.2 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$)\ δ 73.5, 65.4, 61.5, 54.0, 38.1, 17.9, 17.6, 11.9, 11.9. **Minor anti epoxide 4a (anti):** ^{1}H NMR ($CDCl_3$) δ 3.9–3.5 (m, 3 H), 2.79 (qd, J = 5.2, 2.3 Hz, 1 H), 2.60 (m), 1.65 (s, 1 H, variable), 1.35 (m, 1 H), 1.30 (d, J = 5.2 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 73.8, 65.9, 61.7, 53.6, 38.8, 17.9, 17.7, 11.9, 11.7. Anal. Calcd for $C_{16}H_{34}O_3Si$: C, 63.52; H, 11.33. Found: C, 63.40; H, 11.26.

(±)-(2*R,3*R**,4*R**,5*S**)-4,5-Epoxy-3-methyl-1-[(triisopropylsilyl)oxy]-2-hexanol (4b).** Following procedure F, 1.25 g (2.73 mmol) of solid iodo carbonate **6b** provided, after chromatography (4:1 hexane/ethyl acetate), 0.79 g (95%) of **4b**: ^{1}H NMR ($CDCl_3$) δ 3.91 (dd, J = 9.5, 3.3 Hz, 1 H), 3.71 (ddd, J = 8.3, 6.7, 3.3 Hz, 1 H), 3.61 (dd, J = 9.5, 8.3 Hz, 1 H), 3.05 (qd, J = 5.6, 4.4 Hz, 1 H), 2.78 (dd, J = 9.4, 4.4 Hz, 1 H), 1.65 (s, 1 H, variable), 1.40 (m, 1 H), 1.27 (d, J = 5.6 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 74.3, 66.0, 58.5, 51.9, 34.8, 17.8, 12.9, 11.8, 11.6. Anal. Calcd for $C_{16}H_{34}O_3Si$: C, 63.52; H, 11.33. Found: C, 63.43; H, 11.27.

(±)-(2*R,3*S**,4*S**,5*R**)-4,5-Epoxy-3-methyl-1-[(triisopropylsilyl)oxy]-2-hexanol (4c).** Following procedure F, 0.57 g (1.1 mmol) of alkene **3c** produced 0.82 g of iodo carbonate **7a**. Methanolysis provided, after chromatography (4:1 hexane/ether), 0.31 g (51%) of **4c**: ^{1}H NMR ($CDCl_3$) δ 3.80 (m, 3 H), 3.04 (m, 2 H), 1.65 (s, 1 H, variable), 1.52 (m, 1 H), 1.27 (d, J = 5.5 Hz, 3 H), 1.10 (m, 21 H), 1.03 (d, J = 7.3 Hz, 3 H); ^{13}C NMR ($CDCl_3$) δ 75.5, 65.6, 57.6, 50.9, 34.4, 17.8, 13.1, 13.0, 11.8. Anal. Calcd for $C_{16}H_{34}O_3Si$: C, 63.52; H, 11.33. Found: C, 63.38; H, 11.31.

(±)-(2*R,3*S**,4*S**,5*S**)-4,5-Epoxy-3-methyl-1-[(triisopropylsilyl)oxy]-2-hexanol (4d) and (±)-Methyl *trans*-3,4-Epoxy-2-methyl-1-[((triisopropylsilyl)oxy)methyl]pentyl Carbonate (17d).** Following procedure F, 0.18 g (0.6 mmol) of alkene **3d** produced 0.20 g of iodo carbonate **8**. Methanolysis provided, after chromatography (6:1 hexane/ethyl acetate), 0.034 g (15%) of methyl carbonate **17d** and 0.083 g (42%) of **4d**. **17d:** ^{1}H NMR ($CDCl_3$) δ 4.86 (ddd, J = 7.0, 4.4, 4.4 Hz, 1 H), 3.94 (d, J = 11.1, 7.0 Hz, 1 H), 3.86 (d, J = 11.1, 4.4 Hz, 1 H), 3.78 (s, 3 H), 2.73 (m, 2 H), 1.78 (m, 1 H), 1.29 (d, J = 5.0 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 155.6, 79.9, 62.5, 61.1, 54.7, 54.3, 36.7, 17.9, 17.4, 11.8. Anal. Calcd for $C_{18}H_{36}O_5Si$: C, 59.96; H, 10.06. Found: C, 59.96; H, 10.30. **4d:** ^{1}H NMR ($CDCl_3$) δ 4.86 (m, 3 H), 2.82–2.73 (m, 2 H), 1.65 (s, 1 H, variable), 1.47 (m, 1 H), 1.30 (d, J = 4.9 Hz, 3 H), 1.10 (m, 24 H); ^{13}C NMR ($CDCl_3$) δ 74.9, 65.8, 60.6, 52.6, 38.3, 17.9, 13.0, 12.3, 11.9. Anal. Calcd for $C_{16}H_{34}O_3Si$: C, 63.52; H, 11.33. Found: C, 63.32; H, 11.29.

(±)-(2*R,4*S**,5*R**)-4,5-Epoxy-1-[(triisopropylsilyl)oxy]-2-hexanol (4e) and (±)-Methyl *cis*-3,4-Epoxy-1-[((triisopropylsilyl)oxy)methyl]pentyl Carbonate (17e).** Following procedure F, 0.094 g (0.3 mmol) of alkene **3e** gave 0.16 g of iodo carbonate **9**. Methanolysis provided 0.13 g of crude after 24 h. The crude showed a 4:1 mixture of the methyl carbonate of **17e** and epoxide **4e**. After chromatography (6:1 hexane/ethyl acetate), 0.055 g (45%) of **17e** and 10 mg (10%) of **4e** were obtained. **17e:** ^{1}H NMR ($CDCl_3$) δ 4.90 (m, 1 H), 3.86 (dd, J = 10.6, 5.6 Hz, 1 H), 3.78 (m, 1 H), 3.75 (s, 3 H), 3.10 (m, 2 H), 1.90 (m, 2 H), 1.25 (d, J = 5.5 Hz, 3 H), 1.10 (m, 21 H); ^{13}C ($CDCl_3$) δ 155.6, 77.6, 64.3, 54.8, 53.5, 52.2, 29.2, 18.0, 13.3, 12.0. Anal. Calcd for $C_{17}H_{34}O_5Si$: C, 58.92; H, 9.89. Found: C, 58.88; H, 9.89. **4e:** ^{1}H NMR ($CDCl_3$) δ 3.92 (m, 1 H), 3.73 (dd, J = 9.8, 4.1 Hz, 1 H), 3.66 (dd, J = 9.8, 7.0 Hz, 1 H), 3.17–3.02 (m, 2 H), 2.68 (s, 1 H, variable), 1.85–1.65 (m, 2 H), 1.28 (d, J = 5.4 Hz, 3 H), 1.10 (m, 21 H); ^{13}C ($CDCl_3$) δ 70.6, 67.0, 54.3, 52.1, 30.9, 17.9, 13.3, 11.9. Anal. Calcd for $C_{15}H_{32}O_3Si$: C, 62.45; H, 11.18. Found: C, 62.31; H, 11.15.

(±)-(2*R,3*S**,4*S**,5*R**)-3,5-Dimethyl-1-[(triisopropylsilyl)-oxy]-6-octyne-2,4-diol (19).** Following procedure B, 0.32 g (1.1 mmol) of epoxide **4a** (anti)[19] provided 0.25 g (68%) of **19** after flash chromatography (4:1 hexane/ether): ^{1}H NMR ($CDCl_3$) δ 4.10 (ddd, J = 7.5, 5.2, 2.2 Hz, 1 H), 3.64 (dd, J = 9.9, 9.7 Hz, 1 H), 3.59 (dd, J = 9.9, 5.2 Hz, 1 H), 3.34 (dd, J = 8.1, 4.2 Hz, 1 H), 2.90 (s, 2 H, variable), 2.55 (m, 1 H), 2.10 (m, 1 H), 1.71 (d, J = 2.3 Hz, 3 H), 1.19 (d, J = 7.2 Hz, 3 H), 1.05 (m, 21 H), 0.97 (d, J = 7.2 Hz, 3 H); ^{13}C ($CDCl_3$) δ 80.9, 77.6, 77.4, 72.1, 65.4, 35.2, 30.8, 17.9, 17.2, 11.8, 11.3, 3.4.

(±)-(2*R,3*S**,4*S**,5*R**)-3,5-Dimethyl-1-[(triisopropylsilyl)-oxy]-6-octene-2,4-diol (20) and 2,2,5-trimethyl-6-(1-methyl-2,3-butenyl)-4-[((triisopropylsilyl)oxy)methyl]-1,3-dioxane (20a).** Following procedure D, 0.16 g of **19** provided 0.13 g of the cis isomer **20**: ^{1}H NMR ($CDCl_3$) δ 5.40 (m, 1 H), 5.17 (m, 1 H), 4.2–3.2 (m, 6 H), 2.70 (m, 1 H), 1.82 (m, 1 H), 1.59 (d, J = 6.7 Hz, 3 H), 1.10 (m, 27 H); ^{13}C ($CDCl_3$) δ 133.5, 123.1, 80.7, 72.2, 65.3, 35.6, 35.3, 17.8, 16.8, 12.9, 11.8. The crude was used without further purification for the preparation of **21**. Compound **20** (0.13 g) was converted to its acetonide **20a** for characterization purposes using 0.11 mL (1.02 mmol) of 2-methoxypropene and 8 mg of PPTS in 4.0 mL of CH_2Cl_2 to provide, after flash chromatography (8:1 hexane/ethyl ether), 95 mg of **20a** (60% from **19**): ^{1}H NMR ($CDCl_3$) δ 5.38 (m, 1 H), 5.21 (m, 1 H), 3.86 (ddd, J = 7.1, 6.6, 4.5 Hz, 1 H), 3.62 (dd, J = 9.9, 6.6 Hz, 1 H), 3.56 (dd, J = 9.9, 7.1 Hz, 1 H), 2.99 (t, J = 6.9 Hz, 1 H), 2.56 (m, 1 H), 1.75 (m, 1 H), 1.55 (dd, J = 6.0 Hz, 3 H), 1.27 (s, 3 H), 1.25 (s, 3 H), 1.10 (m, 21 H), 0.92 (d, J = 6.6 Hz, 3 H), 0.79 (d, J = 6.8 Hz, 3 H); ^{13}C ($CDCl_3$) δ 133.2, 123.5, 100.2, 78.6, 69.8, 62.9, 36.1, 35.4, 25.4, 23.8, 17.9, 16.6, 13.0, 12.4, 11.9. Anal. Calcd for $C_{22}H_{44}O_3Si$: C, 68.69; H, 11.53. Found: C, 68.63; H, 11.51.

(±)-(2*R,3*S**,4*R**,5*S**,6*S**,7*S**)-7-Iodo-3,5-dimethyl-1-[(triisopropylsilyl)oxy]-2,4,6-octanetriol 4,6-Carbonate (21).** Following procedure E, 0.09 g (0.27 mmol) of **20** provided 0.096 g of crude **21**. The iodo carbonate was used without further purification: ^{1}H NMR ($CDCl_3$) δ 4.64 (dd, J = 7.9, 4.7 Hz, 1 H), 4.36 (m, 1 H), 3.93 (d, J = 4.0 Hz, 2 H), 3.07 (qd, J = 5.5, 4.4 Hz, 1 H), 2.93 (dd, J = 9.3, 4.4 Hz, 1 H), 2.47 (m, 1 H), 1.55 (m, 1 H), 1.25 (d, J = 5.5 Hz, 3 H), 1.10 (m, 27 H); ^{13}C ($CDCl_3$) δ 148.9, 84.2, 79.5, 62.0, 57.2, 52.2, 34.6, 29.2, 17.8, 13.0, 11.7, 11.1, 9.9.

(±)-(2*R,3*S**,4*R**,5*S**,6*S**,7*R**)-6,7-Epoxy-3,5-dimethyl-1-[(triisopropylsilyl)oxy]-2,4-octanediol (22).** Following procedure F, 0.09 g of **21** provided 0.06 g (65% from alkene **20**) of **22**: ^{1}H NMR ($CDCl_3$) δ 4.04 (td, *J* = 6.0, 2.4 Hz, 1 H), 3.70 (d, *J* = 6.0 Hz, 2 H), 3.57 (dd, J = 6.1, 6.1 Hz, 1 H), 3.10 (b s, 2 H, variable), 3.04 (m, 1 H), 2.78 (dd, *J* = 9.4, 4.4 Hz, 1 H), 2.0–1.5 (m, 2 H), 1.25 (d, *J* = 5.5 Hz, 3 H), 1.05–0.95 (m, 27 H); ^{13}C ($CDCl_3$) δ 77.6, 73.3, 64.9, 58.9, 52.4, 36.4, 35.5, 17.9, 13.2, 12.1, 11.2, 11.8.

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Supplementary Material Available: ^{1}H and ^{13}C NMR spectra of compounds **5a, 5b, 7a, 8a, 8b, 9b, 13a, 13b, 19, 21,** and **22** (22 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.