Applications of 5-*Endo*-trigonal Cyclization: Construction of Compounds Relevant to the Synthesis of Prostaglandins and Methyl *epi*-Jasmonate

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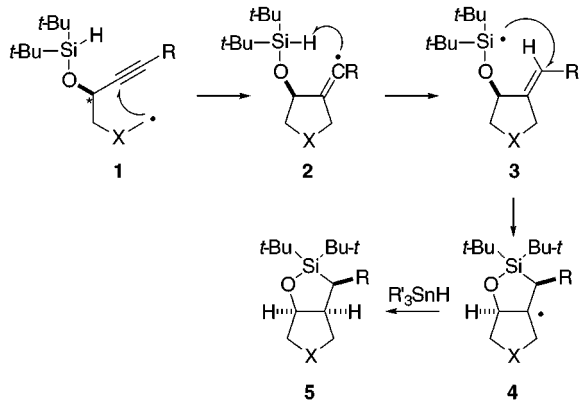
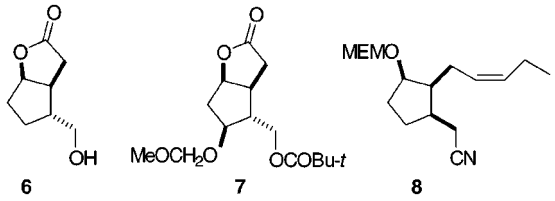
Silane **15**, easily constructed by simple methods, undergoes a cascade of radical reactions when treated with a stannane to afford the bicyclic 1,2-oxasiloles **16**, with the major isomer having the ester group anti to the O−Si unit. This isomer was elaborated via **19** into **6**, a deoxy derivative of the Corey lactone. In a related sequence, ketone **24** was converted into silane **35**; this, too, underwent the radical cascade to afford the highly substituted 1,2-oxasiloles **36**. Again the major isomer had the ester and O−Si units in an anti relationship. Elaboration of **36** (major isomer) gave the Corey lactone derivative **7**. A key intermediate (**32**) in this second sequence was also prepared in optically pure form by starting with 2-deoxy-D-ribose. Compound **19** was converted into **8**, a sequence that constitutes a formal synthesis of methyl (±)-*epi*-jasmonate. Two examples were found of selective silylation of a propargylic secondary hydroxyl in the presence of an ordinary secondary hydroxyl.

Radicals of type **1** (Scheme 1, X = CH_2), when generated from selenides, cyclize in the expected 5-*exo*-digonal manner, but the resulting vinyl radicals (**2**) undergo intramolecular hydrogen transfer to produce a silicon-centered radical (**2** → **3**) which then closes by a 5-*endo*-trigonal pathway (**3** → **4**).[1−3] This unusual last step occurs easily, as it is not subject to the restrictions embodied in the Baldwin rules[4] against 5-*endo*-trigonal cyclization, because of the longer bond lengths involving silicon.[5] Only a few cases have been reported of the cyclization of silicon-centered radicals,[3] but there is a growing number of examples[6] involving carbon radicals. The final bicyclic product (**5**) of the present reaction has a relative stereochemistry at the three asymmetric centers that is related in the indicated manner to the stereocenter (see starred atom in **1**) of the starting radical species. We have previously studied simple cases in which X is carbon[1] or a heteroatom;[7] here we describe the use of this sequence to prepare racemic compounds **6**−**8**. The first two are derivatives of the Corey lactone,[8] and so they are relevant to the synthesis of prostaglandins,[8] while **8** has been converted[9] into the perfume ingredient methyl *epi*-jasmonate, and its preparation constitutes a formal synthesis of the natural product in racemic form. We have also used a silane derived from 2-deoxy-D-ribose, to show that optically pure compounds are available by the method summarized in Scheme 1.

Scheme 1





Synthesis of the Common Intermediate Leading to 6 and 8. The common radical precursor for the synthesis of **6** and **8** is the propargyl silane **15** [as a

(1) Clive, D. L. J.; Cantin, M. *J. Chem. Soc., Chem. Commun.* **1995**, 319−320.

(2) When radicals of type **1** are generated from iodides, the hydrogen translocation (**2** → **3**) does not occur; instead, intermolecular halogen transfer takes place: Martinez-Grau, A.; Curran, D. P. *J. Org. Chem.* **1995**, *60*, 8332−8333.

(3) For other examples involving silicon-centered radicals, see: Cai, Y.; Roberts, B. P. *J. Chem. Soc., Perkin Trans. 1* **1998**, 467−475.

(4) Baldwin, J. E. *J. Chem. Soc., Chem. Commun.* **1976**, 734−736.

(5) Allen, F. H.; Kennard, O.; Watson, D. G.; Brammer, L.; Orpen, A. G.; Taylor, R. *J. Chem. Soc., Perkin Trans. 2* **1987**, S1−S19.

(6) For recent examples involving carbon radicals, see: (a) Bogen, S.; Malacria, M. *J. Am. Chem. Soc.* **1996**, *118*, 3992−3993. (b) Baker, S. R.; Parsons, A. F.; Pons, J.-F.; Wilson, M. *Tetrahedron Lett.* **1998**, *39*, 7197−7200. (c) Ikeda, M.; Ohtani, S.; Yamamoto, T.; Sato, T.; Ishibashi, H. *J. Chem. Soc., Perkin Trans 1* **1998**, 1763−1768. (d) Ishibashi, H.; Higuchi, M.; Ohba, M.; Ikeda, M. *Tetrahedron Lett.* **1998**, *39*, 75−78. (e) Yamamoto, Y.; Ohno, M.; Eguchi, S. *J. Org. Chem.* **1996**, *61*, 9264−9271. (f) Schultz, A. G.; Guzzo, P. R.; Nowak, D. M. *J. Org. Chem.* **1995**, *60*, 8044−8050. Cassayre, J.; Quiclet-Sire, B.; Saunier, J.-B.; Zard, S. Z. *Tetrahedron* **1998**, *54*, 1029−1040.

(7) Clive, D. L. J.; Yang, W. *J. Chem. Soc., Chem. Commun.* **1996**, 1605−1606.

(8) The designation "Corey lactone" has been used in recent literature to refer to a variety of hydroxyl-protected derivatives of the hexahydro-5-hydroxy-4-(hydroxymethyl)-2*H*-cyclopenta[*b*]furan-2-one system. Reviews on prostaglandin synthesis: (a) Mitra, A. *The Synthesis of Prostaglandins*; Wiley: New York, 1977. (b) Newton, R. F.; Roberts, S. M. *Prostaglandins and Thromboxanes*; Butterworth: London, 1982.

(9) Kitahara, T.; Warita, Y.; Abe, M.; Seya, M.; Takagi, Y.; Mori, K. *Agric. Biol. Chem.* **1991**, *55*, 1013−1017.

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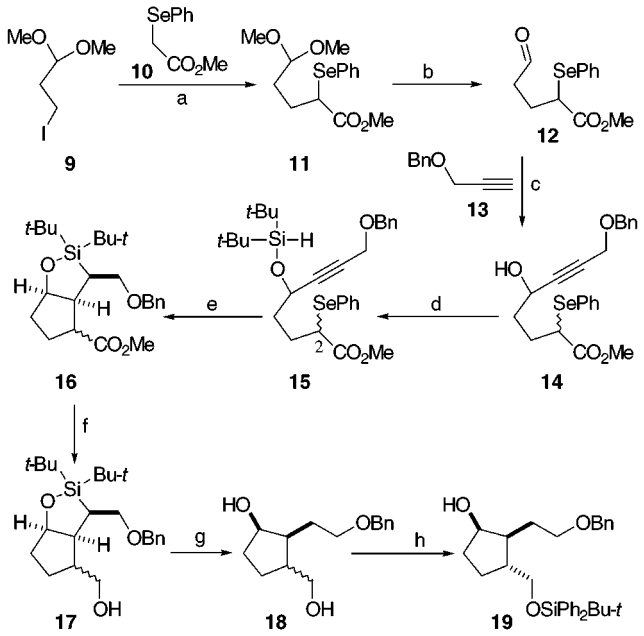
Scheme 2[a]

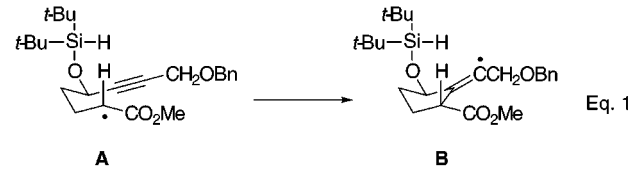


[a] (a) $C_6H_{11}NLiPr$-*i*, −78 °C, THF; (b) 1:1 TFA−water, CH_2Cl_2; 53% over two steps; (c) BuLi, THF, −78 °C; 81%; (d) (*t*-Bu)$_2$SiHCl, THF, imidazole, 65 °C; 95%; (e) Ph_3SnH, AIBN, PhH, reflux; (f) $LiAlH_4$, THF, −78 °C; (g) TBAF, DMF, 60 °C; (h) *t*-BuPh_2SiCl, imidazole, CH_2Cl_2; 33% from **15**.

mixture of C(2) epimers], and this was constructed as shown in Scheme 2. Alkylation of 3-iodo-1,1-dimethoxypropane (**9**[10]) with the anion derived[11] from methyl (phenylseleno)acetate[12] (**10**) gave **11**, which was best directly deprotected (TFA, **11** → **12**; 53% from **9**). The aldehyde reacted smoothly with the anion derived from benzyl propargyl ether (**13**), to afford (81%) a mixture of diastereoisomeric hydroxy selenides (**14**). These were then silylated (*t*-Bu$_2$SiHCl, imidazole, 65 °C; 95%) to give the epimeric precursors (**15**) for radical cyclization, which were elaborated in two ways: one route led to the deoxy Corey lactone **6** and the other to nitrile **8**. It should be noted that there are some limitations[2] on the nature of the radical precursor in the present tandem cyclizations, but a selenide (as in **15**) is very suitable.

Synthesis of Lactone 6. Slow addition of Ph_3SnH and AIBN to a refluxing solution of **15**, gave the expected products (**16**) resulting from sequential 5-*exo*-digonal cyclization, intramolecular hydrogen transfer, and 5-*endo* cyclization. The stereochemistry of 5-*exo*-digonal radical closures (cf. **1** → **2** and **15** → **16**) has not received much attention;[13] however, we expected closure to take place preferentially via conformation **A** (see eq 1), so as to place the ester group trans to the O−Si unit (**A** → **B**), and, in the event, the major (75% of the total) product did have this stereochemical relationship.

Compounds **16** were contaminated by chromatographically inseparable impurities and were used without full



characterization.[14] Likewise, the next two steps also gave products containing small amounts of inseparable impurities. Ester reduction ($LiAlH_4$, THF) gave alcohols **17**, and treatment with Bu_4NF in warm DMF[15] cleaved both the O−Si and C−Si bonds (**17** → **18**). Finally, silylation (*t*-BuPh_2SiCl, imidazole) took the route as far as alcohol **19** (33% over the four steps from **15**), which was easily obtained pure, and fully characterized. The choice of solvent for the desilylation **17** → **18** is crucial, as use of THF served only to cleave the O−Si bond, but left the C−Si bond intact.

Hydrogenolysis of **19** released diol **20** (91%, Scheme 3), and lactone **21** was formed (52%) in a single step by treatment with $KMnO_4$ and $CuSO_4 \cdot 5H_2O$[16] (**20** → **21**). Finally desilylation (Bu_4NF; 93%) gave alcohol **6**.[17,18]

Synthesis of Lactone 7. For synthesis of the Corey lactone derivative **7**, it was necessary to repeat the sequence of Scheme 2, but with a substrate having an additional oxygen substituent, and the route to this species is summarized in Scheme 4. The known hydroxy ester **22**[19] was silylated[20] (**22** → **23**; 93%) and converted (ca. 72%) into the ketone **24** by treatment with the lithium salt of benzyl propargyl ether in the presence of $BF_3 \cdot Et_2O$. Protection of the hydroxyl, and use of an *ethyl* ester is, apparently, necessary[20] for efficient reaction with an acetylide (cf. **23** → **24**), but we did not verify this characteristic of the method for our particular case.

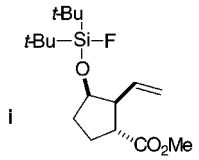
(10) (a) Wohl, A. *Chem. Ber.* **1908**, *41*, 3599−3612. (b) Clive, D. L. J.; Postema, M. H. D. *J. Chem. Soc., Chem. Commun.* **1993**, 429−430.

(11) Rathke, M. W.; Lindert, A. *J. Am. Chem. Soc.* **1971**, *93*, 2318−2320.

(12) Cf. Ryu, I.; Muraoka, H.; Kambe, N.; Komatsu, M.; Sonoda, N. *J. Org. Chem.* **1996**, *61*, 6396−6403. We generated PhSeNa, using the $PhSeSePh/NaBH_4$ system.

(13) Cf. (a) Gaudino, J. J.; Wilcox, C. S. *J. Am. Chem. Soc.* **1990**, *112*, 4374−4380. (b) Crich, D.; Fortt, S. M. *Tetrahedron Lett.* **1987**, *28*, 2895−2898.

(14) The compounds were characterized as follows: Treatment of crude **16** with $BF_3 \cdot Et_2O$ (with the intention of breaking the O−Si and HC−Si bonds) gave **i** as a colorless oil (52% from **15**), which was characterized fully: FTIR ($CHCl_3$ cast) 1738 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 1.0 (s, 9 H), 1.04 (s, 9 H), 1.79−2.03 (m, 3 H), 2.09−2.27 (m, 1 H), 2.60−2.73 (m, 1 H), 2.84−2.99 (m, 1 H), 3.67 (s, 3 H), 4.51−4.61 (m, 1 H), 5.00−5.14 (m, 2 H), 5.81−5.99 (m, 1 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 19.9 (s′) J_{C-Si-F} = 14.4 Hz, 20.6 (s′) J_{C-Si-F} = 16.0 Hz, 26.9 (q′), 27.0 (t′), 27.1 (q′), 34.7 (t′), 46.7 (d′), 51.5 (d′), 54.9 (q′), 79.0 (d′), 116.7 (t′), 136.4 (d′), 176.4 (s′); exact mass *m/z* calcd for $C_{16}H_{28}FO_2Si$ (M − OCH_3) 299.1843, found 299.1840. In principle, compound **i** could have been used for conversion into **6**, but this would have required reintroduction of oxygen. In the event, reduction ($LiAlH_4$) of the ester and protection (MEMCl, *i*-Pr_2NEt) of the resulting alcohol gave an olefin that could be hydroborated only in yields of <40%, and so this approach was abandoned.



(15) Koreeda, M.; Wu, J. *Synlett* **1995**, 850−852, and references therein.

(16) Jefford, C. W.; Wang, Y. *J. Chem. Soc., Chem. Commun.* **1988**, 634−635.

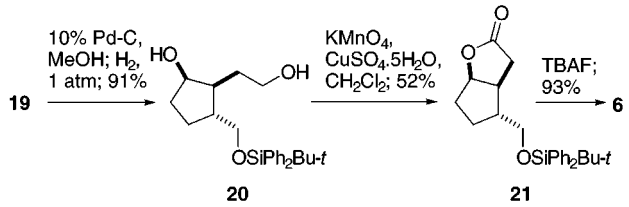
(17) (a) Bindra, J. S.; Grodski, A. *J. Org. Chem.* **1978**, *43*, 3240−3241. (b) For spectral data on the C(4) epimer, see: Zanoni, G.; Vidari, G. *J. Org. Chem.* **1995**, *60*, 5319−5323.

(18) Lactone **21** was also made by acetylation of **19** (Ac_2O, Et_3N, DMAP, 97%), hydrogenolysis (H_2, Pd−C, 92%), oxidation (CH_2OH → CHO, PCC, 4 Å molecular sieves, 93%), further oxidation (CHO → CO_2H, $NaClO_2$, NaH_2PO_4, *t*-BuOH, water), and base hydrolysis (K_2CO_3, MeOH) of the acetate (spontaneous lactonization occurred; 48% from the aldehyde).

(19) Zibuck, R.; Streiber, J. *Org. Synth.* **1992**, *71*, 236−241.

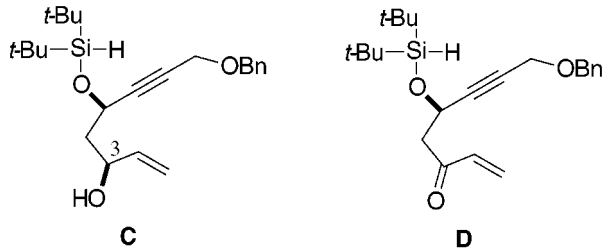
(20) Mohr, P. *Tetrahedron Lett.* **1991**, *32*, 2219−2222.

Scheme 3



Desilylation (HF, MeCN; 47% over two steps)[21] and DIBAL-H reduction (90%) of the resulting hydroxy ketone **25** proceeded with high stereoselectivity (ca. 15:1). Ketalization of the mixture of diols **26** allowed isolation of ketal **27** in 88% yield.[22] This compound was easily separated from its C(6) epimer, and the stereochemistry was assigned by analogy with other reactions of the same type.[20] Acid hydrolysis (CF_3CO_2H, aqueous THF; 93%) then released diol **28**.[23]

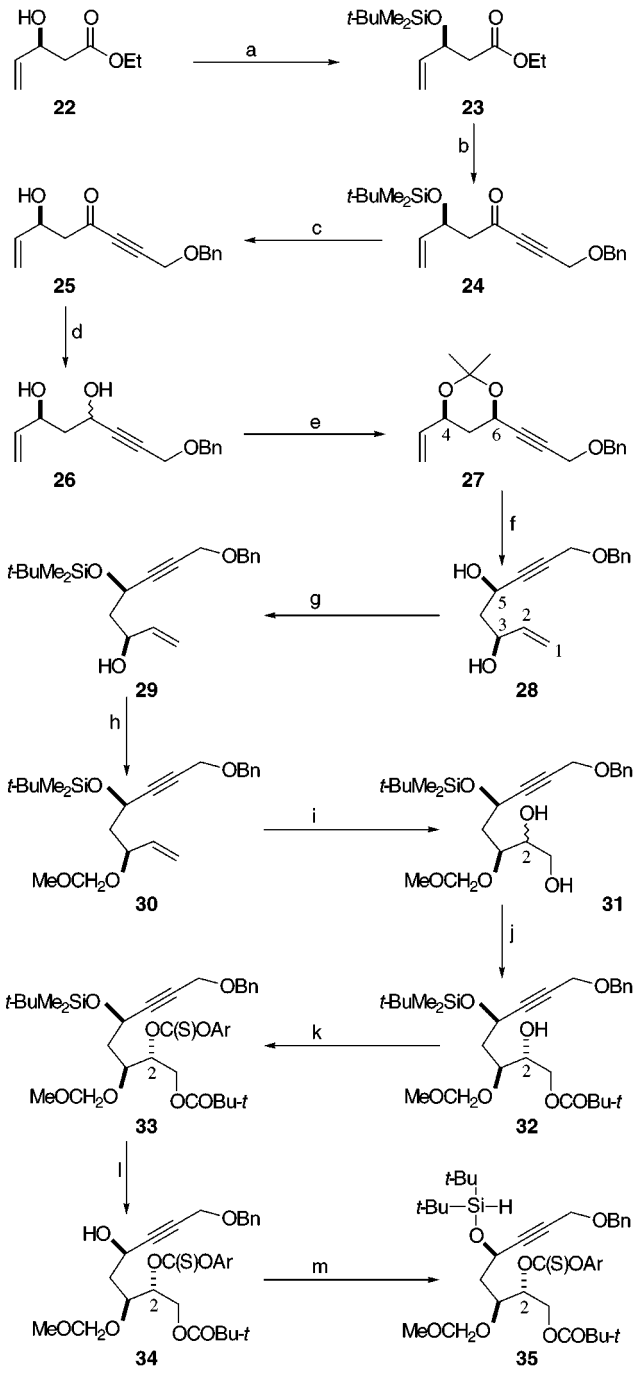
The next task was to place a *t*-Bu_2SiH group on the hydroxyl at C(5) of **28**, protect the C(3) hydroxyl, and dihydroxylate the double bond. Initially, we treated diol **28** with *t*-Bu_2SiHCl/imidazole and observed very high selectivity in favor of the propargylic hydroxyl, the monosilylated compound **C** being isolated in 79% yield (91% based on recovered **28**); only a small amount (4% yield) of doubly silylated material was isolated. NMR decoupling measurements (see Supplementary Information) indicated that the propargylic alcohol had been silylated preferentially, as required for the intended radical reaction. We assume that the propargylic alcohol is more sterically accessible because of the linear geometry of the adjacent alkyne, and the selectivity can be understood on this basis.



A chemical experiment was also performed to confirm the structure of **C**. A sample was treated with PCC, and the resulting ketone **D** (56%) was found to have a ^{1}H NMR spectrum that defined the structure unambiguously. Unfortunately, after protection of the C(3) hydroxyl of **C** (as a methoxymethyl ether), it was not possible to dihydroxylate[24] the double bond without unwanted modification of the *t*-$Bu_2Si(O)H$ group. For this reason, an indirect route, involving protection and deprotection, was used as follows.

Treatment of **28** with *t*-$BuMe_2SiCl$/imidazole gave the monoprotected alcohol **29**. The selectivity between the two hydroxyls was lower than with *t*-Bu_2SiHCl, presumably because the *dimethyl* reagent has a smaller steric demand, and reaction was best stopped well before completion.[25] Under optimum conditions, the yield of **29** was 47%, or 82% after correction for recovered starting material. Protection ($MeOCH_2Cl$, *i*-Pr_2NEt; 86%) and dihydroxylation (OsO_4, NMO, aqueous THF; 54%) gave

Scheme 4[a]



[a] (a) *t*-$BuMe_2SiCl$, imidazole, CH_2Cl_2; 93%; (b) BuLi, THF, $BnOCH_2C{\equiv}CH$ (**13**), $BF_3{\cdot}Et_2O$; ca. 72%; (c) HF, aq MeCN; 47% from **22**; (d) DIBAL, THF, −78 °C; 90%; two alcohols (15:1) are formed; only the major one is shown; (e) 2,2-dimethoxypropane, TsOH·pyridine; 88%; (f) CF_3CO_2H, aq THF; 93%; (g) *t*-$BuMe_2SiCl$, imidazole, CH_2Cl_2; 47% (82% based on conversion); (h) $MeOCH_2Cl$, *i*-Pr_2NEt, CH_2Cl_2; 86%; (i) OsO_4, NMO, aq THF; 54%; (j) *t*-BuCOCl, DMAP, PhMe; 44%; only major isomer of the product is shown; (k) *p*-$FC_6H_4OC(S)Cl$, pyridine, DMAP; 72%; (l) HF, aq MeCN; 87%; (m) *t*-Bu_2SiHCl, imidazole, THF; 93%.

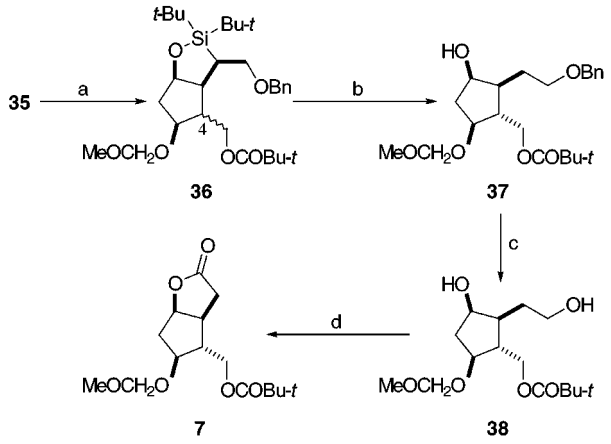
(21) The use of TBAF in this step resulted in complete decomposition of the starting material.

(22) The isomeric ketal was isolated in 6% yield.

(23) For other stereocontrolled routes to 1,3-diols, see, for example: (a) Bartlett, P. A.; Meadows, J. D.; Brown, E. G.; Morimoto, A.; Jernstedt, K. K. *J. Org. Chem.* **1982**, *47*, 4013−4018. (b) Bongini, A.; Cardillo, G.; Orena, M.; Porzi, G.; Sandri, S. *J. Org. Chem.* **1982**, *47*, 4626−4633. (c) Cardillo, G.; Orena, M.; Porzi, G.; Sandri, S. *J. Chem. Soc., Chem. Commun.* **1981**, 465−466.

(24) Dihydroxylation was attempted using OsO_4 under a number of conditions, but the product did not contain the Si−H unit (absence of the Si−H band at ca. 2000 cm^{-1}).

Scheme 5[a]



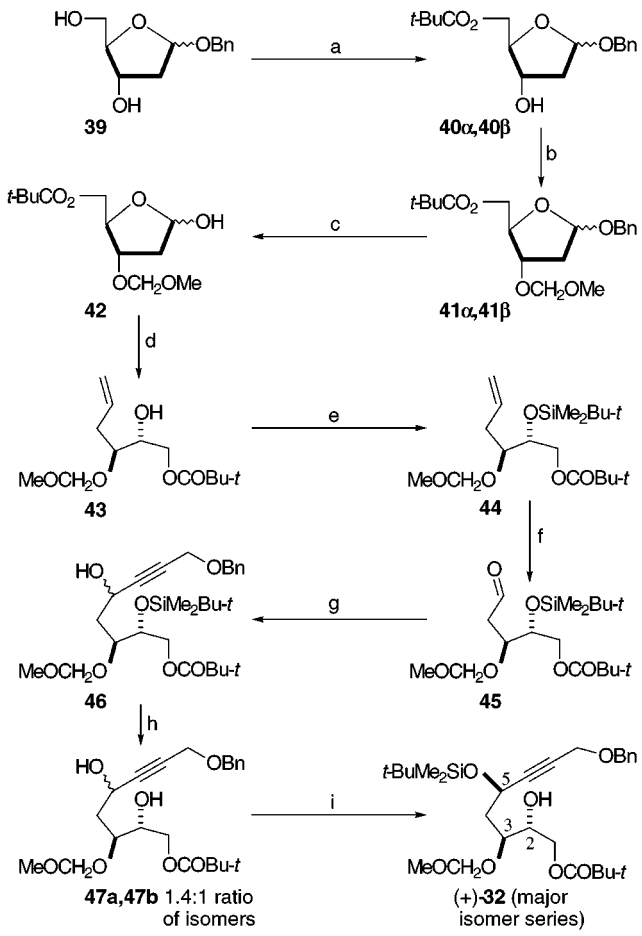
[a] (a) Bu_3SnH, AIBN, PhMe; 79%; (b) TBAF, DMF−THF, 70 °C; 88%; (c) 10% Pd−C, MeOH, H_2; 87%; (d) $KMnO_4$, $CuSO_4 \cdot 5H_2O$, CH_2Cl_2; 63%.

31 as an inseparable mixture of epimers (**29** → **30** → **31**). The primary hydroxyl was protected (*t*-BuCOCl, DMAP; 44%), taking the route as far as alcohols **32** (of which the major isomer only is shown in Scheme 4). In principle the formation of two epimers in the dihydroxylation is inconsequential, as the initial stereochemistry at C(2) is destroyed when a radical is later generated at that carbon. Initially, we did not know the stereochemistry of **32** at C(2); this was established later by comparison with material obtained by a route in which the stereochemistry at this center is known (see below). The remaining hydroxyl of **32** was then acylated (**32** → **33**; 72%) by reaction with *p*-$FC_6H_4OC(S)Cl$/pyridine/DMAP, and the *t*-$BuMe_2Si$ group was removed (HF, aqueous MeCN; 87%). In the acylation, the C(2) epimer of **32** was discarded. Finally, silylation with *t*-Bu_2SiHCl/imidazole) generated the radical cyclization precursor **35**, which was obtained in 93% yield.

Treatment with Bu_3SnH/AIBN (Scheme 5), under the same conditions used earlier, gave (ca. 79%) the required product **36**, as a mixture of C(4) epimers, with one—that corresponding to the type of conformation shown in eq 1—being present in great excess (>88%). Protodesilylation, done earlier (cf. **17** → **18**) in DMF, was now carried out arbitrarily in a 1:1 DMF−THF mixture. From this experiment, alcohol **37** was isolated as a single isomer in 88% yield. As in the route to the simpler model **6**, hydrogenolysis served to remove the benzyl protecting group (**37** → **38**; 87%), and oxidation with the $KMnO_4$−$CuSO_4 \cdot 5H_2O$ system gave (63%) the final target (**7**).

Use of a Starting Material from the Chiral Pool. To establish that the process of Scheme 4 could be applied to compounds from the chiral pool, we converted 2-deoxy-D-ribose into optically pure (+)-**32** (Scheme 6). For this purpose, 2-deoxy-D-ribose was first converted into its benzyl glycosides **39**, and the C(5) hydroxyl was pivaloylated by Mitsunobu reaction (**39** → **40**α,**40**β)[26]—a procedure[27] that gave much better results than direct acylation

Scheme 6[a]



[a] (a) DEAD, Ph_3P, *t*-$BuCO_2H$, THF; 58% (83% based on conversion); (b) $MeOCH_2Cl$, *i*-Pr_2NEt, CH_2Cl_2; 90% for **41**β, 92% for **41**α; (c) H_2, 5% Pd−C, 50 psi, EtOH; 92% for each epimer; (d) Ph_3PCH_3Br, BuLi, PhMe; 72%; (e) *t*-$BuMe_2SiCl$, imidazole, CH_2Cl_2; 89%; (f) O_3, CH_2Cl_2, −78 °C; Ph_3P; 83%; (g) $BnOCH_2C{\equiv}CH$ (**13**), BuLi, −78 °C, THF; 71% (80% based on conversion); 1:1.4 ratio of isomers; (h) HF, aq MeCN; 86%; (i) *t*-$BuMe_2SiCl$, imidazole, CH_2Cl_2; 94% (major isomer), 92% (minor isomer).

with *t*-BuCOCl.[28] In the latter case, extensive acylation of the secondary hydroxyl also occurred. Protection of the C(3) hydroxyl (**40**α → **41**α, **40**β → **41**β; $MeOCH_2Cl$, *i*-Pr_2NEt; 90% for **41**β, 92% for **41**α), and hydrogenolytic removal of the benzyl group (**41**α,**41**β → **42**; 92% for each anomer) proceeded without incident. Homologation of **42** by Wittig reaction with $Ph_3P{=}CH_2$ (72%), and silylation (**43** → **44**; *t*-$BuMe_2SiCl$, imidazole; 89%) of the resulting alcohol set the stage for introduction of an acetylene unit. To this end, the double bond of **44** was ozonized (**44** → **45**; O_3, CH_2Cl_2, −78 °C; Ph_3P; 83%), a process best done using Sudan II red as an internal indicator.[29] Reaction with the anion derived from benzyl propargyl ether (**13**) gave a 1:1.4 mixture of chromatographically inseparable acetylenic alcohols **46** (71%, or 80% based on conversion). Desilylation (HF, aqueous MeCN; 86%) gave diols **47a** (major isomer) and **47b** (minor isomer), which were easily

(25) Use of Et_3SiCl gave only the bis-silylated product, and *t*-$BuPh_2SiCl$ did not react. In retrospect, *t*-$Bu_2MeSiCl$ should have been tested, as its steric bulk (intermediate between Et_3SiCl and *t*-$BuPh_2SiCl$) might have made it react with high selectivity.

(26) The anomeric configuration was established by a TROESY NMR (600 MHz) experiment that established the stereochemistry of **41**α.

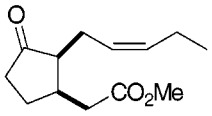
(27) Cf. (a) Serra, C.; Dewynter, G.; Montero, J.-L.; Imbach, J.-L. *Tetrahedron* **1994**, *50*, 8427−8444. (b) Mitsunobu, O.; Kimura, J.; Fujisawa, Y. *Bull. Chem. Soc. Jpn.* **1972**, *45*, 245−247.

(28) Review on selective acylation of carbohydrates: Haines, A. H. *Adv. Carbohydr. Chem. Biochem.* **1976**, *33*, 11−109.

(29) Veysoglu, T.; Mitscher, L. A.; Swayze, J. K. *Synthesis* **1980**, 807−810.

separated. Silylation with *t*-$BuMe_2SiCl$/imidazole proceeded with very high regioselectivity, and again the propargylic secondary hydroxyl reacted preferentially, giving the required product in over 90% yield for both the major (**47a**) and minor (**47b**) isomers. The major product [(+)-**32**, Scheme 6] was found to be spectroscopically (^1H and ^{13}C NMR) identical to the corresponding racemic compound obtained by the reactions of Scheme 4. The stereochemistry at C(2) and C(3) in material from 2-deoxy-D-ribose is set by the stereochemistry of the starting sugar, while the relative stereochemistry at C(3) and C(5) for material obtained by the method of Scheme 4 is set by the procedure used. As the major products from the two routes are structurally identical, the relative stereochemistry of **32** obtained by the method of Scheme 4, and the absolute stereochemistry at C(2), C(3), and C(5) of (+)-**32** obtained from 2-deoxy-D-ribose can be assigned as shown. The route from the sugar constitutes a formal synthesis of optically pure **7** (which has the opposite stereochemistry to that needed, in principle, for elaboration to a natural prostaglandin).

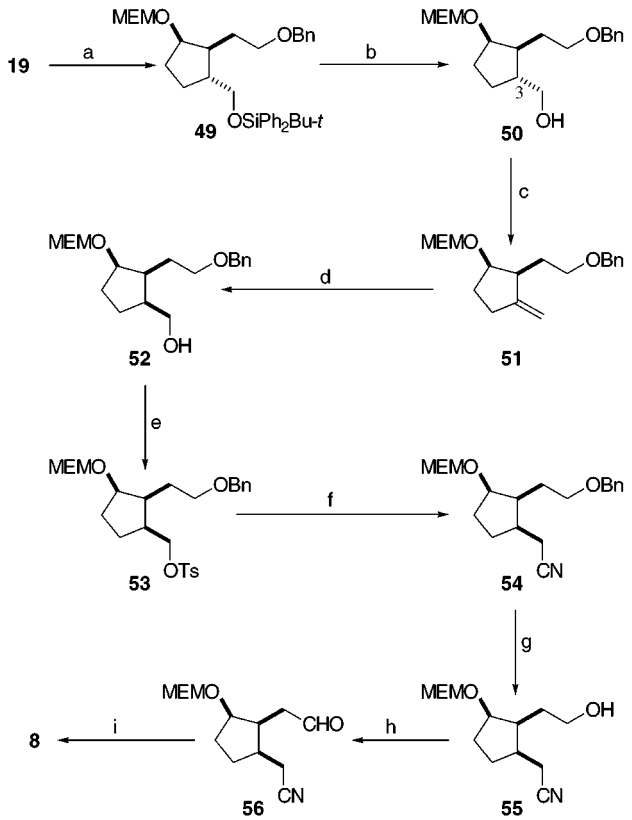
Formal Synthesis of Methyl *epi*-Jasmonate. Methyl *epi*-jasmonate (**48**) is the main component responsible for the odor of jasmine oil,[30] although this fact was long unrecognized. The substance also has a range of plant regulatory and pheromonal properties,[31] and has attracted attention as a synthetic target.[9,31c,32] The radical sequence of Scheme 1 can also be applied to the synthesis of **48**, as described below.



48

Alcohol **19** was protected as its methoxyethoxy methyl ether[33] (Scheme 7, **19** → **49**; MEMCl, *i*-Pr_2NEt; 100%) and desilylated (**49** → **50**; TBAF, THF; 96%). At this point, attempts to invert the stereochemistry at C(3) by oxidation of the alcohol and treatment of the resulting aldehyde with a base were unsuccessful,[34] but the required inversion could be accomplished by dehydration via an intermediate selenide (**50** → **51**; *o*-$O_2NC_6H_4SeCN$, Bu_3P; MCPBA; *i*-Pr_2NEt, 40 °C; 80%), and rehydration (**51** → **52**; BH_3·Me_2S, THF, −20 °C; NaOH, H_2O_2, 0 °C; 85%). The primary hydroxyl of **52** was then replaced by a cyanide group (**52** → **53**, TsCl, pyridine, DMAP, 97%; **53** → **54**, NaCN, DMSO, 100 °C, 87%). Removal of the benzyl group by hydrogenolysis (92%) and PCC oxidation (78%) then gave aldehyde **56**. This was treated with the salt-free Wittig reagent derived from triphenyl(propyl)-phosphonium bromide, under well-established conditions,[32f,h,j] to give in high yield (80%) the *Z*-olefin **8**, which has previously been converted[9,35] into methyl *epi*-jasmonate.

Scheme 7[a]



[a] (a) MEMCl, *i*-Pr_2NEt, CH_2Cl_2; 100%; (b) TBAF, THF; 96%; (c) *o*-$O_2NC_6H_4SeCN$, Bu_3P, THF; MCPBA, *i*-Pr_2NEt, CH_2Cl_2, 40 °C; 80%; (d) BH_3·Me_2S, THF, NaOH, H_2O_2; 85%; (e) TsCl, pyridine, DMAP; 97%; (f) NaCN, DMSO, 100 °C; 87%; (g) H_2, 5% Pd−C, MeOH; 92%; (h) PCC, CH_2Cl_2, 4 Å sieves; 78%; (i) $(Me_3Si)_2NK$, $PrPPh_3Br$, PhMe, −78 °C to room temp; 80%.

Experimental Section

General Procedures. Unless stated to the contrary, the general procedures used previously[36] were followed.

(30) (a) *Chem. Eng. News* **1983**, *61*, 34−36. (b) Acree, T. E.; Nishida, R.; Fukami, H. *J. Agric. Food Chem.* **1985**, *33*, 425−427. (c) Cf. Montforts, F.-P.; Gesing-Zibulak, I.; Grammenos, W.; Schneider, M.; Laumen, K. *Helv. Chim. Acta* **1989**, *72*, 1852−1859. (d) Occurrence in lemons: Nishida, R.; Acree, T. E. *J. Agric. Food Chem.* **1984**, *32*, 1001−1003.

(31) (a) For references to plant regulatory activity and comment on whether the observed effects are due to cis or trans jasmonates, see: Ward, J. L.; Gaskin, P.; Beale, M. H.; Sessions, R.; Koda, Y.; Wasternack, C. *Tetrahedron* **1997**, *53*, 8181−8194. (b) See also: Koda, Y. *Physiol. Plant.* **1997**, *100*, 639−646. (c) Potato tuberization: Kitahara, T.; Nishi, T.; Mori, K. *Tetrahedron* **1991**, *47*, 6999−7006. (d) Pheromone synergist: Baker, T. C.; Nishida, R.; Roelofs, W. L. *Science* **1981**, *214*, 1359−1362.

(32) Previous syntheses: (a) Tanaka, H.; Torii, S. *J. Org. Chem.* **1975**, *40*, 462−465. (b) Kitahara, T.; Miura, K.; Warita, Y.; Tagaki, Y.; Mori, K. *Agric. Biol. Chem.* **1987**, *51*, 1129−1133. (c) Helmchen, G.; Goeke, A.; Lauer, G.; Urmann, M.; Fries, J. *Angew. Chem., Int. Ed. Engl.* **1990**, *29*, 1024−1025. (d) Weinges, K.; Lernhardt, U. *Justus Liebigs Ann. Chem.* **1990**, 751−754. (e) Seto, H.; Yoshioka, H. *Chem. Lett.* **1990**, 1797−1800. (f) Crombie, L.; Mistry, K. M. *J. Chem. Soc., Perkin Trans. 1* **1991**, 1981−1991. (g) Stork, G.; Ouerfelli, O. *New J. Chem.* **1992**, *16*, 95−98. (h) Sarkar, T. K.; Ghorai, B. K.; Banerji, A. *Tetrahedron Lett.* **1994**, *35*, 6907−6908. (i) Stadtmüller, H.; Knochel, P. *Synlett* **1995**, 463−464. (j) Sarkar, T. K.; Ghorai, B. K.; Nandy, S. K.; Mukherjee, B.; Banerji, A. *J. Org. Chem.* **1997**, *62*, 6006−6011. (k) Roth, G. J.; Kirschbaum, S.; Bestmann, H. J. *Synlett* **1997**, 618−620. (l) U, J. S.; Park, H. S.; Gupta, S.; Cha, J. K. *Synth. Commun.* **1997**, *27*, 2931−2941. (m) Sarkar, T. K.; Mukherjee, B.; Ghosh, S. K. *Tetrahedron* **1998**, *54*, 3243−3254.

(33) A methoxymethyl group is unsuitable, as it cannot be removed in a satisfactory manner in the penultimate step of the synthesis of methyl *epi*-jasmonate (cf. ref 9).

(34) We had initially assumed that deprotonation of esters **16**, followed by kinetic reprotonation, would afford an all-syn trisubstituted cyclopentane system, but we were unable to modify the stereochemistry in this way, and the task was accomplished by the indirect method described.

(35) The final oxidation step is best done with PDC (see refs 32c and 32f) or PCC (see ref 32e).

(36) Clive, D. L. J.; Wickens, P. L.; Sgarbi, P. W. M. *J. Org. Chem.* **1996**, *61*, 7426−7437.

The designations s′, d′, t′, and q′ for ^{13}C NMR signals indicate zero, one, two, or three attached hydrogens, respectively. Where the number of signals is less than expected, we assume that two or more signals are coincident.

Methyl 5,5-Dimethoxy-2-(phenylseleno)pentanoate (11). *n*-BuLi (2.5 M in hexanes, 6.29 mL, 15.73 mmol) was added dropwise to a stirred and cooled (−78 °C) solution of freshly distilled *N*-isopropylcyclohexylamine (2.59 mL, 15.73 mmol) in dry THF (8 mL). After 15 min, methyl (phenylseleno)acetate (3.27 g, 14.30 mmol) in dry THF (4 mL plus 2 mL as a rinse) was added dropwise at −78 °C. After 30 min, the cold bath was removed, and the solution was allowed to warm to room temperature (over ca. 40 min). The enolate solution was added quickly (ca. 2 min) to a room-temperature solution of 3-iodo-1,1-dimethoxypropane[10] (4.93 g, 21.44 mmol) in dry DMSO (20 mL), and stirring was continued for 3 h. Water (200 mL) was added, and the aqueous solution was extracted with EtOAc until extraction was complete (TLC control, silica, 1:4 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. The crude product was used in the next step without characterization.

Methyl 5-Formyl-2-(phenylseleno)pentanoate (12). An aqueous solution of TFA (50%v/v, 30 mL) was added dropwise to a stirred solution of **11** (crude material from previous reaction) in CH_2Cl_2 (70 mL), and the resulting heterogeneous mixture was stirred vigorously for 14 h at room temperature. The mixture was cooled (0 °C), titrated with saturated aqueous $NaHCO_3$ until basic (pH paper), and extracted with CH_2Cl_2 until extraction was complete (TLC control, silica, 1:4 EtOAc−hexane). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ and brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (4.5 × 28 cm), using 15:85 EtOAc−hexane, gave **12** (2.15 g, 53% over two steps) as a pale yellow oil: FTIR (CH_2Cl_2 cast) 1728 cm^{-1}; ^1H NMR (CD_2Cl_2, 300 MHz) δ 1.95−2.20 (m, 2 H), 2.60 (dt, J = 1.2, 7.3 Hz, 2 H), 3.55−3.70 (m, 4 H), 7.25−7.40 (m, 3 H), 7.52−7.65 (m, 2 H), 9.71 (t, J = 1.3 Hz, 1 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 24.2 (t′), 42.0 (t′), 42.4 (d′), 52.2 (q′), 127.3 (s′), 128.8 (d′), 129.2 (d′), 135.8 (d′), 172.9 (s′), 200.6 (d′); exact mass m/z calcd for $C_{12}H_{14}O_3Se$ 286.0108, found 286.0100. Anal. Calcd for $C_{12}H_{14}O_3Se$: C, 50.54; H, 4.95. Found: C, 50.57; H, 4.95.

Methyl (2*R,5*R**)- and (2*R**,5*S**)-(±)-5-Hydroxy-8-(phenylmethoxy)-2-(phenylseleno)-6-octynoate (14).** *n*-BuLi (1.6 M in hexanes, 21.0 mL, 33.7 mmol) was added dropwise to a stirred and cooled (−78 °C) solution of benzyl propargyl ether (**13**[37]) (4.92 g, 33.7 mmol) in dry THF (50 mL). After 15 min, aldehyde **12** (3.84 g, 13.5 mmol) in dry THF (20 mL plus 10 mL as a rinse) was added dropwise at −78 °C. After 2 h (stirring), the cold reaction mixture was poured into water (150 mL) and extracted with EtOAc. The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (4.5 × 22 cm), using 1:3 EtOAc−hexane, gave **14** (4.74 g, 81%) as a pale yellow oil: FTIR (CH_2Cl_2 cast) 1728, 3435 cm^{-1}; ^1H NMR (CD_2Cl_2, 200 MHz) δ 1.61−2.20 (m, 5 H), 3.55−3.75 (m, 4 H), 4.20 (s, 2 H), 4.32−4.50 (m, 1 H), 4.55 (s, 2 H), 7.21−7.45 (m, 8 H), 7.51−7.65 (m, 2 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 27.4 (t′), 35.7 (t′), 42.9 (d′), 52.0 (q′), 57.3 (t′), 61.6 (d′), 71.6 (t′), 81.0 (s′), 87.0 (s′), 127.5 (s′), 127.8 (d′), 128.0 (d′), 128.4 (d′), 128.6 (d′), 129.0 (d′), 135.7 (d′), 137.2 (s′), 173.2 (s′). Anal. Calcd for $C_{22}H_{24}O_4Se$: C, 61.25; H, 5.61. Found: C, 61.42; H, 5.47.

Methyl (2*R,5*R**)- and (2*R**,5*S**)-(±)-5-[[Bis(1,1-dimethylethyl)silyl]oxy]-8-(phenylmethoxy)-2-(phenylseleno)-6-octynoate (15).** Imidazole (860.3 mg, 12.64 mmol) and *t*-Bu_2SiHCl (1.60 mL, 7.90 mmol) were added consecutively to a stirred solution of **14** (2.723 g, 6.32 mmol) in dry THF (50 mL), and the resulting white suspension was stirred and refluxed for 12 h, cooled to room temperature, and then poured into water (100 mL). The aqueous mixture was extracted with EtOAc until extraction was complete (TLC control, silica, 5:95 EtOAc−hexane), and the combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (3 × 22 cm), using 5:95 EtOAc−hexane, gave **15** as an inseparable mixture (^{13}C NMR) of diastereoisomers (3.428 g, 95%). The material was a colorless oil: FTIR (CH_2Cl_2 cast) 1733, 2094 cm^{-1}; ^1H NMR (CD_2Cl_2, 300 MHz) δ 0.85−1.10 (m, 18 H), 1.67−2.21 (m, 4 H), 3.50−3.75 (m, 4 H), 4.10 (s, 1 H), 4.12−4.22 (m, 2 H), 4.48−4.62 (m, 3 H), 7.20−7.42 (m, 8 H), 7.52−7.65 (m, 2 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 19.7 (s′), 20.0 (s′), 27.2 (q′), 27.4 (t′), 36.4 (t′), 36.5 (t′), 43.1 (d′), 43.2 (d′), 51.9 (q′), 57.2 (t′), 65.6 (d′), 71.3 (t′), 81.1 (s′), 81.2 (s′), 86.8 (s′), 127.6 (s′), 127.8 (d′), 128.1 (d′), 128.4 (d′), 128.5 (d′), 129.0 (d′), 135.6 (d′), 135.7 (d′), 137.5 (s′), 173.1 (s′); exact mass m/z calcd for $C_{30}H_{42}O_4SeSi$ 574.2018, found 574.2020. Anal. Calcd for $C_{30}H_{42}O_4SeSi$: C, 62.81; H, 7.38. Found: C, 62.98; H, 7.42.

Methyl (3α,3a*β*,4α,6a*β*)- and (3α,3a*β*,4*β*,6a*β*)-(±)-2,2-Bis-(1,1-dimethylethyl)hexahydro-3-[(phenylmethoxy)methyl]-2*H*-cyclopent[*d*]-[1,2]oxasilole-4-carboxylate (16). A solution of Ph_3SnH (629.0 mg, 1.79 mmol) and AIBN (33.9 mg, 0.21 mmol) in dry PhH (20 mL) was added over 7 h by syringe pump to a refluxing solution of **15** (790.0 mg, 1.38 mmol) in dry PhH (100 mL). Refluxing was continued for 1 h after the addition, and the mixture was then allowed to cool to room temperature. Evaporation of the solvent and flash chromatography of the residue over silica gel (4 × 20 cm), using 5:95 EtOAc−hexane, gave crude **16**, contaminated with tin residues. It was used directly in the next step, without full characterization. The ^1H NMR spectrum (300 MHz) showed the presence of two isomers in a 3:1 ratio.

(3α,3a*β*,4α,6a*β*)- and (3α,3a*β*,4*β*,6a*β*)-(±)-2,2-Bis(1,1-dimethylethyl)hexahydro-3-[(phenylmethoxy)methyl]-2*H*-cyclopent[*d*]-[1,2]oxasilol-4-yl]methanol (17). A solution of crude **16** (from the previous reaction) in dry THF (5 mL plus 2 mL as a rinse) was added dropwise to a stirred and cooled (−78 °C) suspension of $LiAlH_4$ (52.31 mg, 1.38 mmol) in dry THF (20 mL). After 5 min, the resulting mixture was allowed to cool to room temperature and was then poured into ice−water (50 mL). The aqueous solution was extracted with EtOAc until extraction was complete (TLC control, silica, 1:4 EtOAc−hexane), and the combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (3 × 21 cm), using 1:4 EtOAc−hexane, gave **17**, which was contaminated (^1H NMR) with some impurities that were not separable by flash chromatography. Alcohols **17** were used in the next step without full characterization. We depict **17** arbitrarily as a mixture of isomers, but we do not know for a fact whether one of the impurities is the isomer, or a totally different compound.

(1α,2α,3*β*)- and (1α,2α,3α)-(±)-3-(Hydroxymethyl)-2-[2-(phenylmethoxy)ethyl]cyclopentanol (18). TBAF (1.0 M in THF, 30 mL, 30 mmol) was added dropwise to a stirred solution of impure **17** in DMF (25 mL). The resulting solution was heated at 60 °C for 3 h, cooled to room temperature, and poured into water (100 mL). The mixture was extracted with EtOAc until extraction was complete (TLC control, silica, 3:1 EtOAc−hexane), and the combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (3 × 18 cm), using 3:1 EtOAc−hexane, gave **18**, which was contaminated (^1H NMR) with some impurities not separable by flash chromatography. Diols **18** were used in the next step without full characterization. We arbitrarily depict **18** as a mixture of isomers, but we do not know for a fact whether one of the impurities is the isomer, or a totally different compound.

(1α,2α,3*β*)-(±)-3-[[[(1,1-dimethylethyl)diphenylsilyl]oxy]-methyl]-2-[2-(phenylmethoxy)ethyl]cyclopentanol (19). Imidazole (96.7 mg, 1.42 mmol) and *t*-$BuPh_2SiCl$ (0.259 mL, 0.995 mmol) were added successively to a room-temperature solution of crude **18** (obtained from the previous reaction) in dry CH_2Cl_2 (20 mL). After 1 h, water (30 mL) was added, and the mixture was extracted with CH_2Cl_2 until extraction was complete (TLC control, silica, 15:85 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue

(37) Kwart, H.; Sarner, S. F.; Slutsky, J. *J. Am. Chem. Soc.* **1973**, *96*, 5234−5242.

over silica gel (3 × 20 cm), using 15:85 EtOAc−hexane, gave **19** (222.8 mg, 33% over four steps) as a colorless oil: FTIR (CH_2Cl_2 cast) 3450 cm^{-1}; ^1H NMR (CD_2Cl_2, 200 MHz) δ 1.05 (s, 9 H), 1.40−2.08 (m, 8 H), 2.68 (s, 1 H), 3.32−3.73 (m, 4 H) 4.23 (s, 1 H), 4.48 (s, 2 H), 7.21−7.50 (m, 11 H), 7.58−7.75 (m, 4 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 19.3 (s′), 26.3 (t′), 26.9 (q′), 28.8 (t′), 33.0 (t′), 45.1 (d′), 47.6 (d′), 66.4 (t′), 70.5 (t′), 73.5 (t′), 74.6 (d′), 127.6 (d′), 127.7 (d′), 128.5 (d′), 129.6 (d′), 134.0 (s′), 135.7 (d′), 137.9 (s′). Anal. Calcd for $C_{31}H_{40}O_3Si$: C, 76.18; H, 8.25. Found: C, 76.28; H, 8.29.

(1α,2α,3*β*)-(±)-3-[[[(1,1-Dimethylethyl)diphenylsilyl]-oxy]methyl]-2-[2-hydroxyethyl]cyclopentanol (20). Pd/C (10%, ca. 8 mg) was added to a solution of **19** (75.8 mg, 0.16 mmol) in bench MeOH (10 mL). The mixture was stirred under a H_2 atmosphere (balloon) for 7 h and then filtered through a short pad (0.5 × 1 cm) of Celite. Evaporation of the filtrate, and flash chromatography of the residue over silica gel (1 × 18 cm), using EtOAc, gave **20** (56.3 mg, 91%) as a colorless oil: FTIR (CH_2Cl_2 cast) 3334 cm^{-1}; ^1H NMR (CD_2Cl_2, 200 MHz) δ 1.07 (s, 9 H), 1.38−2.10 (m, 8 H), 2.74 (br s, 2 H), 3.49−3.82 (m, 4 H), 4.19−4.35 (m, 1 H), 7.29−7.52 (m, 6 H), 7.58−7.81 (m, 4 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 19.3 (s′), 26.0 (t′), 26.9 (q′), 30.9 (t′), 33.4 (t′), 44.8 (d′), 46.6 (d′), 62.1 (t′), 66.3 (t′), 74.8 (d′), 127.6 (d′), 129.6 (d′), 133.8 (s′), 135.6 (d′); exact mass *m*/*z* calcd for $C_{24}H_{34}NaO_3Si$ (M + Na) 421.2175, found 421.2181.

(3aα,4α,6aα)-(±)-4-[[[(1,1-Dimethylethyl)diphenylsilyl]-oxy]methyl]hexahydrocyclopenta[*b*]furan-2-one (21). $KMnO_4$ (0.2 g, 1.27 mmol) and $CuSO_4 \cdot 5H_2O$ (0.02 g, 0.08 mmol) were added consecutively to a stirred solution of **20** (31.9 mg, 0.080 mmol) in dry CH_2Cl_2 (5 mL). After 16 h, the heterogeneous mixture was filtered through a short pad (0.5 × 0.5 cm) of Celite and evaporated. Flash chromatography of the residue over silica gel (1 × 16 cm), using 3:7 EtOAc−hexane, gave **21** (16.5 mg, 52%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1766 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 1.05 (s, 9 H), 1.41−1.55 (m, 1 H), 1.75−2.06 (m, 4 H), 2.30−2.45 (m, 1 H), 2.51−2.63 (m, 1 H), 2.66−2.80 (m, 1 H), 3.45−3.65 (m, 2 H), 4.85−4.95 (m, 1 H), 7.30−7.46 (m, 6 H), 7.55−7.65 (m, 4 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 19.2 (s′), 26.8 (q′), 27.1 (t′), 31.9 (t′), 35.5 (t′), 42.0 (d′), 48.6 (d′), 65.9 (t′), 86.5 (d′), 127.7 (d′), 129.8 (d′), 133.4 (s′), 135.5 (d′), 177.4 (s′); exact mass *m*/*z* calcd for $C_{24}H_{30}NaO_3Si$ (M + Na) 417.1862, found 417.1862.

(3aα,4α,6aα)-(±)-Hexahydro-4-(hydroxymethyl)cyclopenta[*b*]furan-2-one (6). TBAF (1.0 M in THF, 0.18 mL, 0.18 mmol) was added dropwise to a stirred solution of **21** (35.2 mg, 0.089 mmol) in dry THF (5 mL). After 48 h, water (5 mL) was added and the aqueous solution was extracted with EtOAc until extraction was complete (TLC control, silica, EtOAc), and the combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (1.0 × 15 cm), using EtOAc, gave **6**[17] (13.0 mg, 93%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1767, 3427 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 1.41−1.58 (m, 1 H), 1.72 (s, 1 H), 1.80−2.05 (m, 4 H), 2.32−2.45 (m, 1 H), 2.52−2.65 (m, 1 H), 2.70−2.85 (m, 1 H), 3.45−3.63 (m, 2 H), 4.90−5.00 (m, 1 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 27.0 (t′), 31.9 (t′), 35.6 (t′), 41.9 (d′), 48.6 (d′), 64.9 (t′), 86.6 (d′), 177.6 (s′); exact mass *m*/*z* calcd for $C_8H_{12}O_3$ 156.0786, found 156.0788.

Ethyl (±)-3-[[(1,1-Dimethylethyl)silyl]oxy]-4-pentenoate (23). Imidazole (2.982 g, 43.8 mmol) and *t*-$BuMe_2SiCl$ (3.961 g, 26.3 mmol) were added consecutively to a stirred solution of **22** (2.891 g, 21.9 mmol) in dry CH_2Cl_2 (150 mL). After 3 h, water (75 mL) was added, and the aqueous layer was extracted with CH_2Cl_2 until extraction was complete (TLC control, silica, 1:9 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (4.5 × 20 cm), using 1:9 EtOAc−hexane, gave **23** (5.27 g, 93%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1739 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 0.02 (s, 3 H), 0.04 (s, 3 H), 0.85 (s, 9 H), 1.25 (t, J = 7.2 Hz, 3 H), 2.42 (dd, J = 14.5, 5.2 Hz, 1 H), 2.50 (dd, J = 14.5, 8.1 Hz, 1 H), 4.02−4.18 (m, 2 H), 4.50−4.60 (m, 1 H), 5.05 (dt, J = 10.3, 1.3 Hz, 1 H), 5.20 (dt, J = 17.1, 1.5 Hz, 1 H), 5.75−5.90 (m, 1 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ −5.2 (q′), −4.5 (q′), 14.1 (q′), 18.0 (s′), 25.6 (q′), 43.7 (t′), 60.3 (t′), 70.8 (d′), 114.5 (t′), 140.3 (d′), 171.0 (s′). Anal. Calcd for $C_{13}H_{26}O_3Si$: C, 60.42; H, 10.14. Found: C, 60.28; H, 10.17.

(±)-6-[[(1,1-Dimethylethyl)silyl]oxy]-1-(phenylmethoxy)-7-octen-2-yn-4-one (24). *n*-BuLi (2.5 M in hexanes, 10.05 mL, 25 mmol) was added dropwise to a stirred and cooled (−78 °C) solution of benzyl propargyl ether (**13**[37]) (3.67 g, 25.1 mmol) in dry THF (20 mL). After 30 min, the cold bath was removed, and the solution was allowed to warm to room temperature. In a separate round-bottomed flask, $BF_3 \cdot Et_2O$ (2.76 mL, 22.5 mmol) was added dropwise to a stirred and cooled (−78 °C) solution of **23** (5.27 g, 20.4 mmol) in dry THF (30 mL). The lithium acetylide solution (now at room temperature) was added dropwise to the stirred and cooled solution of **23**. Stirring at −78 °C was continued for 2 h, and the mixture was poured into water (150 mL). The aqueous layer was extracted with EtOAc until extraction was complete (TLC control, silica, 1:9 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. During flash chromatography, crude **24** coeluted with benzyl propargyl ether, and so **24** was not characterized, but used directly in the next step.

(±)-6-Hydroxy-1-(phenylmethoxy)-7-octen-2-yn-4-one (25). HF (48% in water, 1.41 mL, 41 mmol) was added in one lot to a solution of crude **24** (from the previous experiment) in MeCN (100 mL). After 5 h, saturated aqueous $NaHCO_3$ (100 mL) was added dropwise from a separatory funnel. EtOAc (50 mL) was added, and the aqueous layer was extracted with EtOAc until extraction was complete (TLC control, silica, 2:3 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (4.5 × 17 cm), using 2:3 EtOAc−hexane, gave **25** (2.33 g, 47% over two steps) as a colorless oil: FTIR (CH_2Cl_2 cast) 1675, 3447 cm^{-1}; ^1H NMR ($CDCl_3$, 200 MHz) δ 2.51 (br s, 1 H), 2.81 (d, J = 6.1 Hz, 2 H), 4.31 (s, 2 H), 4.52−4.75 (m, 3 H), 5.15 (dt, J = 10.5, 1.3 Hz, 1 H), 5.29 (dt, J = 17.2, 1.4 Hz, 1 H) 5.85 (ddd, J = 17.2, 10.5, 5.5 Hz, 1 H), 7.22−7.44 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 51.8 (t′), 56.9 (t′), 68.4 (d′), 72.2 (t′), 85.2 (s′), 89.0 (s′), 115.6 (t′), 128.1 (d′), 128.2 (d′), 128.5 (d′), 136.6 (s′), 138.5 (d′), 185.7 (s′). Anal. Calcd for $C_{15}H_{16}O_3$: C, 73.75; H, 6.60. Found: C, 73.55; H, 6.63.

(3*R,5*S**)- and (3*R**,5*R**)-(±)-8-(Phenylmethoxy)-1-octen-6-yne-3,5-diol (26).** DIBAL (1.0 M in PhMe, 15.3 mL, 15.3 mmol) was added dropwise to a stirred and cooled (−78 °C) solution of **25** (1.488 g, 6.10 mmol) in dry THF (80 mL). After 40 min, MeOH (4 mL), $Na_2SO_4 \cdot 10H_2O$ (4 g), Celite (6.3 g), and water (2 mL) were added sequentially to the cold (−78 °C) mixture. The cold bath was removed, and stirring was continued for an additional 30 min. The mixture was then filtered through a pad (7 × 4 cm) of Celite, EtOAc being used to elute all of the product (TLC control, silica, 1:1 EtOAc−hexane). Evaporation of the filtrate and flash chromatography of the residue over silica gel (2.5 × 17 cm), using 1:1 EtOAc−hexane, gave **26** (1.346 g, 90%) as an inseparable mixture of diastereoisomers. The ratio of the two diols could not be calculated from the ^1H NMR spectrum, and both isomers were used directly in the next step (from which the isomer ratio of the diols could be estimated as ca. 15:1). The major isomer was fully characterized, as described below (see compound **28**).

***trans*-(±)- and *cis*-(±)-4-Ethenyl-2,2-dimethyl-6-[3-(phenylmethoxy)-1-propynyl]-1,3-dioxane (27).** 2,2-Dimethoxypropane (6.73 mL, 54.7 mmol) and PPTS (ca. 10 mg) were added consecutively to a stirred solution of **26** (all the material from the above experiment) in dry CH_2Cl_2 (15 mL). After 6 h, the solution was poured into saturated aqueous $NaHCO_3$ (50 mL) and extracted with CH_2Cl_2 until extraction was complete (TLC control, silica, 1:9 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2.5 × 22 cm), using first 1:19 EtOAc−hexane and then 1:9 EtOAc−hexane, gave **27** (1.370 g, 88%) as a colorless oil, and the minor (trans) diastereoisomer (92.6 mg, 6%), which was discarded. Compound **27**: FTIR (CH_2Cl_2 cast) 1200 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 1.46 (s, 3 H), 1.50 (s, 3 H), 1.68−1.83 (m,

2 H), 4.20 (s, 2 H), 4.30−4.39 (m, 1 H), 4.58 (s, 2 H), 4.72−4.79 (m, 1 H), 5.12−5.18 (m, 1 H), 5.22−5.30 (m, 1 H), 5.73−5.86 (m, 1 H), 7.23−7.38 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 19.3 (q′), 30.0 (q′), 36.9 (t′), 57.4 (t′), 60.1 (d′), 69.6 (d′), 71.6 (t′), 80.7 (s′), 84.9 (s′), 99.3 (s′), 115.9 (t′), 127.8 (d′), 127.9 (d′), 128.4 (d′), 137.3 (s′) 137.7 (d′); exact mass *m*/*z* calcd for $C_{18}H_{22}O_3$ 286.1569, found 286.1531. Anal. Calcd for $C_{18}H_{22}O_3$: C, 75.50; H, 7.74. Found: C, 75.82; H, 7.57.

(3*R,5*S**)-(±)-8-(Phenylmethoxy)-1-octen-6-yn-3,5-diol (28).** CF_3CO_2H (1.0 mL, 13 mmol) was added to a stirred solution of **27** (2.27 g, 7.94 mmol) in THF (45 mL) and water (5 mL). After 4 h, the solution was titrated with saturated aqueous $NaHCO_3$ until basic (pH paper). The aqueous layer was extracted with EtOAc until extraction was complete (TLC control, silica, 3:2 EtOAc−hexane), and the combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2 × 16 cm), using 3:2 EtOAc−hexane, gave **28** (1.82 g, 93%) as a colorless oil: FTIR (CH_2Cl_2 cast) 3374 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 1.88−2.03 (m, 2 H), 2.49 (br s, 2 H), 4.20 (s, 2 H), 4.35−4.43 (m, 1 H), 4.58 (s, 2 H), 4.66−4.72 (m, 1 H), 5.13 (dt, J = 10.4, 1.3 Hz, 1 H), 5.27 (dt, J = 17.1, 1.4 Hz, 1 H), 5.88 (ddd, J = 16.9, 7.1, 6.0 Hz, 1 H), 7.25−7.39 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 43.7 (t′), 57.2 (t′), 61.2 (d′), 71.5 (t′), 71.6 (d′), 80.6 (s′), 87.1 (s′), 114.8 (t′), 127.8 (d′), 128.0 (d′), 128.3 (d′), 137.0 (s′), 139.9 (d′); exact mass *m*/*z* calcd for $C_{15}H_{18}O_3$ 246.1256, found 246.1241.

(3*R,5*S**)-(±)-5-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-8-(phenylmethoxy)-1-octen-6-yn-3-ol (29) and (3*R**,5*S**)-(±)-[(1,1-Dimethylethyl)dimethyl][[5-[[(1,1-dimethylethyl)-dimethylsilyl]oxy]-8-(phenylmethoxy)-1-octen-6-yn-3-yl]oxy]silane.** Imidazole (2.247 g, 33.0 mmol) and *t*-BuMe_2SiCl (2.736 g, 18.2 mmol) were added consecutively to a stirred solution of **28** (4.06 g, 16.5 mmol) in dry CH_2Cl_2 (200 mL). After 20 min, the reaction was quenched by addition of water (100 mL) (the reaction time represents the point at which formation of disilylated product becomes a competing reaction). The aqueous layer was extracted with CH_2Cl_2 until extraction was complete (TLC control, silica, 3:2 EtOAc−hexane), and the combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (4 × 19 cm), using first 1:9 EtOAc−hexane and then 3:2 EtOAc−hexane, gave **29** (2.81 g, 47%, 82% based on recovered starting material) as a colorless oil, starting diol **28** (1.710 g), and the disilylated product (410.6 mg). Compound **29**: FTIR (CH_2Cl_2 cast) 3432 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.18 (s, 3 H), 0.20 (s, 3 H), 0.91 (s, 9 H), 1.86−2.05 (m, 2 H), 2.69 (br s, 1 H), 4.19 (d, J = 1.5 Hz, 2 H), 4.30−4.39 (m, 1 H), 4.58 (s, 2 H), 4.63−4.70 (m, 1 H), 5.11 (dt, J = 10.4, 1.4 Hz, 1 H), 5.28 (dt, J = 17.3, 1.5 Hz, 1 H), 5.87 (ddd, J = 17.1, 10.5, 5.8 Hz, 1 H), 7.24−7.38 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ −5.0 (q′), −4.3 (q′), 18.1 (s′), 25.7 (q′), 45.1 (t′), 57.3 (t′), 62.3 (d′), 71.2 (d′), 71.5 (t′), 81.1 (s′), 87.4 (s′), 114.6 (t′), 127.9 (d′), 128.0 (d′), 128.4 (d′), 137.4 (s′), 140.2 (d′); exact mass *m*/*z* calcd for $C_{17}H_{23}O_3Si$ (M − C_4H_9) 303.1417, found 303.1423.

(4*R,6*S**)-(±)-[(1,1-Dimethylethyl)dimethyl][[6-(methoxymethoxy)-1-(phenylmethoxy)-7-octen-2-yn-4-yl]oxy]-silane (30).** *i*-Pr_2NEt (2.34 mL, 13.4 mmol) and $MeOCH_2Cl$ (1.02 mL, 13.4 mmol) were added consecutively to a stirred and cooled (0 °C) solution of **29** (1.612 g, 4.48 mmol) in dry CH_2Cl_2 (50 mL). After 1 h, the ice bath was removed, and stirring was continued for an additional 9 h. Water (50 mL) was added, and the aqueous layer was extracted with CH_2Cl_2 until extraction was complete (TLC control, silica, 1:9 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2.5 × 16 cm), using 1:9 EtOAc−hexane, gave **30** (1.563 g, 86%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1318 cm^{-1}; ^{1}H NMR ($CDCl_3$, 200 MHz) δ 0.12 (s, 3 H), 0.18 (s, 3 H), 0.91 (s, 9 H), 1.75−1.92 (m, 1 H), 1.96−2.14 (m, 1 H), 3.38 (s, 3 H), 4.14−4.33 (m, 3 H), 4.47−4.74 (m, 5 H), 5.12−5.30 (m, 2 H), 5.55−5.79 (m, 1 H), 7.25−7.43 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ −5.0 (q′), −4.4 (q′), 18.1 (s′), 25.7 (q′), 44.4 (t′), 55.3 (q′), 57.2 (t′), 60.2 (d′), 71.2 (t′), 74.1 (d′), 80.6 (s′), 87.6 (s′), 93.6 (t′), 117.8 (t′), 127.7 (d′), 127.9 (d′), 128.3 (d′), 137.4 (s′), 137.5 (d′). Anal. Calcd for $C_{23}H_{36}O_4Si$: C, 68.27; H, 8.97. Found: C, 67.93; H, 9.21.

(2*R,3*R**,5*S**)- and (2*R**,3*S**,5*R**)-(±)-5-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-3-(methoxymethoxy)-8-(phenylmethoxy)-6-octyne-1,2-diol (31).** 4-Methylmorpholine *N*-oxide (644.9 mg, 5.50 mmol) and OsO_4 (2.5% in *t*-BuOH, 1.86 g, 0.18 mmol) were added consecutively to a stirred solution of **30** (741.5 mg, 1.83 mmol) in THF (90 mL) and water (10 mL). After 20 h, $Na_2S_2O_3$ (1.0 M, 30 mL) was added, the mixture was stirred for 15 min, and the aqueous layer was extracted with EtOAc until extraction was complete (TLC control, silica, 3:1 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2 × 20 cm), using 3:1 EtOAc−hexane, gave **31** (429.6 mg, 54%) as an inseparable mixture of diastereoisomers: FTIR (CH_2Cl_2 cast) 3432 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.13 (s, 3 H), 0.17 (s, 3 H), 0.89 (s, 9 H), 1.86−2.10 (m, 4 H), 3.40 (s, 3 H), 3.58−3.95 (m, 4 H), 4.20 (s, 2 H), 4.58 (s, 2 H), 4.60−4.72 (m, 3 H), 7.23−7.39 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) (only the signals for the major isomer are given) δ −5.0 (q′), −4.5 (q′), 18.1 (s′), 25.7 (q′), 40.4 (t′), 56.0 (q′), 57.3 (t′), 60.4 (d′), 63.2 (t′), 71.5 (t′), 73.2 (d′), 78.8 (d′), 81.4 (s′), 87.1 (s′), 97.5 (t′), 127.9 (d′), 128.0 (d′), 128.4 (d′), 137.4 (s′); exact mass *m*/*z* calcd for $C_{22}H_{35}O_5Si$ (M − OCH_3) 407.2254, found 407.2258.

(2*R,3*S**,5*R**)- and (2*R**,3*R**,5*S**)-(±)-5-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-2-hydroxy-3-(methoxymethoxy)-6-octyn-1-yl 2,2-Dimethylpropionate (32).** DMAP (406.7 mg, 3.33 mmol) and *t*-BuCOCl (0.21 mL, 1.66 mmol) were added consecutively to a stirred and cooled (0 °C) solution of **31** (662.8 mg, 1.51 mmol) in dry PhMe (25 mL). The ice bath was removed and, after 1 h, water (25 mL) was added. The aqueous layer was extracted with EtOAc until extraction was complete (TLC control, silica, 1:4 EtOAc−hexane), and the combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2 × 17 cm), using 1:9 EtOAc−hexane, gave diastereoisomeric alcohols **32** (only the major isomer is shown in Scheme 4) (348.2 mg, 44%) as an inseparable mixture: FTIR (CH_2Cl_2 cast) 1730, 3445 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.14 (s, 3 H), 0.18 (s, 3 H), 0.90 (s, 9 H), 1.20 (s, 9 H), 1.88−1.95 (m, 1 H), 2.05−2.13 (m, 1 H), 3.30−3.42 [m, 4 H, including a singlet at δ 3.39, (3 H)], 3.76−3.91 (m, 2 H), 4.09−4.23 (m, 4 H), 4.58 (s, 2 H), 4.60−4.72 (m, 3 H), 7.24−7.37 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) (signals indicated are for the major diastereoisomer only) δ −5.0 (q′), −4.4 (q′), 18.1 (s′), 25.7 (q′), 27.2 (q′), 38.8 (s′), 40.08 (t′), 56.0 (q′), 57.3 (d′), 60.4 (t′), 65.1 (t′), 71.4 (d′), 71.5 (t′), 78.7 (d′), 81.3 (s′), 87.2 (s′), 97.4 (t′), 127.9 (d′), 128.0 (d′), 128.4 (d′), 137.4 (s′), 178.7 (s′).

(2*R,3*S**,5*R**)-(±)-5-[[(1,1-Dimethylethyl)dimethylsilyl]-oxy]-2-[(4-fluorophenoxy)thiocarbonyloxy]-3-(methoxymethoxy)-6-octyn-1-yl 2,2-Dimethylpropionate (33).** Dry pyridine (0.081 mL, 1.00 mmol), DMAP (40.7 mg, 0.33 mmol), and *p*-$FC_6H_4OC(S)Cl$ (0.28 mL, 2.0 mmol) were added consecutively to a stirred solution of **32** (348.2 mg, 0.67 mmol) in dry CH_2Cl_2 (12 mL). After 18 h, saturated aqueous NH_4Cl (20 mL) was added, and the aqueous layer was extracted with CH_2Cl_2 until extraction was complete (TLC control, silica, 1:9 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2 × 18 cm), using 1:9 EtOAc hexane, gave **33** (324.6 mg, 72%) as a colorless oil, whose relative stereochemistry was later assigned, as described in the text: FTIR (CH_2Cl_2 cast) 1735 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 0.12 (s, 3 H), 0.17 (s, 3 H), 0.90 (s, 9 H), 1.20 (s, 9 H), 1.94−2.12 (m, 2 H), 3.42 (s, 3 H), 4.21 (s, 2 H), 4.22−4.32 (m, 1 H), 4.32−4.51 (m, 2 H), 4.57 (s, 2 H), 4.60−4.68 (m, 1 H), 4.71 (s, 2 H), 5.71−5.80 (m, 1 H), 6.95−7.08 (m, 4 H), 7.24−7.37 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ −5.0 (q′), −4.5 (q′), 18.1 (s′), 25.8 (q′), 27.1 (q′), 38.8 (s′), 40.5 (t′), 56.1 (q′), 57.3 (t′), 60.3 (d′), 61.6 (t′), 71.5 (t′), 73.3 (d′), 81.5 (s′), 83.7 (d′), 86.8 (s′), 96.5 (t′), 116.2 (d′) J_{C-C-F} = 23.5 Hz, 123.4 (d′) $J_{C-C-C-F}$ = 8.3 Hz, 127.8 (d′), 128.1 (d′), 128.4 (d′),

137.4 (s′), 149.2 (s′), 160.6 (s′) J_{C-F} = 245.7 Hz, 178.1 (s′), 194.7 (s′); exact mass *m*/*z* calcd for $C_{35}H_{49}FO_8SSi$ 676.2902, found 676.2892.

(2*R,3*S**,5*R**)-(±)-2-[(4-Fluorophenoxy)thiocarbonyloxy]-5-hydroxy-3-(methoxymethoxy)-6-octyn-1-yl 2,2-Dimethylpropionate (34).** HF (48% in water, 0.5 mL, 14.5 mmol) was added to a solution of **33** [R = *p*-$FC_6H_4OC(S)$] (297.3 mg, 0.44 mmol) in MeCN (10 mL). After 2 h, saturated aqueous $NaHCO_3$ (20 mL) was added, and the aqueous layer was extracted with EtOAc until extraction was complete (TLC control, silica, 3:7 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2 × 14 cm), using 3:7 EtOAc−hexane, gave **34** (216.1 mg, 87%), which was not characterized but used directly in the next step.

(2*R,3*S**,5*R**)-(±)-5-[[Bis(1,1-dimethyl)ethylsilyl]oxy]-2-[(4-fluorophenoxy)thiocarbonyloxy]-3-(methoxymethoxy)-6-octyn-1-yl 2,2-Dimethylpropionate (35).** Imidazole (52.4 mg, 0.77 mmol) and *t*-Bu_2SiHCl (0.10 mL, 0.50 mmol) were added consecutively to a stirred solution of **34** (216.1 mg, 0.38 mmol) in dry THF (20 mL). After 10 h, water (15 mL) was added, and the aqueous layer was extracted with EtOAc until extraction was complete (TLC control, silica, 1:9 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2 × 14 cm), using 1:9 EtOAc−hexane, gave **35** (251.7 mg, 93%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1736, 2095 cm^{-1}; ^1H NMR ($CDCl_3$, 200 MHz) δ 0.99 (s, 9 H), 1.04 (s, 9 H), 1.18 (s, 9 H), 1.92−2.23 (m, 2 H), 3.41 (s, 3 H), 4.12 (s, 1 H), 4.22 (d, *J* = 1.3 Hz, 2 H), 4.25−4.34 (m, 1 H), 4.38 (dd, *J* = 12.3, 7.7 Hz, 1 H), 4.49 (dd, *J* = 12.2, 3.3 Hz, 1 H), 4.56 (s, 2 H), 4.61−4.70 (m, 1 H), 4.71 (s, 2 H), 5.65−5.79 (m, 1 H), 6.89−7.06 (m, 4 H), 7.19−7.35 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 19.7 (s′), 20.0 (s′), 27.1 (q′), 27.2 (q′), 38.8 (s′), 40.2 (t′), 56.1 (q′), 57.3 (t′), 61.6 (t′), 63.8 (d′), 71.4 (t′), 73.4 (d′), 82.3 (s′), 83.6 (d′), 86.1 (s′), 96.7 (t′), 116.2 (d′) J_{C-C-F} = 23.9 Hz, 123.3 (d′) $J_{C-C-C-F}$ = 8.5 Hz, 127.8 (d′), 128.1 (d′), 128.4 (d′), 137.4 (s′), 149.2 (s′), 160.6 (s′) J_{C-F} = 245.6 Hz, 178.0 (s′), 194.6 (s′); exact mass *m*/*z* calcd for $C_{33}H_{44}FO_8SSi$ (M − C_4H_9) 647.2510, found 647.2522.

(3α,3a*β*,4α,5α,6a*β*)- and (3α,3a*β*,4*β*,5α,6a*β*)-(±)-2,2-Bis(1,1-dimethylethyl)hexahydro-5-(methoxymethoxy)-3-(phenylmethoxy)methyl-2*H*-cyclopent[*d*]-[1,2]oxasilol-4-ylmethyl 2,2-Dimethylpropionate (36). A solution of Bu_3SnH (77.6 μL, 0.29 mmol) and AIBN (11.8 mg, 0.07 mmol) in dry PhMe (6 mL) was added over 6 h (syringe pump) to a stirred and heated (100 °C) solution of **35** (127 mg, 0.18 mmol) in dry PhMe (60 mL). Stirring at 100 °C was continued for 1 h after the end of the addition, and the mixture was cooled to room temperature and evaporated. Flash chromatography of the residue over silica gel (1 × 18 cm), using 1:9 EtOAc−hexane, gave **36** (76.1 mg, 79%) as an inseparable mixture of diastereoisomers. The ratio of the diastereoisomers could not be calculated from the ^1H NMR spectrum; however, the relative intensities of the ^{13}C NMR peaks indicated preferential formation of one of them. The compounds were used directly in the next step, but the major isomer was characterized by reductive removal of the pivaloyl group:

DIBAL-H (1 M in PhMe, 0.342 mL, 0.342 mmol) was added dropwise to a stirred and cooled (−78 °C) solution of the above ester (73.1 mg, 0.137 mmol) in CH_2Cl_2 (8 mL). After 30 min, MeOH (1 mL), $Na_2SO_4 \cdot 10H_2O$ (220 mg), Celite (500 mg), and water (0.2 mL) were added in that order, and stirring was continued for 1 h without recharging the cold bath. The resulting slurry was filtered through a short pad of Celite, which was washed with EtOAc (20 mL). Evaporation of the filtrate and flash chromatography of the residue over silica gel (2 × 18 cm), using 10% to 30% EtOAc−hexane, gave the major derived alcohol (43.3 mg, 70%) as a colorless oil: ^1H NMR (CD_2Cl_2, 200 MHz) δ 0.95 (s, 9 H), 1.05 (s, 9 H), 1.68−1.82 (m, 1 H), 2.12−2.22 (m, 2 H), 2.32−2.55 (m, 2 H), 2.60 (br s, 1 H), 3.35 (s, 3 H), 3.55−3.98 (m, 5 H), 4.31−4.42 (m, 1 H), 4.45−4.52 (m, 2 H), 4.52−4.70 (m, 2 H), 7.25−7.37 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 20.4 (s′), 21.9 (s′), 27.8 (q′), 28.6 (q′), 29.2 (d′), 40.7 (t′), 43.5 (q′), 47.9 (d′), 55.4 (d′), 63.0 (t′), 69.6 (t′), 72.9 (t′), 80.7 (d′), 81.2 (d′), 96.0 (t′), 127.9 (d′), 128.0 (d′), 128.5 (d′), 137.4 (s′).

(1α,2*β*,3*β*,5*β*)-(±)-3-Hydroxy-5-(methoxymethoxy)-2-[2-(phenylmethoxy)ethyl]cyclopentylmethyl 2,2-Dimethylpropionate (37). TBAF (1.0 M in THF, 1.42 mL, 1.42 mmol) was added dropwise to a stirred solution of **36** (76.1 mg, 0.14 mmol) in THF (3 mL) and DMF (3 mL), and the mixture was heated at 70 °C for 2 h and then cooled to room temperature. Water (10 mL) was added, and the aqueous layer was extracted with EtOAc until extraction was complete (TLC control, silica, 1:1 EtOAc−hexane). The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated, residual DMF being removed under oil pump vacuum (ca. 0.1 mmHg). Flash chromatography of the residue over silica gel (1 × 14 cm), using 2:3 EtOAc−hexane, gave **37** (49.3 mg, 88%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1727, 3507 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.19 (s, 9 H), 1.60−1.70 (m, 1 H), 1.74−1.98 (m, 3 H), 2.00−2.12 (m, 2 H), 2.75 (d, *J* = 6.0 Hz, 1 H), 3.32 (s, 3 H), 3.49−3.58 (m, 1 H), 3.60−3.69 (m, 1 H), 3.92−4.08 (m, 2 H), 4.08−4.19 (m, 2 H), 4.51 (s, 2 H), 4.63 (s, 2 H), 7.24−7.40 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 27.3 (q′), 28.9 (t′), 39.1 (s′), 40.2 (t′), 45.3 (d′), 49.7 (d′), 55.5 (d′), 64.3 (t′), 70.2 (t′), 73.3 (q′), 73.5 (t′), 79.8 (d′), 95.8 (t′), 128.0 (d′), 128.1 (d′), 128.7 (d′), 138.8 (s′), 178.6 (s′); exact mass *m*/*z* calcd for $C_{22}H_{34}NaO_6$ (M + Na) 417.2253, found 417.2258.

(1α,2*β*,3*β*,5*β*)-(±)-3-Hydroxy-2-(2-hydroxyethyl)-5-(methoxymethoxy)cyclopentylmethyl 2,2-Dimethylpropionate (38). Pd/C (10%, ca. 3 mg) was added to a solution of **37** (35.2 mg, 0.089 mmol) in bench MeOH (4 mL). The mixture was stirred under a H_2 atmosphere (balloon) for 1 h and filtered through a pad (1 × 1 cm) of Celite, using EtOAc. Evaporation of the solvent and flash chromatography of the residue over silica gel (1 × 10 cm), using EtOAc, gave **38** (23.6 mg, 87%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1729, 3425 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.18 (s, 9 H), 1.61−1.71 (m, 1 H), 1.71−1.82 (m, 1 H), 1.82−1.94 (m, 2 H), 1.97−2.07 (m, 1 H), 2.11 (ddd, *J* = 9.9, 9.8, 4.4 Hz, 1 H), 2.19 (br s, 1 H), 2.79 (br s, 1 H), 3.35 (s, 3 H), 3.61−3.80 (m, 2 H), 3.92−4.05 [m, 2 H, including a dd at δ 3.99 (*J* = 11.3, 6.1 Hz, 1 H)], 4.11 (dd, *J* = 11.3, 4.6 Hz, 1 H), 4.20 (br s, 1 H), 4.62 (s, 2 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 27.3 (q′), 31.8 (t′), 39.1 (s′), 40.5 (t′), 45.4 (d′), 50.0 (d′), 55.6 (d′), 62.1 (t′), 64.6 (t′), 74.1 (q′), 80.1 (d′), 95.6 (t′), 178.7 (s′); exact mass *m*/*z* calcd for $C_{15}H_{27}O_5$ (M − OH) 287.1859, found 287.1857.

(3aα,4α,5*β*,6aα)-(±)-Hexahydro-5-(methoxymethoxy)-2-oxocyclopenta[*b*]furan-4-ylmethyl 2,2-Dimethylpropionate (7). $KMnO_4$ (110 mg) and $CuSO_4 \cdot 5H_2O$ (11 mg) were added consecutively to a stirred solution of **38** (16.7 mg, 0.054 mmol) in CH_2Cl_2 (4 mL). The heterogeneous mixture was stirred vigorously for 12 h and then filtered through a pad (2.5 × 1 cm) of Celite, using CH_2Cl_2. Evaporation of the filtrate and flash chromatography of the residue over silica gel (1 × 12 cm), using 1:1 EtOAc−hexane, gave **7** (10.3 mg, 63%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1729, 1776 cm^{-1}; ^1H NMR (CD_2Cl_2, 300 MHz) δ 1.21 (s, 9 H), 2.05−2.20 (m, 1 H), 2.21−2.42 (m, 2 H), 2.51 (dd, *J* = 17.8, 2.4 Hz, 1 H), 2.59−2.71 (m, 1 H), 2.81 (dd, *J* = 17.8, 10.2 Hz, 1 H), 3.33 (s, 3 H), 3.93−4.10 (m, 3 H), 4.59 (q, *J* = 6.9 Hz, 2 H), 4.95 (ddd, *J* = 6.8, 6.8, 2.4 Hz, 1 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 27.1 (q′), 35.4 (t′), 37.9 (t′), 38.8 (s′), 39.9 (d′), 51.6 (d′), 55.6 (q′), 63.9 (t′), 78.9 (d′), 83.5 (d′), 95.5 (t′), 176.6 (s′), 178.2 (s′); exact mass *m*/*z* calcd for $C_{15}H_{24}NaO_6$ (M + Na) 323.1471, found 323.1478.

Phenylmethyl 2-Deoxy-α/*β*-D-*erythro*-pentofuranoside (39). Concentrated hydrochloric acid (1 drop) was added to a stirred solution of 2-deoxy-D-ribose (415.0 mg, 3.09 mmol) in BnOH (7.5 mL). Stirring at room temperature was continued for 10 min (TLC control, silica, 1:9 MeOH−CH_2Cl_2), by which time reaction was over. Anhydrous $MgCO_3$ (415.0 mg) was added, and the resultant slurry was stirred for 5 min and then filtered through a sintered disk, the insoluble material being washed with PhMe. The filtrate was evaporated at room temperature (water aspirator), and the remaining BnOH was removed at room temperature under diffusion pump vacuum (>0.001 mmHg). The residue remaining after 24 h was dissolved in CH_2Cl_2 (1 mL) and purified by flash chromatog-

raphy over silica gel (3 × 22 cm), using first 50:50 EtOAc−hexane (to remove remaining BnOH), followed by 1:9 MeOH−CH_2Cl_2, to give **39** (569.5 mg, 80%) as a colorless oil, which was a ca. 5:3 inseparable mixture of anomers. A sample, highly enriched in one of the anomers: FTIR (CH_2Cl_2 cast) 3386 cm^{-1}; ^1H NMR ($CDCl_3$, 200 MHz) δ 2.05−2.20 (m, 1 H), 2.29−2.40 (m, 1 H), 2.61 (br s, 2 H), 3.60−3.78 (m, 2 H), 4.05−4.15 (m, 1 H), 4.50−4.60 (m, 2 H), 4.72−4.82 (m, 1 H), 5.34 (dd, J = 5.6, 2.1 Hz, 1 H), 7.28−7.48 (m, 5 H); ^{13}C NMR ($CDCl_3$, 50.3 MHz) δ 42.5 (t′), 63.6 (t′), 70.0 (t′), 72.2 (d′), 87.6 (d′), 103.7 (d′), 127.8 (d′), 128.0 (d′), 128.5 (d′), 137.2 (s′); exact mass (HR electrospray) m/z calcd for $C_{12}H_{16}NaO_4$ (M + Na) 247.0946, found 247.0947.

Phenylmethyl 2-Deoxy-5-*O*-(2,2-dimethylpropanoyl)-α-D-*erythro*-pentofuranoside (40α) and Phenylmethyl 2-Deoxy-5-*O*-(2,2-dimethylpropanoyl)-*β*-D-*erythro*-pentofuranoside (40*β*). A solution of diethyl azodicarboxylate (248.7 mg, 1.428 mmol) and *t*-$BuCO_2H$ (145.8 mg, 1.4279 mmol) in dry THF (5 mL) was added to a stirred and warmed (60 °C) solution of alcohols **39** (320.1 mg, 1.428 mmol) and Ph_3P (374.5 mg, 1.428 mmol) in THF (2.5 mL), contained in a flask fitted with a condenser (Ar atmosphere). Stirring at 60 °C was continued for 3 h, the mixture was cooled to room temperature, and the solvent was evaporated. Flash chromatography of the residue [the material was taken up in CH_2Cl_2 (0.5 mL), and the solution was applied to the column] over silica gel (3 × 22 cm), using 1:4 EtOAc−hexane, gave **39** (86.4 mg, 27%), **40**α (94.08 mg, 22%), and **40***β* (157.53 mg, 36%) (combined yield is 83%, based on conversion) as colorless oils. The stereochemical assignment was inferred from the assignment made to compound **41**α (see below).

Compound **40**α: $[\alpha]^{25}_D$ = 104.5° (*c* 2.58, MeOH); FTIR (CH_2Cl_2 cast) 1731, 3508 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.21 (s, 9 H), 2.02 (dd, J = 13.8, 0.6 Hz, 1 H), 2.20 (ddd, J = 13.8, 6.3, 4.8 Hz, 1 H), 2.74 (d, J = 10.6 Hz, 1 H), 4.00−4.18 (m, 3 H), 4.23 (dt, J = 2.0, 4.5 Hz, 1 H), 4.55 (d, J = 11.8 Hz, 1 H), 4.80 (d, J = 11.8 Hz, 1 H), 5.27 (dd, J = 5.5, 1.4 Hz, 1 H), 7.20−7.40 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 27.3 (q′), 39.0 (s′), 41.5 (t′), 64.4 (t′), 69.5 (t′), 73.3 (d′), 85.5 (d′), 104.0 (d′), 128.0 (d′), 128.3 (d′), 128.8 (d′), 138.3 (s′), 178.4 (s′); exact mass (HR electrospray) m/z calcd for $C_{17}H_{24}NaO_5$ (M + Na) 331.1521, found 331.1528.

Compound **40***β*: $[\alpha]^{25}_D$ = −48.9° (*c* 1.68, MeOH); FTIR (CH_2Cl_2 cast) 1730, 3453 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.21 (s, 9 H), 2.13 (dt, J = 13.5, 5.7 Hz, 1 H), 2.29 (ddd, J = 13.5, 6.8, 2.0 Hz, 1 H), 2.38 (br s, 1 H), 4.00−4.10 (m, 1 H), 4.17 (d, J = 5.8 Hz, 2 H), 4.40 (br s, 1 H), 4.42 (d, J = 11.7 Hz, 1 H), 4.74 (d, J = 5.4, 2.0 Hz, 1 H), 5.27 (dd, J = 5.4, 2.0 Hz, 1 H), 7.20−7.40 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 27.3 (q′), 39.0 (s′), 42.0 (t′), 65.5 (t′), 69.7 (t′), 72.9 (d′), 84.3 (d′), 103.8 (d′), 127.9 (d′), 128.3 (d′), 128.7 (d′), 138.4 (s′), 178.7 (s′); exact mass (HR electrospray) m/z calcd for $C_{17}H_{24}NaO_5$ (M + Na) 331.1521, found 331.1520.

Phenylmethyl 2-Deoxy-5-*O*-(2,2-dimethylpropanoyl)-3-*O*-(methoxymethyl)-α-D-*erythro*-pentofuranoside (41α). *i*-Pr_2NEt (0.18 mL, 134.0 mg, 1.037 mmol) was added dropwise to a stirred and cooled (0 °C) solution of alcohol **40**α (106.5 mg, 0.3458 mmol) in CH_2Cl_2 (6 mL). After 15 min, CH_3OCH_2-Cl (0.08 mL, 1.037 mmol) was added dropwise over 5 min, and stirring was continued for 1 h. The cold bath was removed, stirring was continued for 12 h, and the mixture was diluted with water (10 mL) and extracted with CH_2Cl_2. The combined organic extracts were washed with brine, dried (Na_2SO_4), and evaporated. Flash chromatography of the residue over silica gel (2 × 15 cm), using 1:4 EtOAc−hexane, gave **41**α (112.2 mg, 92%) as a colorless oil: $[\alpha]^{25}_D$ = 106.6° (*c* 1.06, MeOH); FTIR (CH_2Cl_2 cast) 1728, 3435 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.21 (s, 9 H), 2.05 (ddd, J = 14.1, 2.9, 1.4 Hz, 1 H), 2.27 (ddd, J = 14.1, 8.3, 5.5 Hz, 1 H), 3.30 (s, 3 H), 4.10−4.18 (m, 2 H), 4.20−4.30 (m, 2 H), 4.46 (d, J = 12 Hz, 1 H), 4.64 (AB q, $\Delta\nu_{AB}$ = 8.7 Hz, J = 6.9 Hz, 2 H), 4.77 (d, J = 12 Hz, 1 H), 5.27 (dd, J = 5.5, 1.4 Hz, 1 H), 7.20−7.40 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 27.3 (q′), 39.0 (s′), 39.8 (t′), 55.7 (q′), 64.1 (t′), 69.5 (t′), 77.7 (d′), 81.6 (d′), 96.6 (t′), 103.6 (d′), 127.9 (d′), 128.2 (d′), 128.6 (d′), 138.8 (s′), 178.4 (s′); exact mass (HR electrospray) m/z calcd for $C_{19}H_{28}NaO_6$ (M + Na) 375.1784, found 375.1780. The anomeric configuration was assigned on the basis of a TROESY NMR (600 MHz) experiment.

Phenylmethyl 2-Deoxy-5-*O*-(2,2-dimethylpropanoyl)-3-*O*-(methoxymethyl)-α/*β*-D-*erythro*-pentofuranose (42). 5% Pd−C (15.0 mg) was added to a solution of **41**α (472.0 mg, 1.34 mmol) in EtOH (95%, 15 mL), and the mixture was shaken in a Parr bottle under H_2 (50 psi) until all the starting material was consumed (ca. 12 h, TLC control, silica gel, 2:3 EtOAc−hexane), the apparatus being opened periodically for examination by TLC. The mixture was filtered through a pad of silica gel (4 × 3 cm), using EtOAc (50 mL). Evaporation of the filtrate and flash chromatography of the residue over silica gel (3 × 15 cm), using 3:2 EtOAc−hexane, gave **42** (323.2 mg, 92%) as a colorless oil containing both anomers and small amounts of the open-chain isomer. These compounds were used directly in the next step.

(2*R*,3*S*)-2-Hydroxy-3-(methoxymethoxy)-5-hexenyl 2,2-Dimethylpropanoate (43). *n*-BuLi (2.5 M in hexane, 2.53 mL, 6.33 mmol) was added dropwise to a stirred suspension of Ph_3PCH_3Br (2.223 g, 6.33 mmol) in dry PhMe (25 mL), and the resulting yellow slurry was stirred at room temperature for 3 h. A solution of lactols **42** (550.7 mg, 2.11 mmol) in dry PhMe (7.5 mL) was added dropwise by syringe pump, and the mixture was then heated at 50 °C for 10 h. The mixture turned brown, and a white solid formed. The mixture was cooled to room temperature, diluted with water (30 mL), and extracted with EtOAc. The combined organic extracts were washed with water, saturated aqueous NH_4Cl (20 mL), and brine and dried ($MgSO_4$). Evaporation of the solvent and flash chromatography of the residue over silica gel (3.5 × 22 cm), using 1:4 EtOAc−hexane, gave **43** (372.2 mg, 72%) as a pale yellow oil: $[\alpha]^{25}_D$ = 29.4° (*c* 1.24, MeOH); FTIR (CH_2Cl_2 cast) 1730, 3486 cm^{-1}; ^1H NMR (CD_2Cl_2, 200 MHz) δ 1.21 (s, 9 H), 2.40−2.50 (m, 2 H), 2.75 (d, J = 6.4 Hz, 1 H), 3.40 (s, 3 H), 3.60−3.70 (m, 1 H), 3.75−3.90 (m, 1 H), 4.10 (dd, J = 11.6, 6.8 Hz, 1 H), 4.20 (dd, J = 11.6, 3.6 Hz, 1 H), 4.64 (AB q, $\Delta\nu_{AB}$ = 8.2 Hz, J = 6.8 Hz, 2 H), 5.00−5.20 (m, 2 H), 5.75−6.00 (m, 1 H); ^{13}C NMR (CD_2Cl_2, 75.5 MHz) δ 27.4 (q′), 35.7 (t′), 39.1 (s′), 56.1 (q′), 65.7 (t′), 71.5 (d′), 80.1 (d′), 97.3 (t′), 117.6 (t′), 134.9 (d′), 179.0 (s′); exact mass (HR electrospray) m/z calcd for $C_{13}H_{24}NaO_5$ (M + Na) 283.1521, found 283.1526.

(2*R*,3*S*)-2-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-3-(methoxymethoxy)-5-hexenyl 2,2-Dimethylpropanoate (44). Imidazole (196.7 mg, 2.89 mmol) and *t*-$BuMe_2SiCl$ (379.8 mg, 2.52 mmol) were added consecutively to a stirred solution of **43** (355.0 mg, 1.364 mmol) in dry CH_2Cl_2 (10 mL). Stirring was continued at room temperature for 10 h, at which point all the starting material had been consumed. The mixture was diluted with water (10 mL) and extracted with EtOAc. The combined organic extracts were washed with water (10 mL) and brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2.5 × 22 cm), using 1:4 EtOAc−hexane, gave **44** (453.0 mg, 89%) as a colorless oil: $[\alpha]^{25}_D$ = −1.72° (*c* 0.94, MeOH); FTIR (CH_2Cl_2 cast) 1730 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 0.10 (s, 6 H), 0.90 (s, 9 H), 1.21 (s, 9 H), 2.30−2.40 (m, 2 H), 3.35 (s, 3 H), 3.65 (dt, J = 4.0, 6.0 Hz, 1 H), 3.82−3.85 (m, 1 H), 4.02 (dd, J = 11.4, 4.9 Hz, 1 H), 4.17 (dd, J = 11.4, 4.3 Hz, 1 H), 4.65 (AB q, $\Delta\nu_{AB}$ = 12.5 Hz, J = 6.7 Hz, 2 H), 5.00−5.20 (m, 2 H), 5.75−6.00 (m, 1 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ −4.51 (q′, two coincident peaks), 18.3 (s′), 26.0 (q′), 27.4 (q′), 35.5 (t′), 39.0 (s′), 56.0 (q′), 65.8 (t′), 72.6 (d′), 78.3 (d′), 96.5 (t′), 117.2 (t′), 135.6 (d′), 178.5 (s′); exact mass (HR electrospray) m/z calcd for $C_{19}H_{38}NaO_5Si$ (M + Na) 397.2386, found 397.2396.

(2*R*,3*S*)-2-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-3-(methoxymethoxy)-5-oxopentyl 2,2-Dimethylpropanoate (45). Ozonized oxygen was bubbled through a stirred and cooled (−78 °C) solution of **44** (537.7 mg, 1.4367 mmol) and Sudan II red (1 mg) in dry CH_2Cl_2 (10 mL) (protection from moisture by Drierite tube). When all of the starting material was consumed (ca. 10 min; discharge of the red color; TLC control, silica gel, 2:3 EtOAc−hexane), the solution was purged with oxygen for 10 min. Ph_3P (753.7 mg, 2.873 mmol) was added, the cooling bath was removed, and stirring was

continued for 2 h, by which time the mixture had attained room temperature. Evaporation of the solvent and flash chromatography of the residue over silica gel (2.0 × 18 cm), using 1:4 EtOAc−hexane, gave **45** (420.9 mg, 83%) as a colorless oil: $[\alpha]^{25}_D = -16.9°$ (*c* 1.28, MeOH); FTIR (CH_2Cl_2 cast) 1732 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 0.10 (s, 6 H), 0.90 (s, 9 H), 1.21 (s, 9 H), 2.60−2.66 (m, 2 H), 3.35 (s, 3 H), 3.90−4.18 (m, 4 H), 4.65 (AB q, $\Delta\nu_{AB} = 23.0$ Hz, $J = 6.8$ Hz, 2 H), 9.81 (t, $J = 2.1$ Hz, 1 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ −4.61 (q′, two coincident peaks), 18.3 (s′), 25.9 (q′), 27.4 (q′), 39.0 (s′), 45.2 (t′), 56.0 (q′), 65.1 (t′), 72.6 (d′), 74.2 (d′), 96.7 (t′), 178.5 (s′), 201.2 (d′); a satisfactory mass spectrum could not be obtained.

(2*R*,3*S*,5*R*)- and (2*R*,3*S*,5*S*)-2-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-5-hydroxy-3-(methoxymethoxy)-8-(phenylmethoxy)-6-octynyl 2,2-Dimethylpropanoate (46). *n*-BuLi (2.5 M in hexane, 1.073 mL, 2.685 mmol) was added dropwise to a stirred and cooled (−78 °C) solution of benzyl propargyl ether (**13**[37]) (391.9 mg, 2.685 mmol) in THF (10 mL). Stirring at −78 °C was continued for 1 h, and then aldehyde **45** (378.0 mg, 1.073 mmol) in THF (3.0 plus 2.0 mL as a rinse) was added dropwise. Stirring was continued for 2 h (TLC control, silica gel, 2:3 EtOAc−hexane), at which point no starting material remained. The cold bath was removed and, after 5 min, water (10 mL) was added. The mixture was extracted with EtOAc, and the combined organic extracts were washed with brine and dried ($MgSO_4$). Evaporation of the solvent and flash chromatography of the residue over silica gel (3.0 × 22.0 cm), using 1:4 EtOAc−hexane, gave **45** (40 mg, 11%) and **46** (398.2 mg, 71%, or 80% based on conversion), each as a colorless oil. Compound **46** was isolated as a 1:1.4 mixture (^1H NMR, 400 MHz) of diastereoisomers: ^1H NMR (CD_2Cl_2, 400 MHz) δ 0.10 and 0.11 (two s, 6 H in all), 0.90 (s, 9 H), 1.20 (s, 9 H), 1.80−2.20 (m, 2 H), 2.80 (d, $J = 4.8$ Hz) and 3.05 (d, $J = 6.0$ Hz) (the signals at 2.80 and 3.05 correspond to 1 H in all), 3.42 and 3.44 (two s, 3 H in all), 3.80−4.20 (m, 4 H), 4.25 and 4.26 (two s, 2 H in all), 4.52 (s, 2 H), 4.60−4.72 (m, 2 H), 4.72−4.80 (m, 1 H), 7.28−7.40 (m, 5 H).

(2*R*,3*S*,5*R*)- and (2*R*,3*S*,5*S*)-2,5-Dihydroxy-3-(methoxymethoxy)-8-(phenylmethoxy)-6-octynyl 2,2-Dimethylpropanoate (47a, 47b). HF (48% in water, 0.4 mL, 11.2 mmol) was added to a stirred solution of **46** (251.2 mg, 0.4812 mmol) in bench MeCN (5 mL). After 30 min, saturated aqueous $NaHCO_3$ (10 mL) was added dropwise, and the aqueous layer was extracted with EtOAc. The combined organic extracts were washed with brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (2 × 40 cm), using 1:4 EtOAc−hexane, gave **47b** (69.8 mg, 35.5%) and **47a** (98.1 mg, 50%) as a separable mixture (1:1.4) of diastereoisomers.

Compound **47a**: $[\alpha]^{25}_D = -15.36°$ (*c* 0.97, MeOH); FTIR (CH_2Cl_2 cast) 1728, 3436 cm^{-1}; ^1H NMR (CD_2Cl_2, 200 MHz) δ 1.21 (s, 9 H), 1.80−2.20 (m, 2 H), 2.60 (d, $J = 5.0$ Hz, 1 H), 3.10 (d, $J = 5.0$, 1 H), 3.35 (s, 3 H), 3.85−3.92 (m, 2 H), 4.00−4.25 (m, 4 H), 4.55 (s, 2 H), 4.60−4.68 (m, 3 H), 7.30−7.40 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 27.3 (q′), 39.0 (s′), 39.4 (t′), 56.3 (q′), 57.8 (t′), 60.2 (d′), 65.5 (t′), 71.8 (d′), 72.0 (t′), 78.4 (d′), 81.5 (s′), 87.3 (s′), 97.5 (t′), 128.1 (d′), 128.3 (d′), 128.7 (d′), 138.1 (s′) 178.9 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{22}H_{32}NaO_7$ (M + Na) 431.2046, found 431.2055.

Compound **47b**: $[\alpha]^{25}_D = -10.0°$ (*c* 1.35, MeOH); FTIR (CH_2Cl_2 cast) 1728, 3439 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.21 (s, 9 H), 1.90 (ddd, $J = 14.6$, 9.0, 3.3 Hz, 1 H), 2.05 (ddd, $J = 14.6$, 3.3 Hz, 1 H), 2.80 (d, $J = 6.0$ Hz, 1 H), 2.90 (d, $J = 6.0$ Hz, 1 H), 3.40 (s, 3 H), 3.80−3.84 (m, 1 H), 3.90−3.96 (m, 1 H), 4.16 (dd, $J = 11.6$, 6.7 Hz, 1 H), 4.18−4.21 (m, 3 H), 4.59 (s, 2 H), 4.60−4.68 (m, 1 H), 4.71 (AB q, $\Delta\nu_{AB} = 12.0$ Hz, $J = 6.7$ Hz, 2 H), 7.30−7.40 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 27.3 (q′), 39.0 (s′), 39.1 (t′), 56.4 (q′), 57.8 (t′), 59.5 (d′), 65.4 (t′), 72.0 (d′), 72.0 (t′), 78.6 (d′), 81.0 (s′), 87.6 (s′), 98.1 (t′), 128.1 (d′), 128.3 (d′), 128.7 (d′), 138.1 (s′) 178.9 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{22}H_{32}NaO_7$ (M + Na) 431.2046, found 431.2057.

(2*R*,3*S*,5*R*)-5-[[(1,1-Dimethylethyl)dimethylsilyl]oxy]-2-hydroxy-3-(methoxymethoxy)-8-(phenylmethoxy)-6-octynyl 2,2-Dimethylpropanoate [(+)-32]. Imidazole (7.85 mg, 0.1154 mmol) and *t*-$BuMe_2SiCl$ (34.78 mg, 0.2308 mmol) were added consecutively to a stirred solution of diol **47a** (23.5 mg, 0.0577 mmol) in dry CH_2Cl_2 (3 mL). Stirring was continued at room temperature for 1 h, at which point all the starting material had been consumed and the bis-silylated product began to form. The mixture was diluted with water (2.5 mL) and extracted with EtOAc. The combined organic extracts were washed with water (2.5 mL) and brine, dried ($MgSO_4$), and evaporated. Flash chromatography of the residue over silica gel (1 × 10.0 cm), using 1:4 EtOAc−hexane, gave (+)-**32** (28.3 mg, 94%) as a colorless oil: $[\alpha]^{25}_D = 7.81$ (*c* 1.42, MeOH); FTIR (CH_2Cl_2 cast) 1730, 3442 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 0.14 (s, 3 H), 0.18 (s, 3 H), 0.90 (s, 9 H), 1.20 (s, 9 H), 1.91 (ddd, $J = 14.1$, 7.3, 4.2 Hz, 1 H), 2.09 (ddd, $J = 14.0$, 7.9, 5.9 Hz, 1 H), 3.15 (d, $J = 6.4$ Hz, 1 H), 3.39 (s, 3 H) 3.76−3.91 (m, 2 H), 4.09−4.23 (m, 4 H), 4.58 (s, 2 H), 4.60−4.72 (m, 3 H), 7.24−7.37 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ −5.0 (q′), −4.4 (q′), 18.4 (s′), 25.9 (q′), 27.3 (q′), 39.0 (s′), 40.5 (t′), 56.2 (q′), 57.8 (t′), 60.9 (d′), 65.4 (t′), 71.8 (d′), 71.8 (t′), 78.9 (d′), 81.7 (s′), 87.5 (s′), 97.8 (t′), 128.1 (d′), 128.3 (d′), 128.7 (d′), 138.1 (s′), 178.7 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{28}H_{46}NaO_7Si$ (M + Na) 575.2911, found 575.2901.

(1α,2β,3β)-(±)-[(1,1-Dimethylethyl)diphenyl[[2-[(2-phenylmethoxy)ethyl]-3-[(2-methoxyethoxy)methoxy]cyclopentyl]methyl]oxy]silane (49). *i*-Pr_2NEt (1.37 mL, 7.91 mmol) was added dropwise to a stirred and cooled (0 °C) solution of **19** (1.28 g, 2.63 mmol) in CH_2Cl_2 (10 mL). After 15 min, MEMCl (0.90 mL, 7.91 mmol) was added dropwise over 5 min, and stirring was continued for 1 h. The cold bath was removed, stirring was continued for 12 h, and the mixture was diluted with water (100 mL) and extracted with CH_2Cl_2. The combined organic extracts were washed with brine, dried (Na_2SO_4), and evaporated. Flash chromatography of the residue over silica gel (3 × 20 cm), using 1:4 EtOAc−hexane, gave **49** (1.51 g, 100%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1199, 3070 cm^{-1}; ^1H NMR (CD_2Cl_2, 200 MHz) δ 1.05 (s, 9 H). 1.50−2.10 (m, 8 H), 3.35 (s, 3 H), 3.40−3.70 (m, 8 H), 4.10−4.20 (m, 1 H), 4.47 (s, 2 H), 4.64 (AB q, $\Delta\nu_{AB} = 18.2$ Hz, $J = 6.8$ Hz, 2 H), 7.20−7.45 (m, 10 H), 7.60−7.70 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 19.5 (t′), 26.1 (t′), 27.0 (q′), 28.7 (t′), 31.0 (t′), 43.4 (d′), 45.3 (d′), 59.0 (q′), 67.0 (t′), 67.4 (t′), 69.8 (t′), 72.2 (t′), 73.0 (t′), 80.5 (d′), 94.6 (t′), 127.7 (d′), 127.9 (d′), 128.0 (d′), 128.6 (d′), 129.9 (d′), 134.4 (s′), 136.0 (d′), 139.5 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{35}H_{48}NaO_5Si$ (M + Na) 599.3169, found 599.3171.

(1α,2β,3β)-(±)-3-[(2-Methoxyethoxy)methoxy]-2-[2-(phenylmethoxy)ethyl]cyclopentanemethanol (50). TBAF (1 M in THF, 4.62 mL, 4.62 mmol) was added dropwise to a stirred solution of **49** (1.33 g, 2.30 mmol) in dry THF (40 mL). Stirring was continued for 20 h, by which time reaction was complete (TLC control, silica gel, 3:4 EtOAc−hexane). The mixture was diluted with water (100 mL) and extracted with EtOAc. The combined organic extracts were washed with brine, dried (Na_2SO_4), and evaporated. Flash chromatography of the residue over silica gel (3 × 20 cm), using 3:4 EtOAc−hexane, gave **50** (758 mg, 96%) as a colorless oil: FTIR (CH_2Cl_2 cast) 3445 cm^{-1}; ^1H NMR (CD_2Cl_2, 200 MHz) δ 1.20−2.10 (m, 9 H), 3.30 (s, 3 H), 3.40−3.70 (m, 8 H), 4.00−4.10 (m, 1 H), 4.50 (s, 2 H), 4.66 (AB q, $\Delta\nu_{AB} = 18.2$ Hz, $J = 6.8$ Hz, 2 H), 7.20−7.40 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 26.2 (t′), 28.8 (t′), 30.8 (t′), 43.7 (d′), 45.4 (d′), 59.0 (q′), 66.4 (t′), 67.4 (t′), 69.8 (t′), 72.2 (t′), 73.2 (t′), 80.6 (d′), 94.6 (t′), 127.9 (d′), 128.1 (d′), 128.7 (d′), 139.1 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{19}H_{30}NaO_5$ (M + Na) 361.1991, found 361.1989.

(2α,3α)-(±)-1-[(2-Methoxyethoxy)methoxy]-3-methylene-2-[2-(phenylmethoxy)ethyl]cyclopentane (51). Bu_3P (0.11 mL, 0.45 mmol) was added dropwise over 5 min to a stirred solution of **50** (76.4 mg, 0.22 mmol) and 2-nitrophenyl selenocyanate (102.5 mg, 0.45 mmol) in dry THF (2 mL). The resulting red solution was stirred for 3 h, at which stage no starting material remained (TLC control, silica gel, 1:5 EtOAc−hexane). The solvent was evaporated, and the crude selenide was used directly in the next step.

A stirred solution of the crude selenide in dry CH_2Cl_2 (5 mL) was cooled to −10 °C, and *m*-CPBA (78.0 mg, 0.45 mmol) was added in one portion. Stirring was continued for 1 h, *i*-Pr_2NH (0.063 mL, 0.45 mmol) was added, and the mixture was refluxed for 1 h. Evaporation of the solvent and flash chromatography of the residue over silica gel (1 × 18 cm), using 1:5 EtOAc−hexane, gave **51** (57.8 mg, 80%) as a yellow oil: FTIR (CH_2Cl_2 cast) 1652, 3070 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.60−2.00 (m, 4 H), 2.35−2.60 (m, 3 H), 3.30 (s, 3 H), 3.40−3.60 (m, 6 H), 4.07−4.09 (m, 1 H), 4.43 (AB q, $\Delta\nu_{AB}$ = 11.5 Hz, J = 11.9 Hz, 2 H), 4.64 (AB q, $\Delta\nu_{AB}$ = 38.3 Hz, J = 6.9 Hz, 2 H), 4.80 (d, J = 2.1 Hz, 1 H), 4.86 (d, J = 2.1 Hz, 1 H), 7.20−7.45 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 100.6 MHz) δ 27.3 (t′), 29.5 (t′), 29.6 (t′), 46.0 (d′), 58.9 (q′), 67.5 (t′), 69.2 (t′), 72.1 (t′), 73.1 (t′), 79.3 (d′), 94.5 (t′), 105.2 (t′), 127.7 (d′), 127.9 (d′), 128.6 (d′), 139.4 (s′), 154.1 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{19}H_{28}NaO_4$ (M + Na) 343.1885, found 343.1889.

(1α,2α,3α)-(±)-3-[(2-Methoxyethoxy)methoxy]-2-[2-(phenylmethoxy)ethyl]cyclopentanemethanol (52). $BH_3{\cdot}SMe_2$ (10.0 M in THF, 0.210 mL, 2.10 mmol) was added dropwise to a stirred and cooled (−20 °C) solution of **51** (337.3 mg, 1.05 mmol) in dry THF (5 mL). After 30 min, the solution was warmed to 0 °C (by replacing the acetone-dry ice bath with an ice bath). Stirring was continued for 1.0 h, the ice bath was removed, and stirring was continued for 30 min. The mixture was cooled to 0 °C, and NaOH (3 N, 0.7027 mL) was added dropwise, followed by 30% aqueous H_2O_2 (0.24 mL), and stirring was continued for 30 min. The mixture was diluted with Et_2O (10 mL), washed with water (2 × 10 mL) and brine, dried (Na_2SO_4), and evaporated. Flash chromatography of the residue over silica gel (1.5 × 20 cm), using 15:85 EtOAc−hexane, gave **52** (303.0 mg, 85%) as a colorless oil: FTIR (CH_2Cl_2 cast) 3453 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.60−1.90 (m, 6 H), 2.05−2.20 (m, 1 H), 2.20−2.30 (m, 1 H), 2.85 (dd, J = 7.8, 3.0 Hz, 1 H), 3.30 (s, 3 H), 3.40−3.70 (m, 8 H), 4.00−4.10 (m, 1 H), 4.41 (s, 2 H), 4.67 (AB q, $\Delta\nu_{AB}$ = 30.3 Hz, J = 6.9 Hz, 2 H), 7.20−7.45 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 25.2 (t′), 25.6 (t′), 30.9 (t′), 42.0 (d′), 43.6 (d′) 59.0 (q′), 62.8 (t′), 67.7 (t′), 70.0 (t′), 72.1 (t′), 73.3 (t′), 80.1 (d′), 94.3 (t′), 127.8 (d′), 128.0 (d′), 128.7 (d′), 139.2 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{19}H_{30}NaO_5$ (M + Na) 361.1991, found 361.1989.

(1α,2α,3α)-(±)-[3-[(2-Methoxyethoxy)methoxy]-2-[2-(phenylmethoxy)ethyl]cyclopentyl]methyl 4-Methylphenylsulfonate (53). *p*-TsCl (304.4 mg, 1.596 mmol) was added in one portion to a stirred solution of **52** (180.0 mg, 0.5322 mmol) in CH_2Cl_2 (5 mL) containing dry pyridine (0.5 mL). A catalytic amount of DMAP was tipped into the solution, and the mixture was stirred overnight, by which time reaction was complete (TLC control, silica gel, 1:4 EtOAc−hexane). The mixture was diluted with water (10 mL) and extracted with CH_2Cl_2. The combined organic extracts were washed with brine, dried (Na_2SO_4), and evaporated. Flash chromatography of the residue over silica gel (1.5 × 18 cm), using 1:4 EtOAc−hexane, gave **53** (254 mg, 97%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1188 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.50−1.90 (m, 6 H), 1.95−2.10 (m, 1 H), 2.25−2.40 (m, 1 H), 2.45 (s, 3 H), 3.25 (s, 3 H), 3.40−3.60 (m, 6 H), 3.90−4.00 (m, 2 H), 4.10 (dd, J = 9.4, 5.5 Hz, 1 H), 4.42 (s, 2 H), 4.57 (AB q, $\Delta\nu_{AB}$ = 33.5 Hz, J = 6.9 Hz, 2 H), 7.20−7.40 (m, 7 H), 7.70−7.80 (m, 2 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 21.5 (q′), 25.3 (t′), 26.7 (t′), 30.3 (t′), 39.5 (d′), 43.7 (d′) 58.8 (q′), 67.2 (t′), 69.4 (t′), 72.0 (t′), 73.0 (t′), 73.4 (t′), 79.6 (d′), 94.3 (t′), 127.6 (d′), 127.8 (d′), 128.0 (d′), 128.5 (d′), 123.0 (d′), 133.5 (s′), 139.0 (s′), 145.0 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{26}H_{36}NaO_7S$ (M + Na) 515.2080, found 515.2083.

(1α,2α,3α)-(±)-3-[(2-Methoxyethoxy)methoxy]-2-[2-(phenylmethoxy)ethyl]cyclopentaneacetonitrile (54). A solution of **53** (195.5 mg, 0.39 mmol) and NaCN (136.5 mg, 2.8 mmol) in dry DMSO (2.5 mL) was heated at 100 °C for 1 h, allowed to cool to room temperature, diluted with water (15 mL), and extracted with Et_2O. The combined organic extracts were washed with brine, dried (Na_2SO_4), and evaporated. Flash chromatography of the residue over silica gel (1.5 × 20 cm), using 1:3 EtOAc−hexane, gave **54** (115.4 mg, 87%) as a pale yellow oil: FTIR (CH_2Cl_2 cast) 2244 cm^{-1}; ^1H NMR (CD_2Cl_2, 300 MHz) δ 1.60−2.10 (m, 7 H), 2.30−2.50 (m, 3 H), 3.35 (s, 3 H), 3.40−3.70 (m, 6 H), 4.00−4.10 (m, 1 H), 4.40 (s, 2 H), 4.62 (AB q, $\Delta\nu_{AB}$ = 25.7 Hz, J = 6.9 Hz, 2 H), 7.20−7.50 (m, 5 H); ^{13}C NMR (CD_2Cl_2, 75.4 MHz) δ 20.4 (t′), 25.8 (t′), 29.6 (t′), 30.7 (t′), 38.0 (d′), 44.8 (d′), 59.1 (q′), 67.6 (t′), 69.6 (t′), 72.2 (t′), 73.4 (t′), 80.1 (d′), 94.7 (t′), 120.9 (s′), 127.99 (d′), 128.02 (d′), 128.7 (d′), 139.2 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{20}H_{29}NNaO_4$ (M + Na) 370.1994, found 370.2003.

(1α,2α,3α)-(±)-2-(2-Hydroxyethyl)-3-[(2-methoxyethoxy)methoxy]cyclopentaneacetonitrile (55). Pd−C (5%) (9 mg) was added to a stirred solution of **54** (55.0 mg, 0.163 mmol) in MeOH (2 mL). The reaction flask was flushed with H_2, and stirring was continued under hydrogen (balloon) until all the starting material was consumed (ca 30 min, TLC control, silica gel, 3:2 EtOAc−hexane). The mixture was filtered through a pad of silica gel (1 × 2 cm), using EtOAc (50 mL). Evaporation of the filtrate and flash chromatography of the residue over silica gel (1 × 10 cm), using 3:2 EtOAc−hexane, gave **55** (38.5 mg, 92%) as a colorless oil: FTIR (CH_2Cl_2 cast) 3442 cm^{-1}; ^1H NMR (CD_2Cl_2, 200 MHz) δ 1.50−2.15 (m, 8 H), 2.30−2.50 (m, 3 H), 3.35 (s, 3 H), 3.45−3.75 (m, 6 H), 4.05−4.15 (m, 1 H), 4.62 (AB q, $\Delta\nu_{AB}$ = 14.7 Hz, J = 6.7 Hz, 2 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 20.4 (t′), 28.5 (t′), 29.3 (t′), 30.8 (t′), 38.1 (d′), 44.6 (d′), 59.0 (q′), 62.0 (t′), 67.7 (t′), 72.2 (t′), 80.3 (d′), 94.8 (t′), 120.8 (s′); exact mass (HR electrospray) *m*/*z* calcd for $C_{13}H_{23}O_4NNa$ (M + Na) 280.1525, found 280.1524.

(1α,2α,3α)-(±)-3-[(2-Methoxyethoxy)methoxy]-2-(2-oxoethyl)cyclopentaneacetonitrile (56). A mixture of PCC (56.8 mg, 0.26 mmol) and powdered 4 Å molecular sieves (20 mg) was added to a stirred solution of **55** (52.2 mg, 0.20 mmol) in dry CH_2Cl_2 (2 mL). Stirring was continued for 1 h, by which time oxidation was complete (TLC control, silica gel, 2:3 EtOAc−hexane), and the mixture was applied directly to a column (1 × 15 cm) of flash chromatography silica gel. The column was developed using 2:3 EtOAc−hexane, to give **56** (41 mg, 78%) as a colorless oil: FTIR (CH_2Cl_2 cast) 1722, 2245 cm^{-1}; ^1H NMR (CD_2Cl_2, 400 MHz) δ 1.60−1.75 (m, 1 H), 1.80−2.05 (m, 3 H), 2.30−2.60 (m, 5 H), 2.65−2.80 (m, 1 H), 3.35 (s, 3 H), 3.42−3.62 (m, 4 H), 4.10−4.20 (m, 1 H), 4.58 (AB q, $\Delta\nu_{AB}$ = 30.5 Hz, J = 6.8 Hz, 2 H), 9.80 (t, J = 1.07 Hz, 1 H); ^{13}C NMR (CD_2Cl_2, 50.3 MHz) δ 20.3 (t′), 29.2 (t′), 30.3 (t′), 37.3 (d′), 39.9 (t′), 41.0 (d′), 59.0 (q′), 67.6 (t′), 72.1 (t′), 79.7 (d′), 94.7 (t′), 120.1 (s′), 201.4 (d′); exact mass (HR electrospray) *m*/*z* calcd for $C_{13}H_{21}NNaO_4$ (M + Na) 278.1373, found 278.1368.

[1α,2α(*Z*),3α]-(±)-3-[(2-Methoxyethoxy)methoxy]-2-(2-pentenyl)cyclopentaneacetonitrile (8). $(Me_3Si)_2NK$ (0.5 M in PhMe, 0.49 mL, 0.25 mmol) was added to a slurry of triphenyl(propyl)phosphonium bromide (100.2 mg, 0.26 mmol) in dry PhMe (1 mL). The mixture was stirred for 1 h, and the resultant bright red solution was then left undisturbed for 1 h. The supernatant liquid was drawn up into a syringe, and an aliquot (ca 1.0 mL, 0.17 mmol) was added dropwise over 5 min to a stirred and cooled (−78 °C) solution of **56** (15.8 mg, 0.06 mmol) in dry PhMe (1 mL). The temperature was maintained at −78 °C for 1 h, and then the cold bath was removed. Stirring was continued overnight, leading to a colorless solution and the formation of Ph_3PO. The solvent was evaporated, and the crude residue was dissolved in CH_2Cl_2 (0.5 mL). The solution was applied directly to a column of flash chromatography silica gel (1.0 × 10 cm), and the column was developed using 1:4 EtOAc−hexane, to give **8**[9] (14.0 mg, 80%) as a colorless oil: FTIR (CH_2Cl_2 cast) 2245 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ 0.96 (t, J = 7.5 Hz, 3 H), 1.60−2.30 (m, 9 H), 2.30−2.50 (m, 3 H), 3.37 (s, 3 H), 3.50−3.70 (m, 4 H), 4.00−4.10 (m, 1 H), 4.64 (AB q, $\Delta\nu_{AB}$ = 35.0 Hz, J = 6.9 Hz, 2 H), 5.25−5.5 (m, 2 H); ^{13}C NMR (CD_2Cl_2, 100.6 MHz) δ 14.3 (q′), 20.2 (t′), 21.0 (t′), 23.1 (t′), 29.5 (t′), 30.8 (t′), 37.6 (d′), 48.1 (d′), 59.0 (q′), 67.4 (t′), 72.1 (t′), 80.2 (d′), 94.9 (t′), 120.8 (s′), 127.5 (d′), 133.0 (d′); exact mass (HR electrospray) *m*/*z* calcd for $C_{16}H_{27}NNaO_3$ (M + Na) 304.1889, found 304.1887.

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Supporting Information Available: Experimental procedures for **C**, **D**, **41**β, **42**, and the epimer of (+)-**32**, and copies of NMR spectra for compounds not analyzed. This material is available free of charge via the Internet at http://pubs.acs.org.

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