Dihydro- and Tetrahydrofuran Building Blocks from 1,4:3,6-Dianhydromannitol. 1. Synthesis of (1*S*,5*R*,7*R*)-*endo*-(-)- and (1*S*,5*R*,7*S*)-(-)-*exo*-Brevicomin and (*R*)-(+)-Dodecanolide[1]

Vanda Cerè, Claudio Mazzini, Claudio Paolucci,* Salvatore Pollicino, and Antonino Fava*

Department of Organic Chemistry, University of Bologna, Viale Risorgimento, 4-I-40136 Bologna, Italy

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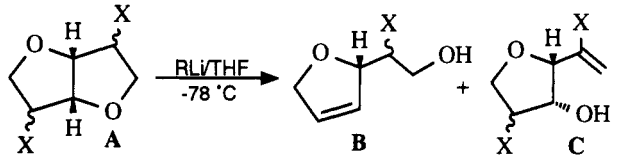
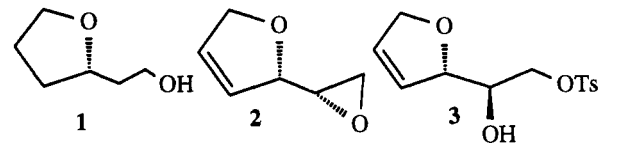
The eliminative ring fission of iodides derived from 1,4:3,6-dianhydromannitol[3] has been exploited for preparing three enantiomerically pure species, **1–3**, which feature a di- or tetrahydrofuran moiety and one or two stereogenic centers. These species are extremely versatile building blocks for the construction of natural products. Their potential was demonstrated by the synthesis of the title insect pheromones.

The use of easily available enantiopure natural substances (sugars among them) has since long been a major route to the synthesis of enantiomerically pure target molecules.[2] One of the problems with common sugars, however, is that, having, as they do, many stereogenic centers, the removal of part of them is often a prerequisite to their effective use.

In 1989 we reported on the alkyllithium-promoted eliminative ring cleavages of halides derived from 1,4:3,6-dianhydrohexitols (**A**).[3] The balance between the dihydrofuran and tetrahydrofuran products, **B** and **C**, respectively, largely depends on the nature of the halide, iodides, and chlorides yielding exclusively dihydrofurans (**B**) and tetrahydrofurans (**C**), respectively. The iodide reaction appears to be especially useful since it brings about the removal of two stereogenic centers while leaving a substituted and functionalized furanose ring.



In this paper the preparation is reported of three simple molecules, **1–3**, which have been obtained *via* the cleavage of di- or monoiodides from 1,4:3,6-dianhydromannitol (isomannide). These species possess several useful features that make them extremely flexible enantiopure building blocks. In fact the side chain can be homologated and the hydroxy or epoxy function stereospecifically transformed into a gamut of different functionalities. Moreover the ring can be oxidized to a furan or to a lactone or reduced and hence cleaved regiospecifically at the primary ether carbon to give functionalized alcohols. To exemplify their possible applications, the syntheses are reported herein of the title pheromones. The syntheses of several additional pheromones starting from the same building blocks will be reported shortly.



Results and Discussion

Building block **1**, (*S*)-(+)-2-(2-hydroxyethyl)tetrahydrofuran, was obtained as outlined in Scheme I. Treatment of isomannide **4** with *p*-toluenesulfonyl chloride in pyridine gave the ditosylate which reacted with NaI in DMF at 100 °C for 24 h, yielding a mixture of the three diiodide diastereomers **5a,b,c** in a ratio ≃4:5:1 (Scheme I). This material, when treated with MeLi in THF at −78 °C, gave a mixture of iodohydrin **6a,b** which on catalytic hydrogenation gave **1** in 57% overall yield from **4**.

Building blocks **2** and **3** possess an additional stereogenic center, of opposite configuration, in the side chain. The epimeric iodohydrins **6a,b** also have this feature and could have been used in lieu of **2** and **3**. Since, however, their separation is rather lengthy, an approach was taken aimed at preserving the configuration of one of the hydroxyl-bearing carbons of the starting material. In view of their endo stereochemistry, the hydroxyl groups of isomannide could be expected to be liable to selective monofunctionalization. Although monotosylation, -benzylation, and -acetylation were found to be unsatisfactory to this purpose, acylation with pivaloyl chloride was found to yield the monopivalate essentially exclusively (Scheme II). Tosylation of the free hydroxyl group of the latter followed by iodide displacement, gave a mixture of the two monoiodide epimers **9a** + **9b** which, subjected to eliminative ring cleavage, yielded a ≃9:1 mixture of primary (**10a**) and secondary (**10b**) pivalates. Apparently the primary lithium alkoxide formed in the ring cleavage undergoes extensive though incomplete acyl transfer.[4] Saponification of the **10a** + **10b** ester mixture followed by selective tosylation of the resulting diol gave the primary tosylate **3** (58% from isomannide **4**).

Although the separation of the 9:1 **10a** + **10b** mixture was cumbersome to achieve on a multigram scale, the mixture of their tosylates, **12a** + **12b**, could be easily separated by crystallization. Thus the ester alkoxide

(1) (a) Abstracted from the Doctoral thesis of C. Mazzini. (b) Supported by CNR and by Ministero della Ricerca Scientifica e Tecnologica.

(2) See for example: Vasella, A. In *Modern Synthetic Methods*: Sheffold, R. Ed., Otto Salle Verlag: Frankfurt a. M., D, 1980; p173 ff. Hanessian, S. *The Total Synthesis of Natural Products: the Chiron Approach*; Pergamon Press: Oxford, U.K., 1983.

(3) Cerè, V.; Paolucci, C.; Pollicino, S.; Sandri, E.; Fava, A. *Tetrahedron Lett.* **1989**, 6737.

(4) The 9:1 ratio of primary to secondary ester, **10a/10b**, is the equilibrium ratio. It can be achieved either by letting the reaction mixture stand at rt for 1–2 h before quenching, or by acid-catalyzed transesterification of the isolated ester mixture.

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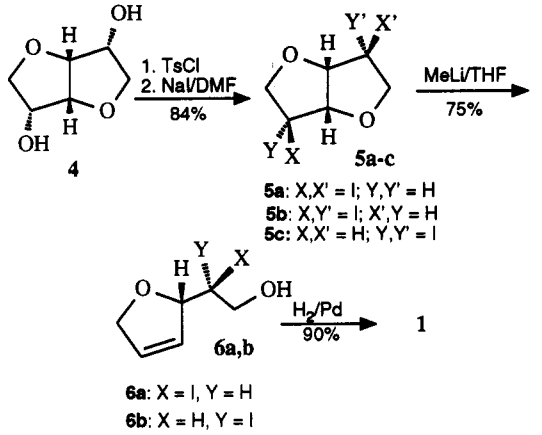
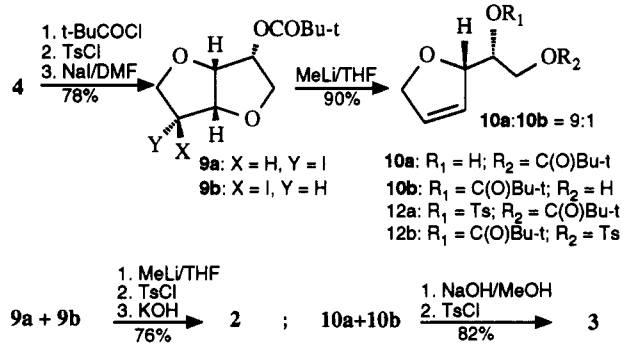
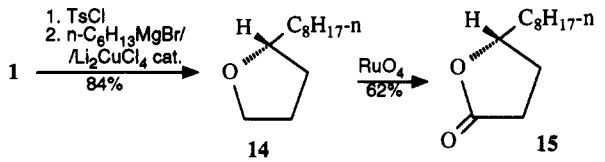
Scheme I



Scheme II



Scheme III

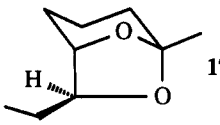


product arising from the eliminative ring cleavage was directly quenched with tosyl chloride to give a mixture from which the secondary tosylate (**12a**) was recovered in 84% yield by crystallization. Saponification of the ester function gave the epoxide **2** directly (60% from isomannide **4**).

Synthesis of *R*-(+)-4-Dodecanolide (15). This lactone is the principal component of the defensive secretion of *Bredius mandibularis* and *B. spectabolis*. The response of the insect to the *S* enantiomer and to the racemic mixture has not yet been precisely defined. Several syntheses have been reported of both enantiomers, none which employed chiral building blocks of natural origin.[5a,6] Our three-step synthesis from **1** is outlined in Scheme III. The tosylate of alcohol **1** was reacted with *n*-hexylmagnesium bromide in THF in the presence of a catalytic amount of lithium tetrachlorocuprate[7] to give 2-(*n*-octyl)tetrahydrofuran (**14**) which was then oxidized to the desired γ-lactone **15** with ruthenium tetroxide in CCl_4.[8] The moderate yield of the oxidation step (62%) reduces the overall yield to 52% (30% from isomannide). Attempts to improve the oxidation yield using $RuCl_3 \cdot xH_2O$ in $CCl_4/MeCN/H_2O$[9] led to over-oxidation and ring opening.

Synthesis of *endo*- and *exo*-Brevicomin. The (1*S*,5*R*,7*R*)-(−) form of *endo*-brevicomin is the enantiomer of the aggregating pheromone of the species *Dendroctonus frontalis* and *Dryocetes autographus*; unlike the natural pheromone it has antiaggregating activity. The (1*S*,5*R*,7*S*)-(−) form of *exo*-brevicomin is the enantiomer of the natural pheromone of the species *Dendroctonus brevicomis* and *Dryocetes confusus*. It is biologically inactive. The two brevicomin diastereomers have been the target of innumerable syntheses in both racemic and enantiomerically pure form. For the latter, sugars such as D-glucose and -ribose, as well as D- and L-tartaric acid and D-glyceraldehyde acetonide have been used as starting material. An account of the syntheses reported up to 1989 has been recently given.[5b] A few more syntheses have been published since.[10]

16: (1*S*,5*R*,7*R*)-(-)-*endo*-Brevicomin



17: (1*S*,5*R*,7*S*)-(-)-*exo*-Brevicomin

The brevicomin skeleton arises from intramolecular acetalization of 2-oxononane-6,7-diol. Since building blocks **2** and **3** are equivalent to hexane-2,3-diol (through the operation of hydrogenation-regiospecific ring cleavage),[11] they can be transformed into brevicomins by appropriate homologations at the two ends of the six-carbon chain.[12]

Our approach to *endo*-brevicomin (**16**) is outlined in Scheme IV. The side chain of **3** was first homologated to **18a** with dimethyllithium cuprate (probably proceeding *via* the epoxide intermediate). After hydrogenation of the double bond, the ring was cleaved with trimethylsilyl iodide in acetone yielding the iodide diol protected as the acetonide **20a**. This was homologated with 2-methyl-2-lithiodithiane to give **21a** whose carbonyl and diol functions were deprotected stepwise to facilitate the separation of the volatile final pheromone **16**. The low isolated yield of the last step is accounted for by the high volatility of the final product. The overall yield of 31% from **3** (18% from isomannide) would likely be considerably improved in larger scale preparations.

(5) (a) Mori, K. In *The Total Synthesis of Natural Products*; ApSimon, J., Ed.; J. Wiley & Sons: New York, 1992; Chapt. 15, pp 234–238. (b) *Ibid.* Chapt. 20, pp 407–424.

(6) For a few more recent syntheses see: (a) Gutman, A. L.; Zuobi, K.; Bravdo, T. *J. Org. Chem.* **1990**, *55*, 3546. (b) Ohkuma, T.; Kitamura, M.; Noyori, R. *Tetrahedron Lett.* **1990**, *31*, 5509. (c) Huffer, M.; Schreier, P. *Tetrahedron Asymmetry* **1991**, *2*, 1164. (d) Kobayashi, K.; Sasaki, A.; Kanno, Y.; Suginome, H. *Tetrahedron* **1991**, *47*, 7245. (e) Ebata, T.; Kawakami, H.; Koseki, K.; Matsushita, H. *Agric. Biol. Chem.* **1991**, *55*, 1685. (f) Kakeya, H.; Sakai, T.; Ohta, H. *Ibid.* **1991**, *55*, 1877.

(7) Fujiwhara, M.; Mori, K. *Agric. Biol. Chem.* **1986**, *50*, 2925.

(8) Smith, A. B., III; Scarborough, R. M., Jr. *Synth. Commun.* **1980**, *10*, 205.

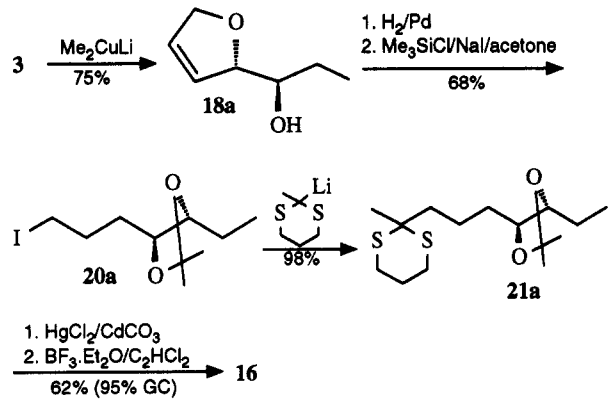
(9) Takeda, R.; Zask, A.; Nakanishi, K.; Park, M. H. *J. Am. Chem. Soc.* **1987**, *109*, 914.

(10) (a) Ibrahim, N.; Eggiman, T.; Dixon, E. A.; Wieser, H. *Tetrahedron* **1990**, *46*, 1503. (b) Padwa, A.; Frixell, G. E.; Zhi, L. *J. Am. Chem. Soc.* **1990**, *112*, 3100. (c) Vandermel, D.; Oehlschlager, A. C. *Ibid.* **1992**, *114*, 5081. (d) Mori, K.; Kiyota, H. *Liebigs Ann. Chem.* **1992**, 989. (e) Matsumoto, K.; Suzuki, N.; Otha, H. *Tetrahedron Lett.* **1990**, *31*, 7163. (f) Schulz, M.; Waldeman, H.; Vogt, W.; Kunz, H. *Ibid.* **1990**, *31*, 867. (g) Pedrocchi-Fantoni, G.; Servi, S. *J. Chem. Soc., Perkin Trans. 1* **1991**, 1784. (h) Bulman Page, D. C.; Rayner, C. M.; Sutherland, I. O. *Ibid.* **1990**, 1375.

(11) Amoroux, R.; Jatczak, M.; Chastrette, M. *Bull. Soc. Chim. Fr.* **1987**, 506.

(12) Jatczak, M.; Amoroux, R.; Chastrette, M. *Tetrahedron Lett.* **1985**, *26*, 2315.

Scheme IV



The synthesis of *exo*-brevicomin (17) was carried out along the same lines starting, however, from building block 2 (see Experimental Section). The overall yield from 2 was 30% (19% from isomannide 4).

Experimental Section

General. Melting points were obtained with a Buchi apparatus and are uncorrected. Yields represent isolated compounds. Proton and ^{13}C NMR spectra were recorded at 200 and 50 MHz, respectively, in $CDCl_3$ solvent. Chemical shifts are expressed in ppm downfield from TMS as internal standard. Signal multiplicities were established by DEPT experiments. *J* values are in hertz. Electron impact mass spectra were obtained with a VG 7070E instrument usually at 70 eV; signals' intensities are reported (in parentheses) as percentages of the most intense signal. Unless specified otherwise, optical rotations were measured in $CHCl_3$ on a Jasco 360 polarimeter. Preparative flash chromatographic separations were performed using ICN Silica Adsorbienten 32–63 60 A. Analytical thin-layer chromatography was performed on precoated glass plates (Stratocrom SIF_{254}, 0.25 mm thick). Solvents and reagents were obtained as follows: THF was distilled from benzophenone ketyl; MeCN, CH_2Cl_2, and DMF were distilled from CaH_2, pyridine from KOH, acetone from K_2CO_3, and Et_2O from $LiAlH_4$. Copper(I) iodide was purified by crystallization.[13] Chloroform used in the tosylation reactions was freed of ethanol by filtration over alumina. For best results, low-salt alkyllithiums were used in the reductive cleavage reactions. Erratic yields were observed in the presence of ionic halides. All reactions employing alkyllithium reagents were performed in freshly distilled THF in an argon athmosphere.

(1*R*,4*S*,5*R*,8*S*)-(+)-4,8-Diiodo-2,6-dioxabicyclo[3.3.0]-octane (5a). Dianhydromannitol (4) was reacted with tosyl chloride under standard conditions to give (96%) the ditosylate, mp 89–90 °C (lit.[14] 83 °C); $[\alpha]^{24}_D$ +98.8° (*c* 2.01), (lit.[14] +94.2° *c* 2.01, $CHCl_3$). The ditosylate (105 g, 0.23 mol) was reacted with NaI (280 g, 1.9 mol) in DMF (0.55 L) at 100 °C for 24 h under stirring. The mixture was poured over 1.5 L of saturated aqueous NaCl and repeatedly extracted with Et_2O. The organic extracts, dried over $CaSO_4$, were evaporated under reduced pressure, and the residue was dissolved in hot MeOH (250 mL), from which part of the product (59 g) was obtained by crystallization. The residue from evaporation of the mother liquor was purified by chromatography (hexane/AcOEt 90/10) to give an additional 16 g of diiodide product (88% overall). GC analysis showed the product to contain three components in *ca.* 4:5:1 ratio (somewhat variable with reaction time). A sample of this mixture was separated by flash chromatography using the above eluting solvent. The title compound, the second abundant component, was eluted second. White solid: mp 83–84 °C (from hexane); $[\alpha]^{28}_D$ +146.7° (*c* 3.22) (lit.[15] 86–87 °C, $[\alpha]^{20}_D$ +138° [*c* 1.0, $CHCl_3$]); ^1H NMR δ 4.28 (m, 6 H), 5.16 (m, 2 H); ^{13}C NMR 25.8 (d), 78.7 (t), 90.0 (d).

(1*R*,4*R*,5*R*,8*S*)-(+)-4,8-Diiodo-26-dioxabicyclo[3.3.0]-octane (5b) was the first eluted and more abundant component of the above mixture. White solid: mp 114–115 °C (from MeOH) (lit.[15] 116–118 °C); $[\alpha]^{28}_D$ +30.5° (*c* 2.45); (lit.[15] 116–118 °C, $[\alpha]^{28}_D$ +30° [*c* 1.0, $CHCl_3$]); ^1H NMR 3.78 (m, 1 H), 4.10 (m, 1 H), 4.24 (m, 3 H), 4.41 (m, 1 H), 4.85 (m, 1 H); ^{13}C NMR 21.4 (d), 26.5 (d), 76.4 (t), 77.9 (t), 82.6 (d), 89.4 (d).

(1*R*,4*R*,5*R*,8*R*)-(+)-4,8-Diiodo-2,6-dioxabicyclo[3.3.0]-octane (5c) was the last eluted and least abundant component of the above mixture. White solid: mp 112–113 °C (from hexane); $[\alpha]^{28}_D$ +151.9 (*c* 2.36); ^1H NMR 3.80 (m, 2 H), 4.20 (m, 2 H), 4.53 (m, 2 H); ^{13}C NMR: 23.4 (d), 76.4 (t), 81.5 (d).

(2*S*,1′*S*)-(−)-(1-Iodo-2-hydroxyethyl)-2,5-dihydrofuran (6a). To the unseparated diiodide mixture **5a–c** (36.6 g, 0.1 mol) dissolved in THF (1 L) was added MeLi at −78 °C (68 mL, 1.6 M in Et_2O, 109 mmol). After stirring for 30 min at −78 °C, the reaction mixture was quenched with aqueous HCl (20 mL, 6 M), extracted with ether, dried, and purified by flash chromatography (hexane/Et_2O 70/30) giving 18.0 g (75%) of a liquid 4:1 iodohydrin mixture **6a + 6b**. A small sample was further separated using the above eluting solvent. The first eluted and major component was the title compound, a liquid: bp 106 °C/0.3 mm, $[\alpha]^{28}_D$ −95.1° (*c* 2.81); ^1H NMR 3.1 (br s, 1 H), 3.90 (m, 2 H), 4.31 (ddd, *J* 6.4, 6.0, 2.6, 1 H), 4.70 (q, *J* 12, 2 H), 4.83 (m, 1 H), 5.92 (q, *J* 6, 2 H); ^{13}C NMR 41.7 (d), 66.2 (t), 76.8 (t), 86.7 (d), 128.1 (d), 129.0 (d).

(2*S*,1′*R*)-(−)-(1-Iodo-2-hydroxyethyl)-2,5-dihydrofuran (6b) was the second eluted and minor component of the above mixture; white solid: mp 75–76 °C (from hexane); $[\alpha]^{26.6}_D$ −117.1° (*c* 2.34); ^1H NMR 3.4 (br s, 1 H), 3.94 (d, *J* 5.7, 2 H), 4.10 (m, 1 H), 4.63 (m, 1 H), 4.79 (m, 1 H), 5.00 (m, 1 H), 6.07 (m, 2 H); ^{13}C NMR 39.1 (d), 66.9 (t), 76.4 (t), 89.1 (d), 128.6 (d), 129.0 (d).

(*S*)-(+)-2-(2-Hydroxyethyl)-2,5-tetrahydrofuran (1). The 4:1 mixture **6a + 6b** (4.8 g, 20 mmol) dissolved in MeOH (50 mL) and Et_3N (10 mL) was hydrogenated (2 atm; 10% Pd/C, 400 mg; 4 h), the reaction being monitored by ^1H NMR. The reaction mixture was poured in 100 mL of ether, neutralized with 2 N HCl, filtered, and concentrated under reduced pressure. After flash chromatography (Et_2O/MeOH 99/1) and distillation (67 °C/0.5 mm), 2.08 g (90%) were obtained of the title compound as a colorless liquid: $[\alpha]^{28.2}_D$ +4.6° (*c* 5.2). Since the procedure for obtaining 1 involved a catalytic hydrogenation, there may be some question about its enantiomeric purity. This was checked by comparing the ^1H and ^{13}C NMR spectra of its ester with Mosher's acid with those of the racemic mixture. Although no signal in the proton spectrum lent itself to accurate analysis, the ^{13}C spectrum showed no appreciable contamination (≤5%) from the other enantiomer. That 1 is essentially enantiomerically pure, however, can be gauged from the specific optical rotation of the final product (15) obtained from it: ^1H NMR 1.50 (m, 1 H), 1.7–2.1 (m, 5 H), 2.9 (br t, 1 H), 3.65–4.05 (m, 5 H); ^{13}C NMR 25.4 (t), 31.5 (t), 37.5 (t), 61.1 (t), 67.8 (t), 78.6 (d); EIMS *m/e* 115 (M − 1) (1), 98 (5), 88 (15), 71 (100), 57 (6), 43 (42).

(1*R*,4*R*,5*R*,8*R*)-(+)-2,6-Dioxa-4-hydroxy-8-*O*-pivaloylbicyclo[3.3.0]octane (7). To a solution of 4 (73.0 g, 0.5 mol) in CH_2Cl_2 (0.8 L) and Et_3N (0.2 L) at 0 °C was added pivaloyl chloride (65 mL, 0.515 mol, dissolved in 0.5 L of CH_2Cl_2) dropwise over a period of 3 h. The cold bath was removed and after 2 h the reaction was quenched with H_2O (200 mL) and extracted with CH_2Cl_2. The organic phase was, in succession, washed with aqueous 6 M HCl, saturated aqueous $NaHCO_3$, and brine, dried over $MgSO_4$, and evaporated under reduced pressure. The crude was distilled (147 °C/1 mm) to give 110 g (95%) of a liquid containing (GC) <5% diester. For characterization, a sample was purified by flash chromatography (hexane/Et_2O 50/50) and distilled to a colorless liquid: bp 137 °C/1 mm; $[\alpha]^{29.4}_D$ +116.1° (*c* 2.26); ^1H NMR 1.25 (s, 9 H), 2.70 (d, *J* 9.5, 1 H), 3.55 (m, 1 H), 3.87–4.16 (m, 3 H), 4.30 (m, 1 H), 4.45 and 4.75 (t's, *J* 5.0, 1 H each), 5.15 (m, 1 H); ^{13}C NMR 27.2 (q), 38.9 (s), 71.6 (t), 72.5 (d), 74.0 (t), 74.1 (d), 80.8 (d), 82.0 (d), 178.2 (s); EIMS 231 (M + 1) (1), 215 (1), 128 (38), 85 (31) 69 (75), 57 (100), 41 (2).

(1*R*,4*R*,5*R*,8*R*)-(+)-2,6-Dioxa-4-*O*-(*p*-tolylsulfonyl)-8-*O*-pivaloylbicyclo[3.3.0]octane (8). To the crude monopivalate 7 (96 g, 0.4 mol) dissolved in pyridine (0.4 L) was added solid TsCl (115 g, 0.6 mol) portionwise at 0 °C. The reaction mixture was allowed to stand at 5 °C for 24 h and then poured on 2 L of

(13) Kauffman, G. B.; Teter, L. A. *Inorg. Synth.* **1963**, *7*, 9.
(14) Bakos, J.; Meil, L.; Marko, J. *J. Organomet. Chem.* **1983**, *253*, 249.
(15) Kussmann, J.; Medgyes, G. *Carbohydr. Res.* **1978**, *64*, 135.

H_2O and ice. Light petroleum ether was added (200 mL) (to solubilize the diester present in the crude starting material), stirred for 2 h, and filtered. The solid was repeatedly washed with H_2O and crystallized (EtOH) to give 150 g (97% with respect to the monopivalate) of a white solid: mp 75–76 °C; $[\alpha]^{29.4}_D$ + 122.4° (*c* 1.94); ^{1}H NMR 1.15 (s, 9 H), 2.45 (s, 3 H), 3.68 (t, *J* 8.8, 1 H), 3.90 (m, 3 H), 4.42 (t, *J* 5.1, 1 H), 4.69 (dd, *J* 5.8, 5.1, 1 H), 4.78 (m, 1 H), 5.03 (q, *J* 5.9, 1 H), 7.45 and 7.85 (d's, *J* 8, 2 H each); ^{13}C NMR 21.6 (q), 27.2 (q), 38.8 (s), 69.6 (t), 71.6 (t), 73.6 (d), 77.9 (d), 80.2 (d), 80.6 (d), 128.4 (d), 130.2 (d), 133.8 (s), 145.5 (s), 178.3 (s); HREIMS 384.12405 (M) (calcd for $C_{18}H_{24}O_7S$, 384.12428), fragmentation 385 (M + 1) (20), 384 (10), 369 (60), 282 (100), 229 (31), 155 (50), 127 (42), 110 (65), 91 (39), 85 (16), 69 (33), 57 (51).

(1*R*,4*R*,5*R*,8*R*)-(+)-2,6-Dioxa-4-iodo-8-*O*-pivaloylbicyclo-[3.3.0]octane (9a). The monotosylate monopivalate 8 (115 g, 0.3 mol) was reacted with NaI (180 g, 1.2 mol) in DMF (0.3 L) as described above for the preparation of **5a–c**. The crude was distilled (170–185 °C/2 mm) to give 91 g (89%) of a liquid mixture of two epimers in a ≃1.8:1 ratio. For characterization a sample was separated by flash chromatography (hexane/Et_2O 70/30). The minor, second eluted component, was the title compound: white solid, mp 85–86 °C; $[\alpha]^{20}_D$ 154.6° (*c* 3.0); ^{1}H NMR 1.25 (s, 9 H), 3.75 (dd, *J* 11, 7.5, 1 H), 3.95–4.18 (m, 4 H), 4.45 (t, *J* 5, 1 H), 4.80 (t, *J* 5.5, 1 H), 5.20 (m, 1 H); ^{13}C NMR: 21.0 (d), 27.2 (q), 38.8 (s), 71.5 (t), 74.4 (d), 75.4 (t), 80.0 (d), 82.8 (d), 178.3 (s); EIMS 341 (M + 1) (2), 238 (100), 157 (24), 111 (15), 99 (16).

(1*R*,4*S*,5*R*,8*R*)-(+)-2,6-Dioxa-4-iodo-8-*O*-pivaloylbicyclo-[3.3.0]octane (9b). The major, first eluted component was obtained as a light brown liquid: bp 152 °C/1 mm; $[\alpha]^{20.5}_D$ +96.6° (*c* 3.96); ^{1}H NMR 1.15 (s, 9 H), 3.85 (m, 2 H), 4.10 (m, 2 H), 4.25 (m, 1 H), 4.75 (m, 1 H), 4.95 (m, 1 H), 5.10 (m, 1 H); ^{13}C NMR 25.8 (d), 27.1 (q), 38.7 (s), 71.6 (t), 73.7 (d), 77.4 (t), 80.6 (d), 91.1 (d), 178.1 (s); EIMS 341 (M + 1) (3), 325 (1), 255 (5), 238 (100), 157 (53), 111 (74), 85 (68), 69 (89), 57 (29), 41 (74).

(2*S*,1′*R*)-(−)-2-(1-Hydroxy-2-*O*-pivaloylethyl)-2,5-dihydrofuran (10a). The mixture of iodo pivalate epimers **9a,b** (17.0 g, 50 mmol) dissolved in THF (0.5 L) was reacted at −78 °C with MeLi (34 mL 1.6 M in Et_2O, 54 mmol), warmed to rt to reach equilibrium and, after 2 h, worked up as described for the preparation of **6a,b**. The crude was distilled (115–122 °C/1 mm) to give 9.7 g (90%) of a slightly yellow liquid mixture of the primary and secondary esters **10a/10b** in a 9/1 ratio. For characterization a sample was separated by flash chromatography (hexane/Et_2O 70/30). The major, first eluted component was the title compound, a liquid: bp 121 °C/1 mm); $[\alpha]^{22.2}_D$ −84.9° (*c* 4.22); ^{1}H NMR 1.25 (s, 9 H), 3.15 (br s, 1 H), 3.83 (m, 1 H), 4.20 (m, 2 H), 4.68 (m, 2 H), 4.85, (m, 1 H), 5.98 (m, 2 H); ^{13}C NMR 27.0 (q), 38.7 (s), 65.5 (t), 72.4 (t), 76.2 (d), 86.8 (d), 126.4 (d), 128.6 (d), 178.8 (s).

(2*S*,1′*R*)-(−)-2-(2-Hydroxy-1-*O*-pivaloylethyl)-2,5-dihydrofuran (10b) was the minor, second eluted component, a liquid: bp 130 °C/1 mm; $[\alpha]^{22.4}_D$ −84.1° (*c* 2.62); ^{1}H NMR: 1.25 (s, 9 H), 3.04 (br s, 1 H), 3.80 (m, 2 H), 4.67 (m, 2 H), 4.85 (m, 1 H), 5.02 (m, 1 H), 5.85 (m, 1 H), 6.05 (m, 1 H); ^{13}C NMR 27.0 (q), 38.8 (s), 62.0, 75.8 (t's), 76.2, 85.6, 126.4, 128.5 (d's), 178.6 (s).

(2*S*,1′*R*)-(−)-2-(1,2-Dihydroxyethyl)-2,5-dihydrofuran (11). The **10a/10b** ester mixture (21.5 g, 0.1 mol) dissolved in CH_2Cl_2 (50 mL) was added at 0 °C with a MeONa solution (prepared from 5 g of Na in 50 mL of MeOH) and stirred for 4 h at rt (TLC monitoring). The reaction mixture was quenched with 2 mL of H_2O, filtered over $MgSO_4$, concentrated under reduced pressure, and distilled to give 11.7 g (90%) of a colorless liquid: bp 130 °C/1 mm; $[\alpha]^{34}_D$ −139.3° (*c* 4.23); ^{1}H NMR 3.50 (m, 3 H), 4.4–4.7 (m, 5 H), 5.80 (m, 2 H); ^{13}C NMR 63.2 (t), 74.3 (d), 75.5 (t), 86.9, 126.9 (d), 127.9 (d). For better characterization a sample of the diol was converted to the acetonide (dimethoxypropane, PTSA) to give **(4*R*,2′*S*)-(−)-4-(2,5-Dihydrofuran-2-yl)-2,2-dimethyldioxolane (11a)**, a liquid: bp 82–83 °C/3 mm, $[\alpha]^{24.6}_D$ −119.9° (*c* 5.38); ^{1}H NMR 1.26 (s, 3 H), 1.45 (s, 3 H), 3.78–4.05 (m, 3 H), 4.58 (m, 2 H), 4.65 (m, 1 H), 5.85 (m, 1 H), 5.90 (m, 1 H); ^{13}C NMR 25.4 (q), 26.7 (q), 66.9 (t), 75.9 (t), 78.4 (d), 87.0 (d), 109.5 (s), 127.5 (d), 128.2 (d); EIMS 155 (M − CH_3) (16), 101 (100), 95 (25), 73 (86), 69 (45), 43 (44).

(2*S*,1′*R*)-(−)-2-[1-Hydroxy-2-*O*-(*p*-tolylsulfonyl)ethyl]-2,5-dihydrofuran (3). To the diol 11 (6.5 g, 50 mmol) dissolved in $CHCl_3$ (50 mL) and pyridine (8.2 mL, 100 mmol) was added TsCl (11.4 g, 60 mmol) and stirred at 0 °C for 3 h (TLC monitoring). After quenching with ice (≃10 mL), the mixture was poured into Et_2O (100 mL) and ice (≃30 mL) and stirred for 2 h. The organic phase was washed in succession with 2 × 10 mL of 2 N HCl saturated aqueous $NaHCO_3$, and brine, dried over $MgSO_4$, and filtered. After solvent evaporation under reduced pressure, the crude was flash chromatographed (hexane/Et_2O 50/50) and crystallized (hexane) as a white solid (12.8 g, 90%): mp 47–48 °C, $[\alpha]^{28.2}_D$ −44.8° (*c* 5.06); ^{1}H NMR 2.43 (s, 3 H), 3.25 (br s, 1 H), 3.80 (m, 1 H), 4.03 (m, 1 H), 4.18 (m, 1 H), 4.55 (m, 2 H), 4.92 (m, 1 H), 5.83 (m, 1 H), 5.95 (m, 1 H), 7.35 (d, 2 H), 7.75 (d, 2 H); ^{13}C NMR 21.4 (q), 71.3 (t), 71.8 (d), 75.6 (t), 86.1 (d), 125.9 (d), 127.8 (d), 128.6 (d), 129.8 (d), 132.5 (s), 144.9 (s); EIMS 285 (M + 1) (5), 241 (6), 215 (9), 173 (63), 155 (53), 91 (79), 69 (100), 41 (35).

(2*S*,1′*R*)-(−)-2-[1-*O*-(*p*-Tolylsulfonyl)-2-*O*-pivaloylethyl]-2,5-dihydrofuran (12a). The product arising from the reaction of the iodo pivalates **9a + 9b** (17.0 g, 50 mmol) with MeLi (34 mL of 1.6 M in Et_2O, 54 mmol) in THF (0.5 L) at −78 °C was allowed to warm to rt and stirred for 2 h before reacting it with TsCl (14.3 g, 75 mmol). After 4 h at 0 °C the mixture was quenched with HCl (10 mL, 6 N), concentrated under reduced pressure, taken up with CH_2Cl_2 (750 mL), washed in succession with saturated aqueous $NaHSO_3$ and 2 × 20 mL H_2O, dried over $MgSO_4$, and evaporated. The crude was crystallized (MeOH) to give 15.5 g (84%) of a white solid: mp 89–90 °C, $[\alpha]^{36.6}_D$ −43.5° (*c* 2.34); ^{1}H NMR 1.20 (s, 9 H), 2.48 (s, 3 H), 4.18 (m, 1 H), 4.30–4.65 (m, 3 H), 4.82 (m, 1 H), 4.96 (m, 1 H), 5.78 (m, 1 H), 6.02 (m, 1 H), 7.35 (d, 2 H), 7.85 (d, 2 H); ^{13}C NMR 21.6 (q), 27.1 (q), 38.9 (s), 62.5 (t), 76.1 (t), 81.0 (d), 84.9 (d), 125.2 (d), 128.1 (d), 129.8 (d), 130.1 (d), 134.8 (s), 145.1 (s), 178.6 (s). (No trace was detectable either in the NMR spectra or in GC of the regioisomer, **12b**). EIMS: 369 (M + 1) (3), 299 (11), 257 (13), 155 (49), 91 (41), 85 (23), 69 (100), 57 (76), 41 (21).

(2*S*,1′*R*)-(−)-2-[1-*O*-Pivaloyl-2-*O*-(*p*-tolylsulfonyl)ethyl]-2,5-dihydrofuran (12b). The mother liquor from crystallization of **12a**, evaporated and purified by flash chromatography, gave 1.5 g (8%) of a nondistillable slightly yellow oil: $[\alpha]^{27.8}_D$ −31.1° (*c* 1.20); ^{1}H NMR 1.15 (s, 9 H), 2.44 (s, 3 H), 4.23 (m, 2 H), 4.58 (m, 2 H), 4.93 (m, 2 H), 44.58 (m, 2 H), 4.93 (m, 2 H), 5.74 (m, 1 H), 5.99 (m, 1 H), 7.34 and 7.76 (d's, 2 H each); ^{13}C NMR 21.4 (q), 26.9 (q), 38.8 (s), 68.0 (t), 72.7 (d), 75.9 (t), 84.4 (d), 125.9 (d), 128.1 (d), 129.2 (d), 130.1 (d), 133.3 (s), 145.2 (s), 177.7 (s); EIMS 327 (3), 227 (11), 215 (26), 155 (49), 91 (43), 69 (100), 41 (8).

(2*S*,2′*S*)-(−)-2-[2-(2,5-Dihydrofuranyl)]oxirane (2). To a solution of **12a** (11.1 g, 30 mmol) dissolved in MeOH/CH_2Cl_2 1/1 v/v (30 mL) was added solid KOH (2.8 g, 45 mmol) and stirred for 1 h at 0 °C and for 4 h more at rt (TLC monitoring). The mixture was then poured into Et_2O, filtered on Celite, and evaporated under reduced pressure (without heating). After purification by flash chromatography (hexane/Et_2O 70/30), a liquid (3.03 g, 90%) was obtained by distillation: bp 77 °C/16 mm; $[\alpha]^{29.4}_D$ −152.6° (*c* 2.56). The same material was obtained from iodohydrin **6b** by treatment with methanolic KOH: ^{1}H NMR 2.70 (m, 2 H), 2.95 (m, 1 H), 4.65 (m, 3 H), 5.75 (m, 1 H), 6.05 (m, 1 H); ^{13}C NMR 43.7 (t), 53.2 (d), 76.1 (t), 86.2 (d), 125.7 (d), 129.6 (d); EIMS 111 (M − 1) (17), 81 (61), 69 (100), 41 (56).

(*S*)-(+)-2-[2-*O*-(*p*-Tolylsulfonyl)ethyl]tetrahydrofuran (13). Tosylation of 1 (5.8 g, 50 mmol) was carried out as described for **3** above. The crude was flash chromatographed (hexane/Et_2O 70/30) to give 13.4 g (95%) of a clear, undistillable oil: $[\alpha]^{28.2}_D$ +14.9° (*c* 2.68); ^{1}H NMR 1.35 (m, 1 H), 1.80 (m, 5 H), 2.38 (s, 3 H), 3.52–3.84 (m, 3 H), 4.06 (t, 7.5, 2 H), 7.28 and 7.73 (d's, 2 H each); ^{13}C NMR 21.9 (q), 25.5 (t), 31.3 (t), 34.8 (t), 67.7 (t), 68.4 (t), 75.3 (d), 128.1 (d), 130.1 (d), 133.5 (s), 145.0 (s); EIMS 227 (3), 172 (6), 98 (66), 91 (31) 71 (100), 43 (24).

(*R*)-(−)-2-Octyltetrahydrofuran (14). The tosylate **13** (2.82 g, 10 mmol) dissolved in THF (10 mL) was reacted at −65 °C with *n*-hexylmagnesium bromide (70 mL of 1 M in THF, 60 mmol) in the presence of Li_2CuCl_4[7] (3.5 mL 0.1 M, in THF). The mixture was allowed to stand at rt for 12 h and then quenched at 0 °C with saturated aqueous NH_4Cl (20 mL). Ethyl ether was added (200 mL) and stirred for 2 h. The aqueous phase was extracted with 2 × 200 mL of Et_2O, the combined organic phases were washed successively with 2 × 10 mL saturated aqueous NH_4Cl and brine and dried over $MgSO_4$, and the solvent was removed under reduced pressure. After flash chromatography (hexane/

Et_2O, 98/2) the crude was distilled: bp 76 °C/14 mm; $[\alpha]^{22.6}_D$ −4.4° (c 3.44); ^1H NMR 0.86 (m, 3 H), 1.2–1.7 (m, 15 H), 1.90 (m, 3 H), 3.78 (m, 3 H); ^{13}C NMR 14.1 (q), 22.7, 25.8, 26.5, 29.3, 31.5, 32.0, 35.9, 67.8 (t's), 79.7 (d); EIMS 185 (M + 1) (3), 183 (6), 166 (16) 71 (100), 43 (2).

(*R*)-(+)-4-Dodecanolide (15). To a solution of RuO_4 in CCl_4 (15 mL), prepared from 200 mg $RuO_2 \cdot xH_2O$ according to the procedure of Smith and Scarborough,[8] 0.37 g (2 mmol) of 14 was added at 0 °C and allowed to stand at rt for 4 h. Four more portions of freshly prepared oxidant were added at 4-h intervals until reaction completion (24 h, GC monitoring). The mixture was filtered and dried over $MgSO_4$, evaporated under reduced pressure, and flash chromatographed (hexane/Et_2O 65/35) to give 0.24 g (62%) of a clear oil: $[\alpha]^{28.6}_D$ +25.7° (c 1.90, $CHCl_3$), $[\alpha]^{24.4}_D$ +39.1 (c 0.56, MeOH). Values of $[\alpha]_D$ in MeOH are reported in the literature ranging from 32.7° to 41.1°.[5a,6] Proton and ^{13}C NMR and IR spectra coincided with those reported in the literature.[6a]

(2*S*,1′*R*)-(−)-2-(1-Hydroxypropyl)-2,5-dihydrofuran (18a). Building block 3 (2.84 g, 10 mmol) in Et_2O (20 mL) was added dropwise to a solution of lithium dimethylcuprate[16] (70 mL 0.29 M, in Et_2O) cooled at −70 °C. After 1 h the temperature was raised to −30 °C and maintained at this value for 3 h (GC monitoring). Quenching was effected by slow addition of saturated aqueous NH_4Cl (10 mL). After extraction with Et_2O/aqueous NH_4Cl, washing, drying, and solvent evaporation, the crude was purified by flash chromatography (hexane/Et_2O 70/30) and distilled to give 0.96 g (75%) of a liquid: bp 82 °C/15 mm; $[\alpha]^{29.0}_D$ −154.5° (c 3.25); ^1H NMR 1.00 (t, J 7.5, 3 H), 1.48 (m, 2 H), 2.25 (br s, 1 H), 3.59 (m, 1 H), 4.67 (m, 2 H), 4.78 (m, 1 H), 5.80 (m, 1 H), 6.01 (m, 1 H); ^{13}C NMR: 10.4 (q), 25.7 (t), 75.2 (t), 75.9 (d), 89.8 (d), 126.2 (d), 129.0 (d); EIMS 97 (30), 84 (61), 69 (100), 59 (91), 57 (45), 41 (52), 31 (80).

(2*S*,1′*S*)-(−)-2-(1-Hydroxypropyl)-2,5-dihydrofuran (18b) was obtained (79%) from epoxide 2 and lithium dimethylcuprate, as described for 18a above. Colorless liquid: bp 88 °C/11 mm, $[\alpha]^{30.6}_D$ −137.1° (c 2.18); ^1H NMR 1.02 (t, J 7.5, 3 H), 1.55 (m, 2 H), 2.01 (br s, 1 H), 3.45 (m, 1 H), 4.68 (m, 3 H), 5.78 and 6.02 (m's, 1 H each); ^{13}C NMR 10.1 (q), 26.3 (t), 75.4 (d), 75.6 (t), 89.5 (d), 127.2 (d), 128.8 (d); EIMS 129 (M + 1) (1), 111 (3), 99 (4), 69 (100), 59 (45), 41 (58).

(2*S*,1′*R*)-(−)-2-(1-Hydroxypropyl)tetrahydrofuran (19a). The dihydrofuran 18a (6.40 g, 50 mmol) in Et_2O (50 mL) was hydrogenated (1.5 atm, 10% Pd/C, 4 h) and, after filtration, solvent evaporation, and flash chromatography (hexane/Et_2O 75/25), the crude was distilled, bp 90 °C/18 mm, to give 5.95 g (90%) of a liquid: $[\alpha]^{36.2}_D$ −18.3° (c 1.50); ^1H NMR 0.91 (t, J 7.5, 3 H), 1.39 (m, 2 H), 1.80 (m, 4 H), 2.15 (br s, 1 H), 3.72 (m, 4 H); ^{13}C NMR 10.3 (q), 24.6 (t), 25.9 (t), 26.2 (t), 68.6 (t), 73.7 (d), 82.2 (d).

(2*S*,1′*S*)-(−)-2-(1-Hydroxypropyl)tetrahydrofuran (19b) was obtained, as described for 19a above, from 18b: bp 95 °C/25 mm; $[\alpha]^{26.2}_D$ −7.3° (c 2.32); ^1H NMR 1.00 (t, 7.5, 3 H), 1.4–1.7 (m, 3 H), 1.95 (m, 3 H), 2.50 (br s, 1 H), 3.36 (m, 1 H), 3.81 (m, 3 H); ^{13}C NMR 9.8 (q), 26.2 (t), 26.7 (t), 27.9 (t), 68.1 (t), 73.5 (d), 82.3 (d).

(4*R*,5*S*)-(−)-4-Ethyl-5-(3-iodopropyl)-2,2-dimethyldioxolane (20a) was prepared according to the procedure reported for the racemic mixture.[12] Oven-dried NaI (1.65 g, 11 mmol) in acetone (15 mL) was added with, sequentially, Me_3SiCl (1.4 mL, 11 mmol) and, *via* syringe, tetrahydrofuran 19a (1.3 g, 10 mmol). The mixture was first stirred at rt for 2 h, hence at reflux for 2 h more. Once cooled, the mixture was poured into Et_2O (50 mL) and filtered on Celite. After solvent evaporation and flash chromatography (hexane/Et_2O 95/5), the crude was distilled to a liquid: 2.26 g (76%), bp 112 °C/1.5 mm; $[\alpha]^{37.8}_D$ −19.1° (c 2.30); ^1H NMR 0.99 (t, J 7.5, 3 H), 1.35 (s, 3 H), 1.45 (s, 3 H), 1.53 (m, 4 H), 1.95 (m, 2 H), 3.26 (t, J 6.5, 2 H), 4.01 (m, 2 H); ^{13}C NMR: 6.8 (t), 10.6 (q), 22.7 (t), 26.0 (q), 28.6 (q), 30.2 (t), 30.7 (t), 77.1 (d), 79.7 (d), 107.9 (s).

(4*S*,5*S*)-(−)-4-Ethyl-5-(3-iodopropyl)-2,2-dimethyldioxolane (20b) was obtained, as described for 20a above, from 19b: bp 110 °C/2 mm; $[\alpha]^{30.6}_D$ −23.6° (c 2.00); ^1H NMR 1.00 (t, J 7.5, 3 H), 1.37 (s, 6 H), 1.60 (m, 4 H), 2.00 (m, 2 H), 3.23 (t, J 6.3, 2 H), 3.58 (m, 2 H); ^{13}C NMR 6.2 (t), 10.0 (q), 25.9 (t), 24.7 (2 signals, q's) 30.3 (t), 34.0 (t), 80.0 (d), 82.4 (d), 108.4 (s).

(4*R*,5*S*)-(−)-4-Ethyl-2,2-dimethyl-5-[3-(2-methyl-1,3-dithian-2-yl)propyl]-1,3-dioxolane (21a). To a solution of 2-methyl-2-lithiodithiane[17] [prepared from 2-methyldithiane (5.36 g, 40 mmol) in THF (200 mL) and BuLi (27 mL 1.6 M in hexane, 43 mmol)] cooled at −65 °C was added the iodide 20a (5.96 g, 20 mmol) *via* syringe. The mixture was stirred for 2 h at −60 °C and quenched with H_2O (30 mL) at this temperature. The solvent was evaporated and the residue taken up with Et_2O (200 mL), washed (2 × 15 mL of H_2O, brine), dried over $MgSO_4$, filtered, evaporated, and flash chromatographed (hexane/Et_2O 90/10) to give 6.02 g (98%) of a liquid: bp 130 °C/10^{-3} mm, $[\alpha]^{36.0}_D$ −6.7° (c 1.56); ^1H NMR 0.99 (t, J 7.5, 3 H), 1.34, 1.43, and 1.63 (s's, 3 H each), 1.5 (m, 6 H), 1.96 (m, 4 H), 2.85 (m, 4 H), 4.00 (m, 2 H); ^{13}C NMR 10.6 (q), 21.5, 22.8, and 25.4 (t's), 26.0 (q), 26.6 (2 signals, t's), 27.8 (q), 28.6 (q), 29.9 (t), 41.8 (t), 49.3 (s), 78.0 (d) 79.7 (d), 107.6 (s); HREIMS 304.15307 calcd for $C_{15}H_{28}O_2S_2$ 304.15209, fragmentation 304 (87), 289 (48), 229 (22), 171 (14), 133 (100), 43 (27).

(4*S*,5*S*)-(−)-4-Ethyl-2,2-dimethyl-5-[3-[2-methyl-1,3-dithian-2-yl]propyl]-1,3-dioxolane (21b) was obtained, as described for 21a above, from 20b: bp 180 °C/0.4 mm, $[\alpha]^{29.4}_D$ −22.5° (c 2.34); ^1H NMR 0.99 (t, J 7.5, 3 H), 1.34 (s, 6 H), 1.56 (m, 6 H), 1.62 (s, 3 H), 1.96 (m, 4 H), 2.85 (m, 4 H), 3.60 (m, 2 H); ^{13}C NMR 10.2 (q), 21.3 (t), 25.3 (t), 25.8 (t), 26.5 × 2 (t's), 27.3 (q), 27.4 (q), 27.8 (q), 33.2 (t), 41.8 (t), 49.2 (s), 80.6 (d), 82.3 (d), 108.0 (s); HREIMS found 304.15297, calcd for $C_{15}H_{28}O_2S_2$ 304.15308; fragmentation 304 (M) (100), 289 (72), 229 (50), 139 (40), 133 (75).

(4′*R*,5′*S*)-5-(5-Ethyl-2,2-dimethyldioxolan-4-yl)pentan-2-one (22a). For hydrolyzing the dithioacetal functionality while preserving the acetal, the procedure of Corey and Erickson[18] was applied to 4.56 g (15 mmol) of 21. After workup and flash chromatography (hexane/Et_2O 70/30), the crude was distilled to give 3.05 g (95%) of a liquid: bp 122 °C/2 mm; $[\alpha]^{32.6}_D$ −3.1° (c 3.30). The ^1H NMR and IR spectra coincided with those previously reported for the racemic mixture.[12] ^{13}C NMR: 10.5 (q), 20.6 (t), 22.7 (t), 25.9 (q), 28.6 (q), 29.0 (t), 28.9 (q), 43.4 (t), 77.8 (d), 79.7 (d), 107.6 (s), 209.0 (s).

(4′*S*,5′*S*)-5-(5-Ethyl-2,2-dimethyldioxolan-4-yl)pentan-2-one (22b) was obtained, as described for 22a above, from 21b: bp 115 °C/2 mm; $[\alpha]^{26.9}_D$ −20.6° (c 1.46). The ^1H NMR and IR spectra coincided with those previously reported for the racemic mixture.[12] ^{13}C NMR: 10.2 (q), 20.5 (t), 25.7 (t), 23.7 (2 signals, q's), 29.9 (q), 32.3 (t), 43.5 (t), 80.5 (d), 82.2 (d), 108.1 (s), 209.0 (s).

(1*S*,5*R*,7*R*)-*endo*-Brevicomin (16a). The acetonide of keto diol 22 was deprotected and cyclized with $BF_3 \cdot Et_2O$ in CH_2Cl_2.[19] From 2.14 g of 22, 1.01 g (65%) of *endo*-brevicomin was obtained after distillation: bp 183 °C/760 mm (lit. 96 °C/77 mm)[15] $[\alpha]^{34.2}_D$ −81.2° (c 2.54), $[\alpha]_D^{23}$ −82.1° (c 1.60, Et_2O). Values of $[\alpha]_D$ in Et_2O are reported in the literature ranging from −67.5° to −93.1°.[5b,10] The ^1H NMR and ^{13}C NMR spectra coincided with those previously reported.[10b]

(1*S*,5*R*,7*S*)-*exo*-Brevicomin (17) was obtained, as described for the endo isomer, from 22b; bp 158 °C/760 mm (lit. 150 °C/760 [kugelrohr]);[20] $[\alpha]_D^{28.4}$ −66.6° (c 0.96). Values of $[\alpha]_D$ in $CHCl_3$ are recorded in the literature ranging from −60.3 to −72.0°.[5b,10] Proton and ^{13}C NMR spectra coincided with those of the literature.[10b]

Supplementary Material Available: Analytical data for new compounds (2 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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