18 (99%), which was used without further purification: ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.31 (m, 10 H), 6.86 (s, 1 H), 4.61 (AB quartet, J = 11.7 Hz, $\delta\nu$ = 32.8 Hz, 4 H), 4.24 (s, 1 H), 4.11 (s, 1 H), 3.60 (t, J = 8.8 Hz, 1 H), 3.32 (m, 2 H), 2.22 (s, 3 H), 1.98 (m, 2 H), 1.11–1.35 (m, 4 H), 0.88 (s, 9 H), 0.15 (s, 6 H).

The above diene was dissolved in ca. 2 mL of deuteriochloroform and treated with 0.336 g of freshly distilled acetaldehyde (7.62 mmol) and 0.263 g of Eu(fod)$_3$. The mixture was allowed to stand at room temperature for 36 h, at which time it was concentrated in vacuo and purified by silica gel chromatography (1:9 ether/hexane) to obtain 0.780 g of the oily pyran **26** (51% from **17**) as well as 0.362 g of recovered **17** (32%). Compound **26**: ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.30 (m, 10 H), 5.80 (t, J = 2.1 Hz, 1 H), 4.73 (AB quartet, J = 11.8 Hz, $\Delta\nu$ = 48.6 Hz, 2 H) 4.64 (AB quartet, J = 11.9 Hz, $\Delta\nu$ = 31.8 Hz, 2 H), 3.86 (m, 1 H), 3.71 (t, J = 8.3 Hz, 1 H), 3.37 (m, 2 H), 2.24 (m, 1 H), 2.00 (s, 3 H), 1.98 (m, 2 H), 1.64 (m, 3 H), 1.28 (m, 2 H), 1.10 (d, J = 6.2 Hz, 3 H), 0.89 (s, 9 H), 0.13 (s, 6 H); IR ($CDCl_3$) 2950, 2800, 1720, 1590, 1420, 1180, 1020 cm^{-1}; MS (20 eV), m/e 596 (M^+, 1%), 537 (12.8%). Anal. Calcd for $C_{34}H_{48}O_7Si$: C, 68.42; H, 8.11; Si, 4.71. Found: C, 68.58; H, 8.44; Si, 4.51. A peak is assigned to the anomeric diastereomer at δ 6.62, which integrated to ca. 6% of the corresponding proton in the major isomer.

Preparation of (2α,4aβ,5aβ,9α,9aα,10aβ)-4a,9-Dihyroxy-2-methyldecahydro-4*H*-pyrano[2,3-*b*][1,4]benzodioxin (27). To a vigorously stirred solution of 61 mg of *m*-chloroperoxybenzoic acid (0.30 mmol) in 2 mL of CH_2Cl_2 was added at room temperature 3 mL of saturated $NaHCO_3$, followed by a solution of 147 mg of **26** (0.25 mmol) in 1 mL of CH_2Cl_2. The resulting biphasic system was vigorously stirred for 10 h, at which time an additional portion of *m*-chloroperoxybenzoic acid (20 mg, 0.10 mmol) was added. After stirring an additional 6 h, the reaction mixture was diluted with 10 mL of CH_2Cl_2. The organic layer was separated and washed successively with 1 × 2 mL of saturated sodium bisulfite, 1 × 2 mL of saturated $NaHCO_3$, and 1 × 2 mL of brine. The reaction mixture was dried (Na_2SO_4) and concentrated in vacuo to afford an unstable oil which was used without further publication: ^{1}H NMR (250 MHz, $CDCl_3$) δ 7.32 (m, 10 H), 5.45 (s, 1 H), 4.48–4.93 (m, 4 H), 3.98 (m, 1 H), 3.75 (t, J = 8.8 Hz, 1 H), 3.44 (m, 2 H), 2.55 (dd, J = 14.0, 2.0 Hz, 1 H), 1.90–2.10 (m, 3 H), 1.72 (s, 3 H), 1.16–1.25 (m, 4 H), 0.85 (s, 9 H), 0.18 (s, 3 H), 0.17 s, 3 H); IR ($CDCl_3$) 2940, 2850, 1770, 1750, 1450, 1380, 1250, 1090 cm^{-1}.

To a solution of the above material in 5 mL of ethyl acetate was added a spatula tip of $Pd(OH)_2$ on carbon (10%). The above suspension was stirred at room temperature for 30 min under a balloon of hydrogen gas, at which time TLC analysis showed the formation of several new products. The suspension was filtered through Celite and concentrated in vacuo to afford an unstable oil which was used directly in the next step without further purification or characterization.

The above oil was dissolved in 10 mL of tetrahydrofuran. To this was added 10 drops of an approximately 50% aqueous solution of hydrogen fluoride, and the resultant solution was stirred at room temperature for 16 h. Triethylamine was added to adjust the pH of the reaction mixture to ca. 8, and the cloudy mixture was filtered through Celite, concentrated in vacuo, and rapidly filtered through a plug of silica gel with 2% methanol/chloroform as eluent. In this manner, 31 mg of the desired tricyclic **27** (48% from **26**) was obtained as a white powder: mp 124–127 °C; ^{1}H NMR (250 MHz, $CDCl_3$) δ 4.67 (s, 1 H), 4.40 (s, 1 H), 3.90 (1 H), 3.87 (t, J = 10.3 Hz, 1 H, partially obscured), 3.74 (m, 1 H), 3.72 (m, 1 H), 2.81 (dd, J = 14.2, 11.8 Hz, 1 H), 2.45 (dd, J = 14.2, 2.0 Hz, 1 H), 2.38 (br s, 1 H), 2.01 (m, 1 H), 1.77 (m, 2 H), 1.55 (br s, 1 H), 1.41 (d, J = 6.1 Hz, 3 H), 1.23–1.35 (m, 2 H), irradiation of the singlet at δ 4.67 produced an approximately 10% NOE enhancement in the signal at δ 3.74 (determined by NOEDS at 500 MHz); ^{13}C NMR ($CDCl_3$, 93.6 Hz) δ 97.0, 90.8, 77.1, 70.4, 69.9, 67.9, 66.9, 44.6, 38.8, 31.8, 30.5, 29.2, 28.9, 24.5, 23.9, 23.0, 21.5, 20.2, 14.0; IR ($CDCl_3$) 3500, 3020, 1710, 1140, 1100, 1040, 1010 cm^{-1}; high-resolution MS (20 eV), m/e calcd for $C_{12}H_{18}O_6$ 258.1103, found 258.1085. Anal. Calcd for $C_{12}H_{18}O_6$: C, 55.80; H, 7.02. Found: C, 55.79; H, 7.14.

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Total Synthesis of (−)-Coriolin[1]

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Abstract: The first total synthesis of the diterpene coriolin in the enantiomerically pure (−)-form is described. The key step is the photochemical generation of the 3,3,6-trimethyltricyclo[3.3.0^{2,8}]octane-4,7-dione building blocks (−)-**12a** and (−)-**12b** in solutions of exceptionally high concentrations (≥20%). It involves the site selective oxadi-π-methane rearrangement of one β,γ-enone partial chromophore of the β,γ-unsaturated ϵ-diketones (−)-**9a** and (−)-**9b** which are obtained from bicyclo[2.2.2]oct-7-ene-2,5-dione, (±)-**7**, by optical resolution, in multigram batch preparations, via the tartrate monoacetals followed by trimethylation. (−)-Coriolin is thus accessible in 14 steps from (±)-**7**.

Coriolin,[2] a sesquiterpene with potent antitumor and antibacterial properties,[3] has attracted the attention of numerous synthetic groups over the recent years.[4,5] The challenge of building up the cis,anti,cis-fused tricyclo[6.3.0.0^{2,6}]undecane skeleton with an array

(1) For a preliminary report on the analogous synthesis of (±)-coriolin, see: Demuth, M.; Ritterskamp, P.; Schaffner, K. *Helv. Chim. Acta* **1984**, *67*, 2023.

(2) (a) Isolation of coriolin: Takeuchi, T.; Iinuma, H.; Iwanaga, J.; Takahashi, S.; Takita, T.; Umezawa, H. *J. Antibiot.* **1969**, *22*, 215. (b) Isolation of coriolin B and preparation of diketocoriolin B: Takeuchi, T.; Iinuma, H.; Takahashi, S.; Umezawa, H. *Ibid.* **1971**, *24*, 631. (c) Structure elucidation: Takahashi, S.; Naganawa, H.; Iinuma, T.; Takita, T.; Maeda, K.; Umezawa, H. *Tetrahedron Lett.* **1971**, 1955. Nakamura, H.; Takita, T.; Umezawa, H.; Kunishima, M.; Nakayama, Y. *J. Antibiot.* **1974**, *27*, 301.

(3) (a) Biological activity: Umezawa, H. *Heterocycles* **1979**, *13*, 23. (b) Nishimura, Y.; Koyama, Y.; Umezawa, S.; Takeuchi, T.; Ishizuka, M.; Umezawa, H. *J. Antibiot.* **1980**, *33*, 404; see also ref 2.

(4) Syntheses of (±)-coriolin: (a) For a survey, see: Mulzer, J. *Nachr. Chem., Tech. Lab.* **1984**, *32*, 429. (b) Danishefsky, S.; Zamboni, R.; Kahn, M.; Etheredge, S. J. *J. Am. Chem. Soc.* **1980**, *102*, 2097; **1981**, *103*, 3460. Danishefsky, S.; Zamboni, R. *Tetrahedron Lett.* **1980**, *21*, 3439. (c) Tatsuta, K.; Akimoto, K.; Kinoshita, M. *J. Antibiot.* **1980**, *33*, 100. *Tetrahedron* **1981**, *37*, 4365. (d) Shibasaki, M.; Iseki, K.; Ikegami, S. *Synth. Commun.* **1980**, *10*, 551. Shibasaki, M.; Iseki, K.; Ikegami, S. *Tetrahedron Lett.* **1980**, *21*, 3587. Iseki, K.; Yamazaki, M.; Shibasaki, M.; Ikegami, S. *Tetrahedron* **1981**, *37*, 4411. (e) Wender, P. A.; Howbert, J. J. *Tetrahedron Lett.* **1983**, *24*, 5325. (f) Koreeda, M.; Mislankar, S. G. *J. Am. Chem. Soc.* **1983**, *105*, 7203. (g) Schuda, P. F.; Heimann, M. R. *Tetrahedron* **1984**, *40*, 2365.

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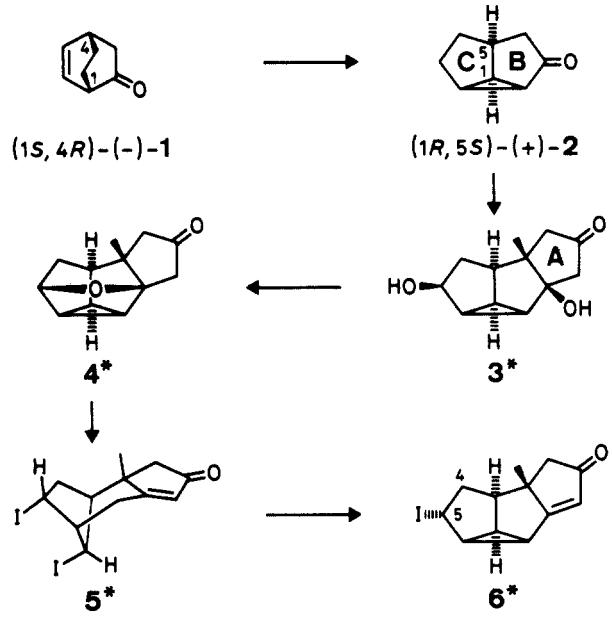
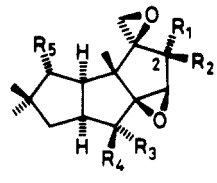
Scheme I. The Tricyclooctane Approach to Coriolin[6-8]



[a] The starred compounds have been prepared in racemic form only.

of eight asymmetric centers has stimulated innovative work aimed at the construction of five-membered rings. The two presently known natural products in this series, coriolin[2a] and coriolin B,[2b] differ only as to the oxidation state of ring A. Coriolin B does not exhibit substantial biological activity whereas its derivative, diketocoriolin B, again shows a pronounced activity profile.[2b] The



Coriolin: $R_1, R_2 = O$, $R_3 = H$, $R_4 = R_5 = OH$

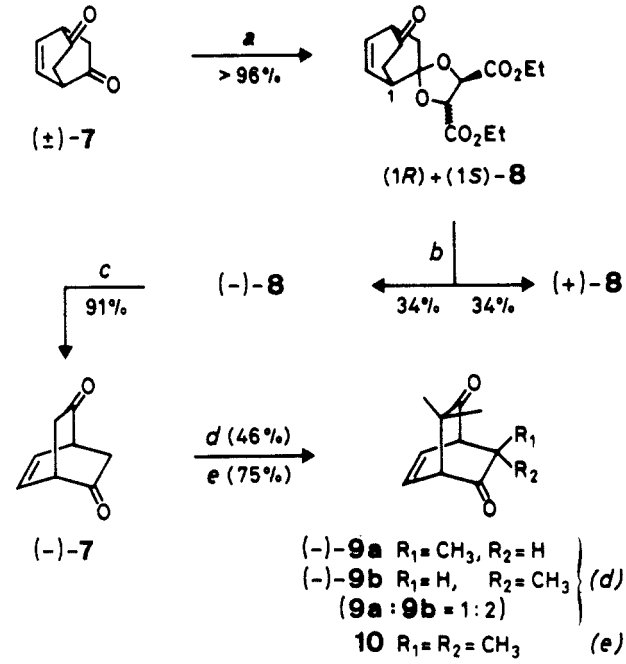
Coriolin B: $R_1 = R_3 = H$, $R_2 = R_4 = OH$, $R_5 = OCO(CH_2)_6CH_3$

Diketocoriolin B: $R_1, R_2 = R_3, R_4 = O$, $R_5 = OCO(CH_2)_6CH_3$

2-keto group seems to be an imperative structural unit for the specific biological responses. All coriolin syntheses reported up to date have been restricted to the preparation of (±)-materials,[1,4,5] with the exception of one synthesis of a bicyclic building block which was obtained with a noteworthy enantiomeric excess and which in its (±)-form served as a precursor of racemic coriolin.[5a]

Tricyclooctanone vs. Tricyclooctanedione Approach. Our own first approach used enantiomerically pure tricyclo[3.3.0.0^{2,8}]octan-3-one, (+)-**2** (Scheme I),[6-8] a building block which is obtained

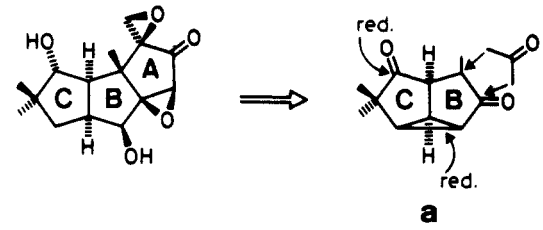
Scheme II.[12] Resolution and Methylation of Bicyclo[2.2.2]oct-7-ene-2,5-dione (7)[a]



[a] (a) Diethyl (*R,R*)-tartrate, *p*-TsOH, toluene, reflux; (b) chromatography; (c) 1 N HCl, EtOH, 60 °C; (d) NaH (2 equiv), dimethoxyethane, MeI (2 equiv), room temperature, 45 min; NaH (1 equiv), 18-crown-6 ether, MeI, room temperature, 195 h; (e) (±)-7 + NaH (ca. 5 equiv), dimethoxyethane, MeI (excess), 60 °C, 2 h.

in a photochemical oxadi-π-methane rearrangement from the β,γ-unsaturated ketone (-)-**1** and which has proved—in both enantiomeric forms—to be an important key intermediate for the synthesis of cyclopentanoid natural products.[6,8,9]

Scheme I outlines the BC → ABC principle chosen for the elaboration of the tetracycloundecanes **3**, **4**, and **6** which were to be precursors for the synthesis of coriolin.[7] The X-ray analysis of the diiodo derivative **5**, obtained as a product of sequential ring cleavage of **4** with trimethylsilyl iodide,[10] confirmed the earlier spectral evidence for the anti ring fusion in **3**. Although this route had offered the first access to the enantiomerically pure coriolin ring skeleton, we felt that the entire sequence to the final target would employ more steps than desirable. Especially the further elaboration of the functionalities at C-4 and C-5 would have required a considerable number of additional steps. We decided to avoid this obstacle by incorporating the proper functions from the beginning. Such a strategy, however, posed open questions as to the introduction of optical activity and, moreover, to the photochemical step since the generation of intermediate **a** required



the unprecedented site selective oxadi-π-methane phototrans-

(5) (a) Synthesis of the (±)-precursor **19** and its transformation to (±)-coriolin: Trost, B. M.; Curran, D. P. *J. Am. Chem. Soc.* **1981**, *103*, 7380. (b) Syntheses of (±)-**19**: Ito, T.; Tomiyoshi, N.; Nakamura, K.; Azuma, S.; Izawa, M.; Maruyama, F.; Yanagiya, M.; Shirahama, H.; Matsumoto, T. *Tetrahedron. Lett.* **1982**, *23*, 1721. *Tetrahedron* **1984**, *40*, 241. (c) Mehta, G.; Reddy, A. V.; Murthy, A. N.; Reddy, D. S. *J. Chem. Soc., Chem. Commun.* **1982**, 540. (d) Exon, C.; Magnus, P. *J. Am. Chem. Soc.* **1983**, *105*, 2477.

(6) Demuth, M.; Schaffner, K. *Angew. Chem.* **1982**, *94*, 809; *Angew. Chem., Int. Ed. Engl.* **1982**, *21*, 820.

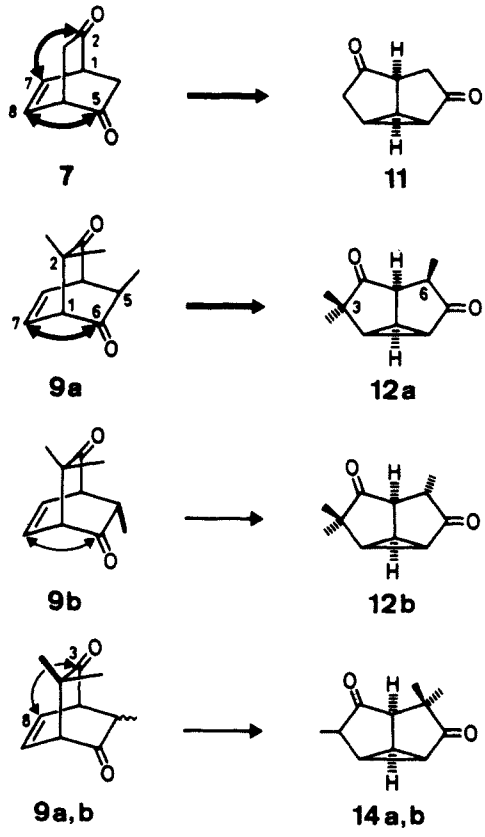
(7) Demuth, M.; Canovas, A.; Weigt, E.; Krüger, C.; Tsay, Y.-H. *Angew. Chem.* **1983**, *95*, 747; *Angew. Chem., Int. Ed. Engl.* **1983**, *22*, 721; *Angew. Chem. Suppl.* **1983**, 1053. Weigt, E. Ph.D. Thesis, Max-Planck-Institut für Strahlenchemie/Ruhr-Universität Bochum, 1985.

(8) Demuth, M. *Chimia* **1984**, *38*, 257.

(9) (a) Ritterskamp, P.; Demuth, M.; Schaffner, K. *J. Org. Chem.* **1984**, *49*, 1155. (b) Demuth, M.; Chandrasekhar, S.; Schaffner, K. *J. Am. Chem. Soc.* **1984**, *106*, 1092. (c) For extensions of the tricyclooctanone approach, see: Demuth, M.; Wietfeld, B.; Pandey, B. Schaffner, K. *Angew. Chem.* **1985**, *97*, 777; *Angew. Chem., Int. Ed. Engl.* **1985**, *24*, 763. Demuth, M.; Hinsken, W. *Angew. Chem.* **1985**, *97*, 974; *Angew. Chem., Int. Ed. Engl.* **1985**, *24*, 973. Hinsken, W.; Demuth, M. *J. Am. Chem. Soc.*, in press [(-)-5-oxosilphiperfol-6-ene].

(10) See ref 7 for the consecutive double ring cleavage of **4**.

Scheme III. Primary Photochemical Bridging Sites (Arrows) in the Oxadi-π-Methane Rearrangement of **7**, **9a**, and **9b**

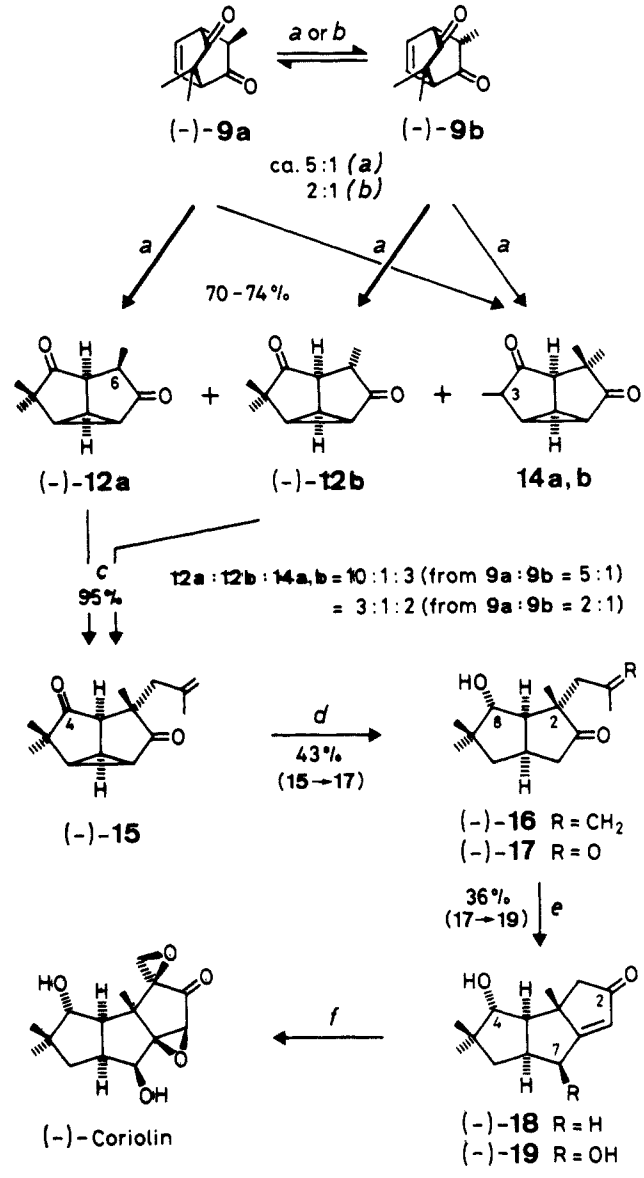


formation of a β,γ-unsaturated ε-diketone. The completion of the scheme, when based on an elaborate building block such as **a**, would require standard transformations only, i.e., simultaneous reduction of the three-membered ring and the ring C ketone and annulation of ring A using previously employed methods.

Results and Discussion

Preparation of the Trimethylbicyclooctenediones (-)-9a and (-)-9b. Bicyclo[2.2.2]oct-7-ene-2,5-dione, (±)-**7**, can be prepared in three steps from hydroquinone and maleic anhydride.[11] The initially[11a] poor yield of the first step, a Diels–Alder addition, has since been somewhat improved,[11b,c] and it has been raised to 16% in our own efforts.[12] The optical resolution of (±)-**7** was carried out via the mixture of diastereoisomeric monoacetals **8** which was formed nearly quantitatively from (±)-**7** and diethyl (*R,R*)-(+)-tartrate with *p*-toluenesulfonic acid in boiling toluene (Scheme II). The diacetals were not formed under these conditions. The mixture could easily be separated by chromatography (34% yield of each diastereoisomeric acetal, besides mixed fractions). The acid-catalyzed hydrolysis of (-)-**8** gave (-)-**7** in 91% yield and in >98% enantiomeric excess. This procedure for the preparation of enantiomerically pure **7** was directly adopted from our earlier synthesis of the (+)- and (-)-bicyclo[2.2.2]oct-5-en-2-ones.[9a,b] Here again, the procedure can be used to prepare multigram batches of optically pure starting diketone. The chiroptical data for (-)-**7** are in good agreement with the prediction by Schippers and Dekker,[13] and the configurational assignment, which accords also to the general octant rule for β,γ-unsaturated ketones,[14] is

Scheme IV.[12] First Total Synthesis of (-)-Coriolin[a]



[a] (a) ≥20% acetone solution, *hν* (λ_{irr} 300 nm), room temperature, 6 h; (b) NaOMe, MeOH, 0 °C, 24 h; (c) methallyl chloride, KBr, *t*-BuOK, *t*-BuOH, toluene, 50 °C, 30 min; (d) Li, NH_3, THF, *t*-BuOH, -78 °C, 1-2 min; OsO_4, $NaIO_4$, dioxane–H_2O, room temperature; (e) *t*-BuOK, *t*-BuOH, toluene, 40 °C; isopropenylacetate, *p*-TsOH, reflux, oxone (= $2KHSO_5 \cdot K_2SO_4 \cdot KHSO_4$), $NaHCO_3$, $MeOH/H_2O$, room temperature; (f) See ref 5a.

now confirmed by the transformation of (-)-**7** into (-)-coriolin. Subsequent triple methylation of (-)-**7** at room temperature afforded in a single operation a 1:2 ratio of the epimers (-)-**9a** and (-)-**9b**. In the first stage of the methylation procedure, in which 2 equiv each of sodium hydride and methyl iodide were employed, two substituents only were introduced. Substitution by the third methyl was then selectively enforced by adding another equivalent of base combined with 18-crown-6 ether, which suppressed permethylation to **10** and was followed by excess methyl iodide. For the purpose of comparison, the tetramethyl homologue (±)-**10** was prepared from (±)-**7** by the use of excess sodium hydride and methyl iodide at elevated temperature.

The Enedione Oxadi-π-Methane Photorearrangement. The 1:2 ratio of the epimeric trimethyl enediones (-)-**9a** and (-)-**9b** seemed a priori an unfavorable result in view of the planned photorearrangement to **12**. On the basis of the accepted stepwise mechanism

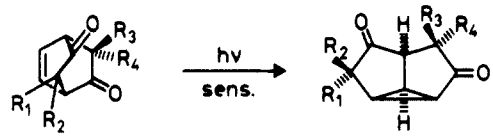
(11) (a) Grob, C. A.; Weiss, A. *Helv. Chim. Acta* **1960**, *43*, 1390. For a further improvement of the yield, see: (b) Weitemeyer, C.; de Meijere, A. *Angew. Chem.* **1976**, *88*, 721; *Angew. Chem., Int. Ed. Engl.* **1976**, *15*, 686 and (c) Weitemeyer, C. Ph.D. Thesis, Universität Göttingen, 1976.

(12) All yields refer to isolated pure products.

(13) Schippers, P. H.; Dekkers, H. P. J. M. *J. Chem. Soc. Perkin Trans. 2* **1982**, 1429. Schippers, P. H.; Dekkers, H. P. J. M. *Tetrahedron* **1982**, *38*, 2089. Δε values for 100% enantiomeric purity were extrapolated from partial photodegradation of (±)-**7** with circularly polarized light. These values are larger by 10–20% than our data for enantiomerically pure (-)-**7**.

(14) Snatzke, G. *Optical Rotatory Dispersion and Circular Dichroism in Organic Chemistry*; Heydon and Son: London, 1967.

Table I. Quantum Yield Determinations at λ_{irr} 303 nm[a]



7	R_1, R_2, R_3, R_4 = H	**11**
9a	R_1, R_2, R_3 = CH_3, R_4 = H	**12a**
9b	R_1, R_2, R_4 = CH_3, R_3 = H	**12b**
10	R_1, R_2, R_3, R_4 = CH_3	**13**

run	starting diketone	prod.	ϕ^b (in acetone)
1	**7**	**11**	0.93
2	**9a**	**12a**	0.36
3	**9b**	**12b**	0.17
4	**10**	**13**	0.34

[a] Concentration 5×10^{-2} M; measured at 20 °C with an electronically integrating actinometer;[18] error limits ±5%; see also ref 17. [b] The values are extrapolated to zero conversion and to maximum sensitization rate.

of the oxadi-π-methane rearrangement[15] one anticipates that in the phototransformation of the epimers one of the total of four possible routes should prevail (Scheme III): (a) Bridging in the primary photochemical step between C-6 and C-7 of **9a**, which leads to **12a**, should be the least-hindered oxadi-π-methane channel. (b) In the corresponding bridging in **9b** the secondary methyl group, which now occupies the "endo" position with respect to the bonding sites, should sterically impede the approach of the two partial chromophores (see arrow) in the 6,7-bonding process. (c) A similar steric control should also be exerted by the "endo" group of the geminal methyls of both **9a** and **9b** in the alternative 3,8-bridging, which affords the epimeric regioisomers **14a** and **14b**.

Quantum yield measurements (Table I) with the individual ketones indeed strongly support the argument of steric hindrance by the "endo" methyl group. Thus, the photorearrangement of the parent enedione, **7** (→ **11**),[16,17] which is not subject to any of the steric constraints discussed above and which has a choice of two identical bridging modes (C-2,7 and C-5,8), was the most efficient. The reactions of the trimethyl homologues **9a** (→ **12a**) and **9b** (→ **12b**) followed in this order of decreasing quantum yields. Furthermore, the rearrangement efficiency of the tetramethyl enedione **10** (→ **13**), which again has the choice of two identical bridging modes, is greater than that for **9b** → **12b** which presumably competes with the regioisomeric process **9** → **14** less efficiently than does **9a** → **12a**. The fact that the rearrangement efficiency of **9a** → **12a** is about 3 times greater than that of **9b** → **12b** offers a means to steer the regioselectivity favoring the desired products, **12a,b** (the two epimers are of synthetically equal use), over **14a,b**. However, the direct use of the 1:2 mixture of **9a** and **9b** for the photorearrangement a priori was risked to diminish the impact of the greater regioselectivity of **9a** on the preparative outcome.

The stereochemical assignment for the secondary methyl in **9a** and **9b** is based upon ^{1}H NMR high field shifts, each of 0.05 ppm, of a C-2 methyl singlet and the doublet in **9a** due to mutual shielding. This interpretation is confirmed by the observation that the "endo" C-4 methyl of **12a** upon the base treatment in the alkylation step to **15** is equilibrated to the "exo" position (**12b**). This argument presupposes that the photorearrangements of **9a** and **9b** occur without epimerization and that **12a** and **12b**, respectively, are formed stereospecifically.

With the intent to select for the preparatively most attractive route (−)-**9a** → (−)-**12a**, the 1:2 ratio of (−)-**9a** and (−)-**9b** was reversed into a more favorable 2:1 ratio by treating the mixture with sodium methoxide in methanol at 0 °C. Irradiation of the 2:1 mixture in acetone with 300 nm at room temperature afforded a 3:1:2 mixture of **12a**, **12b**, and **14a,b**. However, epimerization by base prior to irradiation proved to be unnecessary since the 1:2 mixture of (−)-**9a** and (−)-**9b**, as obtained by chromatography of the crude methylation product ("preparative purity", ≥96%), could be directly transformed into a 10:1:3 mixture of **12a**, **12b**, and **14a,b** under the same photochemical conditions. These runs, **9a,b** → **12a,b** + **14a,b**, could be carried out with highly concentrated sample solutions (≥20%) and on a large scale without sacrifice of yield. In either case, the irradiation times required for >95% conversions were in the range of 4–6 h, and the yields of **12a** + **12b** were 70–74%.

The one-pot photochemical transformation of the 1:2 mixture of **9a** and **9b** into ≥70% **12a,b** evidently comprises a highly efficient light-driven epimerization as well as the oxadi-π-methane rearrangement. In fact, GLC monitoring revealed that the 1:2 ratio was changed into 5:1 within the first few minutes of the irradiation. Although the occurrence of some Norrish type I cleavage is indicated by the formation of <10% of cyclobutanone isomers—the alternative type I products by way of allylic 1,3-acyl shifts—in the crude reaction mixture (IR and GLC screening), the interconversion of **9a** and **9b** cannot be attributed (at least not to the extent observed) to type I cleavage and thermal reclosure of the acyl–alkyl biradical, as we had initially suggested.[1] Acetone-sensitized irradiation of "analytically pure" samples of (−)-**9a** and (−)-**9b** [≥98%; chromatographically isolated from the mixture (−)-**9a** + (−)-**9b** of "preparative quality"], or of a mixture of the two, did *not* effect epimerization within a period of time comparable to that required for the "preparative" overall conversions nor did epimerization take place in the acetone solutions of "preparative quality" on standing in the dark. Apparently, an as yet unknown impurity present (<4% by GLC) in the runs with starting material of "preparative purity" acts as a photocatalyst for efficient epimerization.[19] It is interesting to note that the photocatalyst is less effective in the 2:1 mixture of **9a** and **9b** obtained by methoxide treatment.

The BC → ABC Route from (−)-12a,b to (−)-Coriolin. As expected, the final steps of this coriolin synthesis (Scheme IV) were straightforward. The product mixture (−)-**12a,b** could directly be used for the alkylation with methallyl chloride, which gave (−)-**15** as a single product. Birch reduction to (−)-**16** and, without further purification of this quite labile compound, oxidative cleavage of the methylene double bond furnished (−)-**17**. The base-catalyzed ring closure, (−)-**17** → (−)-**18**, as well as the procedures for the alkylation and double bond cleavage were adopted from the analogous steps involved in the transformations of **2** to **3** (Scheme I).[7] The Birch reduction had been the only critical step in the entire final sequence. The reaction was quenched with ammonium chloride after a few minutes, resulting in both high regioselection in the cyclopropane cleavage and high stereoselection in the thermodynamically controlled reduction of the 4-keto group.[20]

(15) Schuster, D. I. In *Rearrangements in Ground and Excited State*; de Mayo, P., Ed.; Academic Press: New York, 1980; Vol. 3, p 167. For the stepwise nature of the oxadi-π-methane rearrangement, see: Winter, B.; Schaffner, K. *J. Am. Chem. Soc.* **1976**, *98*, 2022. Dauben, W. G.; Lodder, G. Robbins, J. D. *J. Am. Chem. Soc.* **1976**, *98*, 3030. Dauben, W. G.; Lodder, G.; Robbins, J. D. *Nouv. J. Chim.* **1977**, *1*, 243.

(16) The near-unity quantum yield of the oxadi-π-methane rearrangement of **7** parallels that of the β,γ-unsaturated monoketone, bicyclo[2.2.2]oct-5-en-2-one: Demuth, M.; Raghavan, P. R.; Carter, C.; Nakano, K.; Schaffner, K. *Helv. Chim. Acta* **1980**, *63*, 2434.

(17) All oxadi-π-methane rearrangements listed in Table I also occur upon direct excitation at λ_{irr} 300 nm in *n*-hexane (1–20% sample solutions), but they are less efficient [ϕ(in acetone) = ca. $5 \times \phi$(in *n*-hexane)], and they are accompanied by the formation of cyclobutanone isomers arising from Norrish type I cleavage (note that it is claimed in ref 13 that under similar conditions no oxadi-π-methane rearrangement occurs and type I cleavage is exclusive).

(18) Actinometry: Amrein, W.; Gloor, J.; Schaffner, K. *Chimia* **1974**, *28*, 185.

(19) The photocatalytic action of the impurity was reproduced in several independent runs with material of "preparative purity". It could also be reproduced when "analytically pure" samples of **9b** were doped with portions of "preparative quality" material (**9a** + **9b**).

(20) ^{1}H NMR gave no indication for the formation of any regio- and stereoisomers of **16**. The configuration at C-8 follows from the conversion of (±)-**16** into the known[5a] intermediate (±)-**19**.[1] For a precedent of the regioselective reductive cleavage of the external cyclopropane bond in tricyclo[3.3.0.0^{2,8}]octan-3-one, see: Monti, S. A.; Bucheck, D. J.; Shepard, J. C. *J. Org. Chem.* **1969**, *34*, 3080. For a precedent of the stereoselective reduction of the 4-keto group of (−)-**15** in a related system, see ref 4b.

The 7-hydroxy group was introduced into (-)-**18** by treatment of the dienol acetate derivative with oxone,[21] a method which has been used before for the γ-hydroxylation of various other α,β-enones and which could directly be adopted in the present case. The stereoselectivity of the reaction derives from the 7,7a-epoxide intermediate, the β-configuration of which should be favored by the syn AB ring fusion. The synthesis was completed by the conversion of (-)-**19** to (-)-coriolin following the steps described already for the synthesis of racemic compound.[5a] The mp, IR and ^{1}H NMR spectra, and the specific optical rotation, $[\alpha]_D$, -20.7°, of the synthetic final product were in full accord with the literature values[3b] for the naturally abundant (-)-coriolin.

Experimental Section

General Methods. Melting points were taken under a microscope on a Kofler hot plate and are uncorrected. Specific optical rotations, $[\alpha]_D$, were measured at 23 °C in $CHCl_3$, *c* in parentheses, experimental error ±5%. ^{13}C and ^{1}H NMR spectra were measured in $CDCl_3$, unless stated otherwise, on Bruker WH-270 and AM-400 instruments in FT mode. The chemical shifts are in δ units (with $(CH_3)_4Si$ as internal reference) and the coupling constants (*J*) in Hz; abbreviations are s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet). IR spectra were run in $CHCl_3$, unless stated otherwise, on a Perkin-Elmer 298 instrument and are given in cm^{-1}. The UV spectra (*n*-hexane) were measured on a Cary 17 spectrophotometer; maxima are given in nm, with ϵ_{max} values in parentheses. The CD spectra (*n*-hexane) were recorded on a Jasco J20 instrument; maxima are given in nm with CD Cotton effect and Δε in parentheses. Mass spectra (MS, in *m/e*) were recorded on a Varian MAT CH5 instrument at 70 eV. GLC analyses were performed with a Varian Aerograph 1700 instrument equipped with a flame ionization detector coupled to a Spectra Physics Autolab System I computing integrator. OV 101 glass capillary columns of 20 and 35 m length were used, with nitrogen as the carrier gas. Column chromatography and flash chromatography were performed on silica gel (Merck, 0.063–0.2 mm). The analytical samples of all new compounds were purified by flash chromatography. Preparative thick-layer chromatography was carried out on 2-mm silica plates (Merck). The solvents were purified by using standard procedures. All reactions were run under argon atmosphere. The homogeneity of the products was ≥96% by GLC and ^{1}H NMR, unless stated otherwise. The elemental analyses were performed by Dornis and Kolbe, Mülheim a. d. Ruhr.[12]

(±)-Bicyclo[2.2.2]oct-7-ene-2,5-dione (7). (±)-**7** was prepared by a known procedure[10] involving Diels–Alder addition of hydroquinone to maleic anhydride followed by hydrolysis of the adduct and oxidative bisdecarboxylation with lead tetraacetate. The literature yield of 4%[10b,c] in the Diels–Alder step could be raised to 16% by the addition of water to the reaction mixture: hydroquinone (300 g), maleic anhydride (580 g), and water (10 mL) were heated to 180 °C for 4 h in a round-bottomed flask. The mixture was subsequently cooled to 50–60 °C. Portionwise addition of ether (1.5 L) precipitated the adduct which was transformed, without purification, to (±)-**7** by following again the literature procedure.[10]

Diethyl Tartrate Acetals (1*R*)- and (1*S*)-8. A solution of (±)-**7** (3 g, 22 mmol), *p*-toluenesulfonic acid (2 g, 10.5 mmol), and diethyl (*R*,*R*)-(+)-tartrate (30 g, 146 mmol) $[\alpha]_D$ +7.9°, neat) in 30 mL of toluene was refluxed in a Dean–Stark apparatus. After 2 h (>96% conversion) the reaction mixture was cooled to room temperature and washed with 3 100-mL portions of H_2O. The organic layer was separated and dried, and the solvent was evaporated. The residue of 16.5 g was composed of a 1:1 mixture of the diastereoisomeric acetals **8** and excess diethyl (+)-tartrate. It was passed in three portions through two Merck ready-made columns (Li-Chroprep SI 60, type C, mesh 63-125; solvent, toluene/ether 95:5; pressure, 2–4 bar) connected in series. The separation afforded a total of ca. 2.45 g (34%) of each diastereoisomer in pure form (>98% purity by GLC), besides ca. 1.5 g (21%) of mixed fractions.

(-)-**8**: $[\alpha]_D$ -234.7° (0.3); ^{1}H NMR 1.28 + 1.31 (2 × 3 H, 2 t, *J* = 7), ca. 1.9–2.6 (4 H, m), ca. 3.1 (2 H, m), 4.23 + 4.25 (2 × 2 H, 2 q, *J* = 7), ca. 4.7–4.85 (2 H, m), 6.34 (1 H, dd, *J* = 2 and 8), 6.45 (1 H, dd, *J* = 2 and 6); ^{13}C NMR (100.6 MHz) 209.81 + 169.32 + 168.58 + 133.92 + 116.58 (5 s), 129.0 + 76.98 + 71.80 + 48.87 + 41.75 (5 d), 61.53 + 61.52 + 37.44 + 34.56 (4 t), 13.58 (2 q); IR 1750, 1730, 1605, 1240, 1170, 1090; MS, *m/e* 324 (M^+, $C_{16}H_{20}O_7$), 251, 230 (base peak), 116, 115, 91, 79, 66, 43, 29.

(+)-**8**: $[\alpha]_D$ + 226° (0.13); ^{1}H NMR 1.26 + 1.29 (2 × 3 H, 2 t, *J* = 7), ca. 1.9–2.6 (4 H, m), ca. 3.1 (2 H, m), 4.22 + 4.25 (2 × 2 H, 2 q, *J* = 7), ca. 4.7–4.9 (2 H, m), 6.35 (1 H, dd, *J* = 2 and 8), 6.45 (1 H, dd, *J* = 2 and 6); IR and MS data identical with those for (-)-**8**.

(21) Suryawanshi, S. N.; Fuchs, P. L. *Tetrahedron Lett.* **1981**, *22*, 4201.

(1*S*,4*S*)-(-)- and (1*R*,4*R*)-(+)-Bicyclo[2.2.2]oct-7-ene-2,5-diones (7). A solution of (-)-**8** (1.82 g, 5.62 mmol) in 50 mL of EtOH and 15 mL of 30% aqueous HCl was heated to 60 °C for 24 h. After having been cooled to room temperature, 100 mL of saturated Na_2CO_3 were slowly added, and the mixture was extracted with 4 50-mL portions of $CHCl_3$. The combined organic layers gave after evaporation of the solvent 0.87 g of (-)-**7** as colorless crystals (81% purity by GLC; 97% yield). Crystallization from $CHCl_3$/petroleum ether (1:1) afforded 0.695 g of (-)-**7** (99% purity by GLC; 91% yield). For the analytical data, see ref 10: $[\alpha]_D$ -1160° (0.66); CD 320 (-15.9), 308 (-23.4), 298 (-21.7), 288 (-15.7), 227 (+3.8). Hydrolysis of (+)-**8** gave (+)-**7** with comparable yield and purity.

(1*S*,4*S*,5*R*)- and (1*S*,4*S*,5*S*)-(-)-2,2,5-Trimethylbicyclo[2.2.2]oct-7-ene-3,6-diones (9a and 9b). NaH (0.69 g, 50% oil suspension, 14.4 mmol) was washed with pentane and then suspended in 5 mL of freshly distilled DME. A solution of (-)-**7** (0.98 g, 7.2 mmol) in 50 mL of DME was added dropwise under stirring at room temperature. The mixture was refluxed for 2 h and cooled again to room temperature before 0.9 mL (14.4 mmol) of MeI in 2 mL of DME were added. After 45 min a second portion of NaH (0.345 g, as 50% oil suspension, 7.2 mmol) and 18-crown-6 ether (2.85 g, 10.8 mmol) was added, and the mixture was refluxed for 1 h prior to cooling to room temperature and adding more MeI (0.58 mL, 9.2 mmol). The reaction was completed within 1.5 h at room temperature. Excess NaH was destroyed by the addition of 0.5 mL of MeOH. The reaction was worked up by addition of brine and repeated extractions with ether. The combined organic layers were dried over Na_2SO_4. Evaporation of the solvent gave 3.2 g of crude (-)-**9a,b** (**9a**:**9b** = 1:2; 55% purity by GLC). This material was chromatographed (silica gel, 20-fold; pentane/ether, 19:1) and 0.589 g of a 1:2 mixture of **9a** and **9b** ["preparative purity" (see text), ≥96% by GLC] were collected as a colorless oil (46% yield). A sample of this material was again chromatographed (silica gel, 60-fold; pentane/ether, 19:1) in order to separate the two diastereoisomers ["analytical purity" (see text), ≥98% by GLC]. Anal. Calcd for $C_{11}H_{14}O_2$: C, 74.16; H, 7.87. Found: C, 73.89; H, 7.88.

(-)-**9a**: $[\alpha]_D$ -239° (0.12); ^{1}H NMR 1.03 (3 H, s), 1.11 (3 H, d, *J* = 8), 1.13 (3 H, s), 2.28 (1 H, dq, *J* = 1.5 and 8), 3.14 (1 H, dd, *J* = 3 and 6), 3.30 (1 H, m, fine coupling *J* = 1.5), ca. 6.45 (2 H, m); ^{13}C NMR (20.1 MHz) 212.5 + 210.0 + 29.7 (3 s), 131.9 + 130.8 + 61.7 + 56.2 + 40.9 (5 d), 26.7 + 24.1 + 15.3 (3 q); IR 1720, 1605, 1225, 1180, 1075; UV 321 (112), 309 (155), 299 (158), 289 (160), 228 (2205); MS, *m/e* 178 (M^+, $C_{11}H_{14}O_2$), 135, 122, 107, 91, 79, 70 (base peak), 42, 27.

(-)-**9b**: $[\alpha]_D$ -236° (0.14); ^{1}H NMR 1.08 (3 H, s), 1.13 (3 H, s), 1.16 (3 H, d, *J* = 7), 2.28 (1 H, dq, *J* = 1 and 7), 3.14 (1 H, dd, *J* = ca. 4 and 4), 3.30 (1 H, m, fine coupling *J* = 1), ca. 6.35 (2 H, m); ^{13}C NMR (20.1 MHz) 212.5 + 210.0 + 29.1 (3 s), 131.5 + 129.9 + 62.1 + 56.4 + 38.9 (5 d), 25.7 + 25.0 + 16.5 (3 q); IR, UV, and MS data identical with those for (-)-**9a**.

Epimerization of (-)-9a and (-)-9b. (a) Photochemical equilibration [5:1 ratio of (-)-**9a** and (-)-**9b**] is achieved within the first 5 min of the irradiation described for the preparation of (-)-**12a,b**. (b) Base-catalyzed equilibration: a solution of (-)-**9a,b** (0.18 g, 1.1 mmol) in MeOH (5 mL) containing MeONa (30 mg, 0.55 mmol) was stirred at room temperature for 24 h. Neutralization with AcOH was then followed by concentration, extraction of the residue with ether–H_2O, and washing of the organic layer with $NaHCO_3$ solution. Evaporation of the organic solvent gave a 2:1 mixture (GLC detection) of (-)-**9a** and (-)-**9b** (0.175 g, 98% yield).

(±)-2,2,5,5-Tetramethylbicyclo[2.2.2]oct-7-ene-3,6-dione (10). NaH (0.4 g, 50% oil suspension, 8.4 mmol) was washed with pentane and then suspended in 2 mL of freshly distilled DME. A solution of (±)-**7** (0.2 g, 1.5 mmol) in 20 mL of DME and 1 mL (15.8 mmol) of MeI were added, and the mixture was heated to 60 °C for 2 h. Excess NaH was destroyed by the addition of 0.5 mL of MeOH after cooling to room temperature. The reaction was worked up by addition of brine and extraction with ether. Evaporation of the organic solvent and chromatography of the crude residue (silica gel, 30-fold; pentane/ether, 9:1) gave (±)-**10** as a colorless oil (0.21 g, 75% yield): ^{1}H NMR 1.10 (6 H, s), 1.18 (6 H, s), 3.15 (2 H, dd, *J* = 3 and 4), 6.38 (2 H, m); IR 1720, 1605, 1225, 1180, 1075; UV 325 (148), 314 (179), 303 (174), 291 (135), 223 (1995); MS, *m/e* 192 (M^+, $C_{12}H_{16}O_2$), 121, 70 (base peak), 50, 42, 27.

(±)-Tricyclo[3.3.0.0^{2,8}]octane-3,6-dione (11). Following the procedure described for the preparation and purification of (-)-**12a,b**, acetone solutions (1–20%) of (±)-**7** were irradiated for 4 h. (±)-**11** was obtained in 75% yield: ^{1}H NMR 2.02 (1 H, d, *J* = 2), ca. 2.2 + 2.3 + 2.55 + 3.1 (4 × 1 H, 4 m), 2.40 (1 H, d, *J* = 2), 2.70–2.84 (2 H, m); IR 1740, 1705, 1220, 1090; MS, *m/e* 136 (M^+, $C_8H_8O_2$), 108, 94, 80, 79 (base peak), 66, 53, 39, 27.

(1*S*,5*R*,6*S*)-(-)- and (1*S*,5*R*,6*R*)-(-)-3,3,6-Trimethyltricyclo-[3.3.0.0^{2,8}]octane-4,7-dione (12a and 12b). A solution of (-)-**9a,b** (0.59 g, 3.3 mmol; **9a**:**9b** = 1:2; "preparative purity") in 3.5 mL of acetone was

purged with argon and irradiated in a water-cooled quartz vessel placed in a Rayonet RPR-208 photoreactor (RUL-3000 Å lamps). After 6 h 96% of the starting materials was converted into (−)-**12a**, (−)-**12b**, and **14a,b** (10:1:3 by GLC). The acetone was distilled off. Chromatography of the residue (silica gel, 20-fold; pentane/ether, 9:1) afforded epimeric mixtures of (−)-**12a,b** (0.408 g, 70% yield; **12a**:**12b** = 10:1) and **14a,b** (0.070 g, 12%; **14a**:**14b** = 5:1) as colorless oils.

(−)-**12a,b**: $[\alpha]_D$ −85.7° (0.2); ^{1}H NMR 0.89 + 1.09 (3 H, each d 10:1, J = 7), 0.96 + 0.98 (3 H, each s 10:1), 1.22 + 1.25 (3 H, each s 10:1), 1.93 (0.09 H, dd, J = 7 and 8), 2.01 (0.91 H, dd, J = 7 and 10), ca. 2.12 + 2.19 (1 H, each m 1:10), ca. 2.79 (2 H, m), ca. 3.1 (1 H, m); IR 1740, 1720, 1100, 1020; MS, m/e 178 (M^+, $C_{11}H_{14}O_2$), 135, 122, 107 (base peak), 93, 91, 79, 55, 33.

14a,b: ^{1}H NMR 0.84 + 0.90 (3 H, each d 1:5, J = 7), 0.88 + 0.97 (3 H, each s 1:5), 1.21 + 1.26 (3 H, each s 5:1), 1.86 (0.17 H, dd, J = 7 and 9), 2.01 (0.83 H, dd, J = 7 and 8), ca. 2.2 (1 H, m), ca. 2.78 (2 H, m), ca. 3.1 (1 H, m); IR 1740, 1720; MS, m/e 178 (M^+, $C_{11}H_{14}O_2$).

(±)-3,3,6,6-Tetramethyltricyclo[3.3.0.0^{2,8}]octane-4,7-dione (13). Following the procedure described for the preparation and purification of (−)-**12a,b**, acetone solutions (1–20%) of (±)-**10** were irradiated for 9 h. (±)-**13** was obtained in 60–65% yield: ^{1}H NMR 0.87 + 0.97 + 1.22 + 1.25 (4 × 3 H, 4 s), ca. 2.05 + 2.2 + 2.75 (3 × 1 H, 3 m), 2.68 (1 H, d, J = 6); IR 1735, 1729, 1370; MS, m/e 192 (M^+, $C_{12}H_{16}O_2$).

(1*S*,5*R*,6*S*)-(−)-6-Isobutenyl-3,3,6-trimethyltricyclo[3.3.0.0^{2,8}]octane-4,7-dione (15). A solution of (−)-**12a,b**, (0.408 g, 2.29 mmol) in toluene (40 mL) was added to t-BuOK (0.38 g, 3.28 mmol) in t-BuOH (2.5 mL). The mixture was warmed to 40 °C for 15 min and then cooled to room temperature, and KBr (0.12 g, 1 mmol) and 3-chloro-2-methylpropene (0.45 mL, 4.6 mmol) were consecutively added. After 30 min at 50 °C, the reaction was cooled to room temperature, brine was added, and the mixture was extracted with $CHCl_3$. The organic layer was dried over Na_2SO_4 and taken to dryness. (−)-**15** was obtained as a light yellow oil (0.561 g, 90% purity by GLC, 95% yield). For analytical purposes a sample of (−)-**15** was flash chromatographed (silica gel, 50-fold; pentane/ether, 19:1): $[\alpha]_D$ −148.9° (0.03); ^{1}H NMR 0.89 + 1.0 + 1.24 + 1.77 (4 × 3 H, 4 s), 2.04 (1 H, dd, J = 7 and 9), 2.17 (1 H, d, J = 14), ca. 2.15 (1 H, m), 2.34 (1 H, d, J = 14), 2.72 (1 H, dd, J = 5 and 10), 2.96 (1 H, d, J = 5), ca. 4.75 + 4.96 (2 × 1 H, 2 m); ^{13}C NMR (20.1 MHz), 39.5 + 58.8 + 128.3 + 215.1 + 220.2 (5 s), 18.5 + 22.4 + 46.2 + 56.6 (4 d), 48.4 + 116.6 (2 t), 24.4 + 26.5 + 26.8 + 35.6 (4 q); IR 1735, 1715, 1640; MS, m/e 232 (M^+, $C_{15}H_{20}O_2$), 217, 162, 149, 133, 122, 91, 55, 41 (base peak). Anal. Calcd for $C_{15}H_{20}O_2$: C, 77.59; H, 8.62. Found: C, 77.69; H, 8.56.

(1*R*,2*S*,5*R*,8*R*)-(−)-2-(2-Oxopropyl)-2,7,7-trimethyl-8-hydroxybicyclo[3.3.0]octan-3-one (17) via (−)-16. (−)-**15** (0.45 g, 90% purity, 1.74 mmol) was dissolved in THF and added slowly to liquid NH_3 (60 mL). After consecutive additions of t-BuOH (0.3 mL) and Li (35 mg, 5 mmol) at −78 °C, the solution was stirred until the blue color faded. The reaction was quenched 1–2 min later by the addition of NH_4Cl (0.4 g), and the NH_3 was evaporated. Extraction with NaCl solution and $CHCl_3$ afforded, after drying of the organic layer over Na_2SO_4 and evaporation, **(1*R*,2*S*,5*R*,8*R*)-(−)-2-isobutenyl-2,7,7-trimethyl-8-hydroxybicyclo[3.3.0]octan-3-one** [(−)-**16**; 0.434 g, 52% purity by GLC, ca. 55% yield: $[\alpha]_D$ −352° (0.19); IR 3590, 3500, 1728]. The material was directly used for the next transformation without further purification. It was dissolved in 1:1 dioxane–H_2O (30 mL), and $NaIO_4$ (0.2 g, 0.92 mmol) and 4 mL of an OsO_4 solution (2 g of OsO_4 in 1 L of dioxane–H_2O, 1:1) were added. After 18 h of stirring at room temperature the white precipitate formed was filtered off and repeatedly washed with $CHCl_3$. The combined $CHCl_3$ portions were dried over Na_2SO_4 and evaporated to give 0.43 g of crude (−)-**17** (53% purity by GLC). Chromatography on silica gel (20-fold); pentane/ether, 19:1) afforded white crystals of pure (−)-**17** (0.18 g, 79% yield from **16**): mp 121 °C; $[\alpha]_D$ −84.1° (0.04); ^{1}H NMR 0.90 + 1.03 + 1.12 + 2.10 (4 × 3 H, 4 s), 1.54 (1 H, s), ca. 1.9–2.15 (3 H, m), 2.36 (1 H, t, J = 10), 2.5 (1 H, exchangeable with D_2O), 2.58 (1 H, d, J = 10), 2.70 + 2.91 (2 ×1 H, 2 d, J = 18), 3.69 (1 H, d, J = 5); IR 3590, 3500, 1725, 1710; MS, m/e 220 (M^+, $C_{14}H_{22}O_3$–H_2O), 177, 162, 135, 109, 55, 43 (base peak).

(3a*R*,3b*S*,4*S*,6a*S*)-(−)-3,3a,3b,4,5,6,6a,7-Octahydro-4-hydroxy-3a,5,5-trimethylcyclopenta[4,5]pentalen-2-one (18). t-BuOK (30 mg, 1.26 mmol) was added to a solution of (−)-**17**, (0.05 g, 0.21 mmol) in toluene (10 mL) and t-BuOH (0.5 mL). The mixture was warmed at 40 °C for 1 h, then cooled to room temperature, and, after addition of brine, carefully extracted with $CHCl_3$. The material isolated from the organic layer was purified[5b] by chromatography over alumina with AcOEt to give 45 mg of colorless crystals of (−)-**18** (83% yield): $[\alpha]_D$ −115.4° (0.2). The ^{1}H NMR, IR and MS spectra were compatible with the data reported for (±)-**18**.[5a]

(3a*R*,3b*S*,4*S*,6a*S*,7*S*)-(−)-3,3a,3b,4,5,6,6a,7-Octahydro-4,7-dihydroxy-3a,5,5-trimethylcyclopenta[4,5]pentalen-2-one (19). (−)-**18** (41 mg, 0.14 mmol) was dissolved in isopropenyl acetate (3 mL), p-toluenesulfonic acid (5 mg) was added, and the solution was heated to 110 °C for 18 h under an argon stream. The mixture was then cooled to 0 °C, and $NaHCO_3$ solution was added. Extraction with ether and evaporation of the solvent and excess AcOEt at 10^{-2} torr gave the dienol acetate (IR 1740) as a brown oil which, without further purification, was dissolved in MeOH (5 mL) and treated with a solution (pH 3) of oxone ($2KHSO_5{\cdot}K_2SO_4{\cdot}KHSO_4$, 15 mg) and $NaHCO_3$ (2 mg) in H_2O (10 mL). After 4 h of stirring at room temperature more $NaHCO_3$ was added slowly. Extraction with $CHCl_3$ and flash chromatography (20-fold; hexane/ether, 19:1) gave (−)-**19** [19 mg, 43% yield, $[\alpha]_D$ −105.2° (0.11)]. The product was identified with an authentic sample of (±)-**19**[5a] by mixed mp, TLC, GLC, and spectral data (UV, IR, and 270-MHz ^{1}H NMR).

(−)-Coriolin. (−)-**19** was converted into (−)-coriolin by following the sequence described for the racemic material.[5a] The nonstereoselective variant[4b] for the final epoxidation step in this sequence proved in our hands superior over the selective transformation[5b,c] by using the Sharpless procedure. The mp, IR and ^{1}H NMR spectra, and the specific optical rotation of the final product, $[\alpha]_D$ −20.7° (0.03), were as reported[3b] for (−)-coriolin.

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