suggest that the small differences in total π energy may be an artifact of the calculations, it is nevertheless interesting that the π energies qualitatively parallel the observed isomer stabilities.

The Pariser–Parr–Pople calculations used here (cyanine dye parameters, fixed acetylenic bond lengths, nonconjugated bond omitted) reproduce most of the characteristics in the visible spectra of acetylenic dyes and their carbocyanine analogues. Some π-charge localization was observed in dye **1a** similar to previous suggestions made on the basis of experimental bond lengths from an x-ray crystal structure.[3a] In addition, total π energies excluding components of the triple bond in the molecular plane provide qualitative estimates of the relative stabilities of isomeric acetylenic dyes. Thus, in both a qualitative and quantitative sense, the primary differences between acetylenic dyes and their symmetrical carbocyanine analogues can be understood as a consequence of asymmetry in the conjugated π-electron chromophore.

Experimental Section

Electronic spectra were recorded using a Perkin-Elmer Model 450 spectrophotometer.

Equilibration Experiments. Solutions of the acetylenic dyes in acetonitrile, in the concentration range of $1–2 \times 10^{-5}$ M, were used. To 3 ml of dye solution was added 1–2 drops of acetic acid. Visible absorption spectra were then recorded periodically until equilibrium was attained, giving a family of absorption curves passing through an isosbestic point (the time required to reach equilibrium varied from a few minutes to several hours). The equilibrium proportion of each acetylenic dye of a pair was readily computed using the absorption curves of the two pure isomers and that of the equilibrium mixture.

Acknowledgments. The authors would like to thank Mrs. T. M. Berke and Dr. J. M. McKelvey for valuable discussions and assistance with the molecular orbital calculations, and Mr. J. T. Gefell for assistance with the equilibration experiments.

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(8) (a) Quantum Chemistry Program Exchange (Program No. 174, CNDO/M with CNDO/2 and CNDO/S options), Chemistry Department, Indiana University, Bloomington, Ind. 47401. (b) The present calculations utilized the CNDO/S options in a more recent version of CNDO/M, kindly provided by Professor H. H. Jaffé, Chemistry Department, University of Cincinnati, Cincinnati, Ohio (see ref 8c–e) and adapted for calculations on larger molecules by J. M. McKelvey and R. A. Phillips, Eastman Kodak Co., Rochester, N.Y. 14650. (c) J. DelBene and H. H. Jaffé, *J. Chem. Phys.*, **48**, 1807, 4050 (1968); **49**, 1221 (1968); **50**, 1126 (1969). (d) R. L. Ellis, G. Kuehnlenz, and H. H. Jaffé, *Theor. Chim. Acta*, **26**, 131 (1972). (e) H. M. Chang, H. H. Jaffé, and C. A. Masmandis, *J. Phys. Chem.*, **79**, 1108, 1109 (1975).
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Synthesis of 6,9-Bisnormethyl-8-methoxy-12,13-epoxy-6,8,10-trichothecatriene

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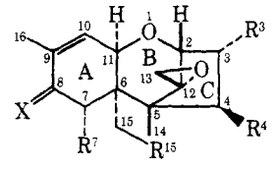
An efficient synthesis of an A-ring aromatic trichothecane analogue, 6,9-bisnormethyl-8-methoxy-12,13-epoxy-6,8,10-trichothecatriene (**11**), has been developed. The aryl allyl ether, **2**, was converted in a series of six steps to **7b** in ca. 74% overall yield. Bromination of the enolate anion of **7b**, removal of the benzyl protecting group, and cyclization (sodium hydride in ether) gave the tricyclic ketone, **9**, in very high yield. Alternatively, hydrogenolysis of **7b** followed by acetylation and bromination gave **13c**. Treatment of **13c** with DBN gave **9**. The spiro epoxide, **11**, was prepared from **9** by treatment with dimethylsulfonium methylide.

The trichothecanes are a group of sesquiterpene mycotoxins which possess the general structure **1**. Interest in this group emanates from the discovery that a number of the trichothecanes display potent activity against fungi, protozoa, viruses, and/or neoplasms. The significant mammalian toxicity which most of the trichothecanes exhibit has also been implicated as a cause of massive livestock poisoning, a result of ingestion of certain moldy foods.[1]



1

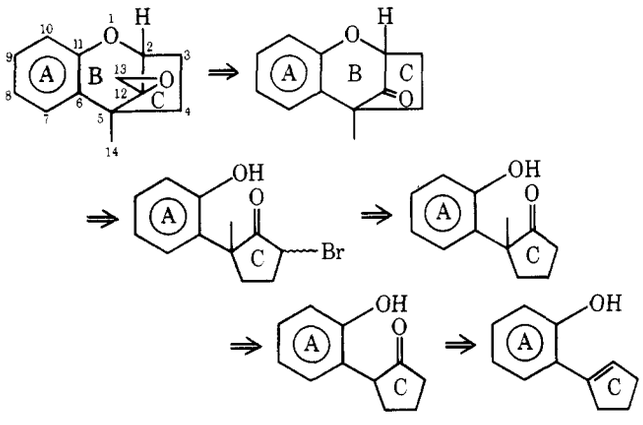
Structurally, the trichothecanes range in complexity from 12,13β-epoxytrichothec-9-ene (**1**, $R^3 = R^4 = R^7 = R^{15} = H$; X = H_2) to highly oxidized compounds such as nivalenol (**1**, $R^3 = R^4 = R^6 = R^{15} = OH$; X = O).[1] Macrocyclic lactone derivatives, bridging C-4 to C-15, are also quite common.[1] Three

trichothecane syntheses have been reported: trichodermin[2a] (1, $R^3 = R^7 = R^{15} = H$; $R^4 = OCOCH_3$; X = H_2) and 12,13β-epoxytrichothec-9-ene.[2b,3] The first two syntheses[2a,b] utilize a similar strategy insofar as the C ring is formed onto a precursor which contains the A and B rings. The most recent synthesis[3] is patterned after the proposed biosynthetic scheme for trichodermin; in this approach the bond between O-1 and C-11 is formed in a key step. All of the syntheses afford the final product in low overall yield and cannot be regarded as generally applicable for the preparation of a wide variety of compounds for thorough biological studies.

As a first step in the study of antineoplastic structure–activity requirements for the trichothecanes we examined several possible synthetic routes to this group of compounds. Our basic goal was to develop an approach which would be efficient and versatile. The versatility is required to provide synthetic approaches to a variety of trichothecanes and trichothecane analogues. We now wish to report our results in the synthesis of a trichothecane analogue which possesses an aromatic A ring.

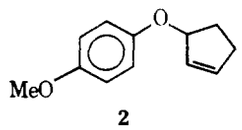
The basic strategy for the synthesis of A-ring aromatic trichothecanes is presented in Scheme I.[4] The literature

Scheme I

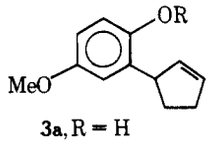


contains ample precedent for the conversion of ketones to the corresponding spiro epoxide, so the synthetic target becomes the tricyclic ketone. We chose, in our synthetic approach, to develop the tricyclic structure by an intramolecular Williamson reaction on a substrate which contained the preformed A and C rings. Thus, the first synthetic goal was to construct the 11-carbon trichothecane backbone with the A and C rings already intact. Such an approach should offer some considerable versatility in the elaboration of a variety of trichothecane analogues.

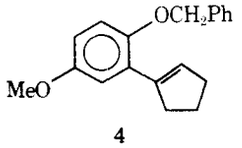
The requisite 11-carbon backbone of the A-ring aromatic trichothecane was readily assembled in two steps. Treatment of sodium *p*-methoxyphenoxide with 3-chlorocyclopentene[9] gave **2**, which, upon distillation, afforded **2** along with rearranged phenol, **3a**, in a combined yield of 70%. The thermal Claisen rearrangement of pure **2** proceeded to give **3a** in 98% yield. Attempts to isomerize the double bond in **3a**, in the



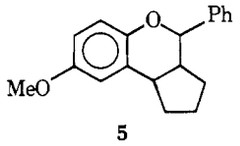
2



3a, R = H
b, R = CH_2Ph



4

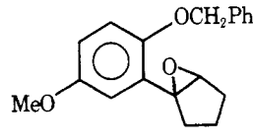


5

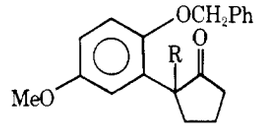
presence of the free phenol, were uniformly unsuccessful; so the phenol was converted to the benzyl ether, **3b** (96%); **3b** was smoothly converted to **4** (97%) by treatment with potassium *tert*-butoxide in Me_2SO–water.[5]

When water was omitted from the latter reaction none of the desired olefin was obtained; instead a product tentatively formulated as the chroman, **5**, was produced (90%). Support for this structure assignment was obtained when **5** was treated with hydrogen (10% Pd/C): the hydrogenolysis product, a phenol [2-(2′-benzylcyclopentyl)-4-methoxyphenol], was characterized spectroscopically.[6]

Epoxidation of **4** with *m*-chloroperbenzoic acid in a dichloromethane–aqueous sodium bicarbonate biphase system[7] gave a crystalline epoxide, **6**, in high yield (90%). The epoxide,



6

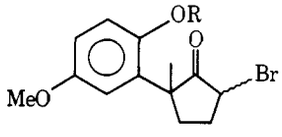


7a, R = H
b, R = Me

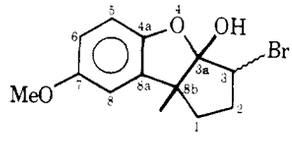
without purification, was converted to the ketone, **7a**, by treatment with boron trifluoride etherate in benzene for 1 min at 23 °C. The yield of **7a** from **4** was 89%.

The ketone, **7a**, was converted to the enolate anion by the action of sodium amide in liquid ammonia (ca. 6 h as judged by complete dissolution of starting material), then treated with excess methyl iodide to give **7b** (91%). The NMR spectrum of **7b** shows a sharp singlet at δ 1.28 for the newly introduced methyl group; absent from the NMR spectrum of **7b** was a multiplet at δ 2.90–3.42 which was assigned to the benzylic methine proton (adjacent to the carbonyl) in **7a**. Both **7a** and **7b** showed characteristic cyclopentanone IR absorption, 1745 and 1748 cm^{-1}, respectively.

Bromination of **7b** with phenyltrimethylammonium bromide perbromide (PTAB) in THF gave **8a** in only 42% yield along with *gem*-dibrominated material (ca. 25%) and unreacted starting material (ca. 25%). Pyridinium hydrobromide perbromide gave inferior results compared with PTAB. Treatment of **7b** with cupric bromide in chloroform–ethyl acetate resulted in cleavage of the benzyl group. Acetamide was added as a hydrogen bromide scavenger in an effort to avoid this cleavage; under these conditions the cupric bromide was consumed, the hydrogen bromide–acetamide complex precipitated from solution, and starting material was recovered. The preparatively useful bromination of **7b** was effected by using lithium diisopropylamide followed by bromine,[8] affording **8a** in 60% yield along with 37% of unreacted starting



8a, R = CH_2Ph
b, R = H

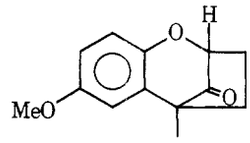


8b′

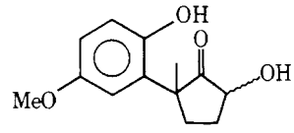
material. The separation of **8a** and **7b** was readily accomplished and the yield of **8a**, based upon recovered starting material, was 97%. No dibrominated side products were formed in this reaction when excess **7b** was used (ca. 0.68 equiv of Br_2 was used).

The benzyl group in **8a** was cleaved with anhydrous HBr in methylene chloride. The cleavage reaction proceeded to a certain point and stopped; presumably the benzyl bromide concentration reached a sufficient level such that the cleavage and rebenzylation reactions were at equilibrium. The reaction afforded **8b** in 62% yield along with 36% of recovered **8a**. Thus, the yield of **8b**, based upon the recovered starting material,

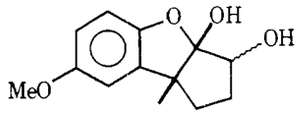
was 98%. The IR spectrum of **8b** contained no carbonyl absorption since **8b** exists as the hemiketal, **8b'**. It was possible, using medium-pressure liquid chromatography, to separate the two isomeric bromohemiketals; however, this was unnecessary since the epimeric mixture was perfectly suitable for the next step. Cyclization of **8b** with sodium hydride in anhydrous ether gave **9** in 99% yield. Considerable care had to be exercised in the handling of **9** because it showed a



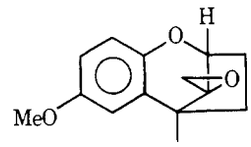
9



10



10'

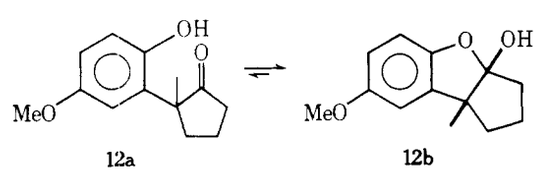


11

marked tendency to undergo hydrolytic ring opening to give **10**, particularly in the presence of acid. Both tautomeric forms of **10** could be obtained. The compound, in $CHCl_3$ solution, exists as the ketone, **10**. Dissolution of **10** in CCl_4 led to the crystallization of the less soluble hemiketal, **10'**. Spectra of **10'** could be determined in $CHCl_3$ solution provided that the spectra were recorded quickly after the solutions were prepared.

Treatment of **9** with dimethylsulfonium methylide gave the spiro epoxide, **11**, in 79% yield (based on recovered starting material). The stereochemistry of **11** is undefined. It was necessary to use an inverse addition procedure because the product spiro epoxide showed a tendency to react with the ylide to give a tertiary allylic alcohol. Formation of the tertiary allylic alcohol was quite pronounced when the ketone was added to the ylide solution. Dimsyl sodium (Me_2SO–NaH) was found to be the base of choice for generation of the ylide in this rection; when *n*-butyllithium was used a tertiary *n*-butylcarbinol was invariably formed. This latter product was observed even when excess trimethylsulfonium iodide was used and times in excess of 1 h were allowed for ylide formation.

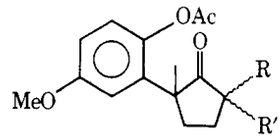
Other phenol blocking groups were examined during the course of this study. The benzyl group was removed from **7b** by hydrogenolysis (5% Pd/C); the product, **12**, existed almost exclusively as the hemiketal **12b**. The IR spectrum of **12**



12a **12b**

($CHCl_3$) showed no carbonyl absorption; however, upon the addition of a trace of triethylamine a medium intensity band appeared at 1745 cm^{-1}. Bromination of **12** with PTAB in freshly distilled anhydrous THF or with cupric bromide in chloroform–ethyl acetate yielded complex, tarry mixtures; bromination of **12** with PTAB in methylene chloride yielded 5-bromo-3a-hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran, the product of aromatic bromination ortho to the phenolic hydroxyl.

Acetylation of **12** gave the phenyl acetate, **13a**, in high yield. Bromination of **13a** with PTAB afforded the α,α-dibromo ketone, **13b**, as the major product. Treatment of **13a** with cupric bromide in chloroform yielded **13c** as the major product (72%) with only a trace (5%) of **13b**. Treatment of **13c** with



13a, R = R' = H
b, R = R' = Br
c, R = Br; R' = H

DBN effected cleavage of the phenyl acetate and cyclization in one pot and **9** was obtained in 82% yield from **13c**.

In conclusion, the series of six steps from **2** to **7b** can be carried out in ca. 74% yield with a minimum of difficulty. Three of the remaining four steps (via **8a**) require chromatography to recover starting material for recycling but the overall yield of **11** from **2** (ten steps, via **8a**) is 55%. The synthesis is relatively simple to carry out and is versatile. The alternate synthesis of **9** from **7b** (via **12**) adds an additional step and the overall yield of **11** from **2** is reduced to 43%; however, the simplicity of the procedures involved affords some merit to this approach. Other phenols have been reacted with 3-chlorocyclopentene to give analogues of **2** which also readily undergo Claisen rearrangement; these intermediates will provide a series of compounds with a range of A-ring functionality. The intermediates **7a** and **8a** are particularly well suited for elaboration of necessary C-ring functionality; this work is in progress. Finally, this approach may also be employed for the synthesis of trichothecanes which possess an aliphatic A ring; the stereochemistry of the substituents at C-5 and C-6 (cf., **1**) can be controlled in the initial Claisen rearrangement and this work will be the subject of a forthcoming communication.

Experimental Section

NMR spectra were determined for solutions in CCl_4 (unless otherwise specified), containing ca. 1% Me_4Si as internal standard, with a Varian T-60 spectrometer. IR spectra were determined for neat samples (unless otherwise specified) with a Perkin-Elmer 237 spectrophotometer. UV data were determined for solutions in 95% ethanol (unless otherwise specified) with a Beckman DB-G spectrophotometer. Mass spectra were determined by the NIH Biomedical Technology Center at Cornell University. Melting points are uncorrected and were determined in capillary tubes with a Hoover-Thomas Unimelt apparatus. Microanalyses were performed by Galbraith Laboratories, Knoxville, Tenn., and by Atlantic Microlab, Inc., Atlanta, Ga.

3-(*p*-Methoxyphenyloxy)cyclopentene (2). A solution of sodium ethoxide was prepared by gradual addition of sodium metal (23.0 g, 1.0 mol) to absolute ethanol (500 ml). The reaction mixture was allowed to cool to room temperature and *p*-methoxyphenol (124 g, 1 equiv) was added with vigorous stirring. The reaction mixture was allowed to stir for at least 1 h before being used in the subsequent reaction. The vigorously stirred suspension of sodium *p*-methoxyphenoxide in absolute ethanol was cooled to −45 °C (dry ice in chloroform–carbon tetrachloride, 1:1) and freshly prepared 3-chlorocyclopentene (102 g, 1.0 mol) was slowly added. The pH of the reaction mixture was continuously monitored (pH test paper) to ensure that the reaction remained basic. Water was added to the cooling bath and the temperature of the reaction mixture was permitted to increase to −4 °C (over ca. 1 h). (If the temperature was allowed to rise above ca. 5–7 °C, the reaction became uncontrollably exothermic with reaction temperature going over 30 °C. The reaction mixture then turned a greenish-blue color and was found to be very acidic—lower isolated yields resulted.) Anhydrous K_2CO_3 (138.2 g, 1.0 mol) was added (addition of anhydrous K_2CO_3 was made at lower temperatures only if the reaction mixture was found to have a pH of 7 or less) and the mixture was maintained below 0 °C for 5 h. The temperature was allowed to slowly increase to 15 °C after which careful monitoring of the reaction temperature was no longer essential. (Any indication of a sudden exothermic reaction required recooling of the reaction mixture to 0 °C for an additional 2 h.) The reaction mixture was stirred at room temperature for 36 h and filtered through Celite. The inorganic residue was thoroughly washed with acetone and the combined filtrate was concentrated in vacuo (below 50 °C). (It was es-

sential to monitor the pH of the filtrate and the various residues; any indication of acidity required the addition of K_2CO_3 to achieve neutralization or slight alkalinity.) The residue was dissolved in ether (1 l.), washed with 5% KOH solution (7 × 250 ml), water (1 × 250 ml), and saturated NaCl solution (1 × 500 ml), and dried (anhydrous Na_2SO_4). The ethereal solution was concentrated in vacuo and the residue was distilled in the presence of anhydrous K_2CO_3 (20% of the weight of the residue) under the lowest pressure possible. (In reactions where more than 1 mol of 3-chlorocyclopentene was employed the residue was divided according to the number of moles used and was distilled separately in the presence of anhydrous K_2CO_3.) Fluctuations in vacuum typically occurred when the pot temperature reached 160 °C; however, a gradual return to the original vacuum occurred. (In one instance where starting phenol was not removed, prolonged and continual reductions in vacuum occurred and complete destruction of product resulted.)

Distillation of the crude product gave **2** (77.8 g, 41%) and **3a** (55.7 g, 29%). 3-(*p*-Methoxyphenoxy)cyclopentene (**2**) had bp 115–120 °C (0.4 Torr); IR 969, 889, 824, 790, and 756 cm^{-1}; UV max 223 nm (ϵ 3650) and 291 (2590); NMR δ 1.87–2.57 (m, 4), 3.75 (s, 3), 5.10–5.33 (m, 1), 5.83–6.12 (m, 2), and 6.77 (s, 4).

Anl. Calcd for $C_{12}H_{14}O_2$: C, 75.76; H, 7.42. Found: C, 75.79; H, 7.46.

2-(3′-Cyclopentenyl)-4-methoxyphenol (3a). A mixture of **2** (91.9 g, 0.483 mol) and anhydrous K_2CO_3 (9.2 g) was heated at 185 °C for 30 min (N_2 atmosphere) and distilled to yield 90.1 g of **3a** (98%): bp 110 °C (0.28 Torr); IR 3356 cm^{-1}; UV max 226 nm (ϵ 3760) and 271 (3310); NMR δ 1.43–2.73 (m, 4), 3.63 (s, 3), 3.79–4.32 (m, 1), 4.80 (s, 1, –OH), 5.61–6.07 (m, 2), and 6.52 (s, 3).

Anal. Calcd for $C_{12}H_{14}O_2$: C, 75.76; H, 7.42. Found: C, 75.96; H, 7.49.

2-(3′-Cyclopentenyl)-1-benzyloxy-4-methoxybenzene (3b). A stirred mixture of **3a** (12.38 g, 0.65 mmol), anhydrous K_2CO_3 (17.97 g, 130 mmol), and benzyl bromide (33.35, 195 mmol) in acetone (100 ml) was heated under reflux for 51 h. The cooled reaction mixture was filtered, the precipitate was washed with acetone (2 × 100 ml), and the combined acetone solution was concentrated in vacuo. The residue was dissolved in ether (500 ml) and the ethereal solution was washed with water (100 ml) and saturated NaCl solution (100 ml), dried (Na_2SO_4), and concentrated in vacuo. Anhydrous K_2CO_3 (1.3 g) was added and the residue was distilled to yield 17.5 g (96%) of **3b:** bp 163 °C (0.35 Torr); IR 1587, 917, 876, 855, 800, 735, and 696 cm^{-1}; UV max 232 nm (ϵ 4750) and 290 (3080); NMR δ 1.47–2.73 (m, 4), 3.67 (s, 3), 4.10–4.57 (m, 1), 4.98 (s, 2), 5.62–6.07 (m, 2), 6.48–6.82 (m, 3), and 7.33 (s, 5).

Anal. Calcd for $C_{19}H_{20}O_2$: C, 81.39; H, 7.19. Found: C, 81.29; H, 7.21.

2-(1′-Cyclopentenyl)-1-benzyloxy-4-methoxybenzene (4). Potassium *tert*-butoxide (11.8 g, 0.11 mol) was added to Me_2SO (120 ml) with stirring; the solution was stirred for 30 min and Me_2SO was added to bring the volume to 150 ml. The mixture was treated with water (7.5 ml) and **3b** (17.56 g, 62.6 mmol), then heated at 95 °C for 1.5 h. The cooled mixture was diluted with water (1.5 l.) and extracted with ether (600 ml) in a liquid–liquid extraction apparatus. The ethereal solution was washed with water and saturated NaCl solution, dried (Na_2SO_4), and concentrated in vacuo. The residue was dried under high vacuum (P_2O_5) for 8 h and crystallized from petroleum ether to yield 16.98 g (97%) of **4:** mp 57–58 °C; IR 957, 909, 870, 851, and 694 cm^{-1}; UV max 224 nm (ϵ 10 500) and 310 (3170); NMR δ 1.63–2.93 (m, 6), 5.00 (s, 2), 6.27–6.42 (m, 1), 6.45–6.88 (m, 3), and 7.33 (s, 5).

Anal. Calcd for $C_{19}H_{20}O_2$: C, 81.39; H, 7.19. Found: C, 81.40; H, 7.23.

1,2,3,3a,4,9a-Hexahydro-4-phenyl-8-methoxycyclopenta[*c*]-benzofuran (5). Potassium *tert*-butoxide (121.1 g, 1.05 mol) was added to anhydrous Me_2SO (1.4 l. with stirring); after 30 min Me_2SO was added to bring the volume to 1.5 l. and **3b** (168.0 g, 0.672 mol) was added to the stirred solution at room temperature. The mixture was heated for 1.5 h at 85 °C, cooled, diluted with water (6 l.), and extracted with ether (1.5 l.) in a liquid–liquid extraction apparatus. The ethereal solution was washed with water (3 l.) and saturated NaCl solution (500 ml), dried (Na_2SO_4), and concentrated in vacuo. The residue was crystallized from anhydrous ether to yield 151.2 g (90%) of **5:** mp 106.5–107.5 °C; IR (KBr) 999, 865, 824, 772, 748, 714, and 704 cm^{-1}; UV max 230 nm (ϵ 6240) and 293 (3620); NMR δ 1.30–2.07 (m, 6), 2.13–2.63 (m, 1), 2.80–3.16 (m, 1), 3.73 (s, 3), 4.26 (d, 1, J = 10 Hz), 6.65 (s, 3), and 7.34 (s, 5).

Anal. Calcd for $C_{19}H_{20}O_2$: C, 81.39; H, 7.19. Found: C, 81.30; H, 7.19.

2-(2′-Benzylcyclopentyl)-4-methoxyphenol. A mixture of **5** (0.5 g, 1.76 mmol) and 10% Pd/C (0.5 g) in ethyl acetate (6.0 ml) was stirred under a hydrogen atmosphere for 4 days. The mixture was filtered (Celite bed) and the residue was washed with ethyl acetate (30 ml). The combined ethyl acetate solution was concentrated in vacuo and the residue was purified by TLC (silica gel–benzene) to give 2-(2′-benzylcyclopentyl)-4-methoxyphenol (97%): mp (crystallized from ether) 95–96 °C; IR 3425, 1043, 872, and 695 cm^{-1}; UV max 225 nm (ϵ 6080) and 296 (3640); UV max (NaOH in 95% ethanol) 257 nm (ϵ 2510) and 316 (5150); NMR δ 1.16–3.00 (m, 9), 3.26–3.86 [m, 4 (CH_3O, s, 3.78)], 4.80 (s, 1, OH), 6.60–6.93 (m, 3), and 7.37 (s, 5).

Anal. Calcd for $C_{19}H_{22}O_2$: C, 80.81; H, 7.85. Found: C, 80.54; H, 7.86.

1-(2′-Benzyloxy-5′-methoxyphenyl)-1,2-epoxycyclopentane (6). A stirred mixture of **4** (11.2 g, 40.0 mmol), dichloromethane (400 ml), and 0.5 M aqueous $NaHCO_3$ (120 ml) was cooled to 8 °C and slowly treated with solid *m*-chloroperbenzoic acid (85%, 8.12 g, 40.0 mmol) such that the temperature never rose above 10 °C. The cooling bath was removed and the reaction was allowed to warm to room temperature over 3.5 h (peracid consumption was monitored with potassium iodide–starch test paper). The organic phase was separated, washed with 10% aqueous Na_2SO_3 solution (120 ml), dried (Na_2SO_4), and concentrated in vacuo below 35 °C. The residue was dried over a high vacuum (P_2O_5) for 30 min and used directly in the subsequent reaction. The NMR spectrum of the crude product showed no trace of unreacted **4:** NMR δ 1.23–2.47 (m, 6), 3.33 (s, 1), 3.77 (s, 3), 5.03 (s, 2), 6.67–7.07 (m, 3), and 7.37 (s, 5).

2-(2′-Benzyloxy-5′-methoxyphenyl)cyclopentanone (7a). The crude epoxide obtained from the previous reaction was dissolved in anhydrous benzene (400 ml) and the stirred solution was treated with freshly distilled boron trifluoride etherate [2.4 ml (2.77 g), 20 mmol]. After 1 min at 23 °C the reaction was quenched with saturated aqueous Na_2CO_3 (100 ml) and stirred for 5 min. The pale yellow solution, which turned dark green upon the addition of the boron trifluoride etherate, returned to its original color ca. 1 min after the reaction was quenched. The organic phase was separated, washed with water (100 ml) and saturated NaCl solution (100 ml), dried (Na_2SO_4), and concentrated in vacuo to yield 10.5 g (94%) of **7a.** Crystallization from a small quantity of anhydrous ether yielded 9.97 g (89%) of **7a:** mp 100–101.5 °C; IR (CCl_4) 1745 cm^{-1}; UV max 217 nm (ϵ 6310), 228 (6210), and 291 (2680); NMR δ 1.55–2.60 (m, 6), 2.90–3.42 (m, 1), 3.70 (s, 3), 4.88 (s, 2), 6.48–6.88 (m, 3), and 7.33 (m, 5).

Anal. Calcd for $C_{19}H_{20}O_3$: C, 77.00; H, 6.80. Found: C, 76.86; H, 6.89.

2-Methyl-2-(2′-benzyloxy-5′-methoxyphenyl)cyclopentanone (7b). 2-(2′-Benzyloxy-5′-methoxyphenyl)cyclopentanone (**7a,** 25.85 g, 87.2 mmol) was added to a suspension of sodium amide (10.2 g, 261.6 mmol) in liquid ammonia (2.5 l.) with vigorous stirring. The reaction mixture was stirred for 6.5 h in refluxing ammonia until the initially cloudy suspension became a yellow-green transparent solution. Methyl iodide (37.15 g, 261.6 mmol) was added rapidly with stirring. The reaction mixture was stirred for an additional 2.5 h and anhydrous ether (1 l.) was added. The reaction mixture was allowed to stand without stirring until all of the liquid ammonia was distilled from the reaction (24 h). Ether was added to bring the volume to 1.25 l. and the ethereal solution was washed with water (3 × 500 ml), dried (Na_2SO_4), and concentrated in vacuo. The residue was thrice crystallized from anhydrous ether to yield 24.6 g (91.0%) of 2-methyl-2-(2′-benzyloxy-5′-methoxyphenyl)cyclopentanone (**7b**): mp 95–96 °C; IR (CCl_4) 1748 cm^{-1}; UV max 220 nm (ϵ 6780), 229 (7310), and 290 (3260); NMR δ 1.28 (s, 3), 1.47–2.43 (m, 6), 3.75 (s, 3), 4.89 (s, 2), 6.52–6.93 (m, 3), and 7.37 (s, 5).

Anal. Calcd for $C_{20}H_{22}O_3$: C, 77.39; H, 7.14. Found: C, 77.39; H, 7.17.

5-Bromo-2-methyl-2-(2′-benzyloxy-5′-methoxyphenyl)cyclopentanone (8a). Method A. 2-Methyl-(2′-benzyloxy-5′-methoxyphenyl)cyclopentanone (**7b,** 1.00 g, 3.22 mmol) was added to a stirred solution of phenyltrimethylammonium perbromide (1.30 g, 3.45 mmol) in dry tetrahydrofuran (25 ml) at room temperature. The orange reaction mixture gradually became colorless as the white phenyltrimethylammonium bromide precipitated from solution and after 2.5 h the reaction mixture was filtered and concentrated in vacuo. The residue was purified by column chromatography (silica gel, methylene chloride) to give **7b** (0.3 g, 30%), **8a** (0.53 g, 42%), and 5,5-dibromo-2-methyl-2-(2′-benzyloxy-5′-methoxyphenyl)cyclopentanone (0.39 g, 25%). **8a** had mp 91–92 °C (crystallized from ether); IR (KBr) 1757 cm^{-1}; UV max 238 nm (ϵ 4700) and 294 (3280); NMR δ 1.43 (s, 3), 1.60–2.67 (m, 4), 3.63–4.10 [m, 4 H (OCH_3, s, 3.76)], 4.82 and 5.07 (br d of d, J = 4 Hz, 2), 6.53–6.93 (m, 3), and 7.41 (s, 5); mass spectrum *m/e* (rel abundance) $M^+ + 2$ 390 (27), M^+ 388 (29), 299 (7), 297 (7), 218 (54), 177 (14), 162 (22), 91 (100), and 77 (6).

Anal. Calcd for $C_{20}H_{21}BrO_3$: C, 61.71; H, 5.44; Br, 20.53. Found: C, 61.70; H, 5.46; Br, 20.64.

Method B. A solution of *n*-butyllithium in hexane (8.18 ml of 1.3 M solution 106.3 mmol) was added (via syringe through a rubber injection septum) to a magnetically stirred solution of freshly distilled diisopropylamine (10.76 g, 106.3 mmol) in THF (300 ml, freshly distilled over $LiAlH_4$) maintained at −78 °C under a N_2 atmosphere. After 15 min a solution of **7b** (30.0 g, 96.65 mmol) in anhydrous THF (100 ml) was injected and the mixture was stirred at −78 °C for 30 min. At this point the white, heterogeneous mixture was treated with a 0.5 M solution of bromine in methylene chloride—the bromine solution was added rapidly until the mixture was a homogeneous, pale yellow color (131 ml, 65.6 mmol, of Br_2 was added; this corresponded to 68% of the stoichiometric requirement of Br_2). Further addition of Br_2 led to formation of dibrominated product. Immediately following the addition of bromine the cooling bath was removed and the reaction was quenched with a twofold excess of aqueous $NaHCO_3$ (17.8 g, 0.212 mmol, in 100 ml of H_2O). The cold THF layer was separated and washed with saturated NaCl solution (2 × 250 ml); the aqueous $NaHCO_3$ phase was extracted with ether (2 × 250 ml) and the ethereal solution was washed with the brine solution from the previous washing. The combined THF–ether solution was dried (Na_2SO_4) and concentrated in vacuo to yield 35.7 g of a semisolid yellow oil. Silica gel chromatography (CH_2Cl_2) afforded 22.73 g (60%) of **8a** along with 11.16 g (37%) of recovered **7b.**

3-Bromo-3a-hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran (8b). A stirred solution of **8a** (15.8 g, 40.59 mmol) in CH_2Cl_2 (200 ml, purified through a basic alumina I column) was treated at room temperature with anhydrous HBr (via a gas dispersion tube) and maintained at a positive pressure of ca. 5 psi for 4 h. The reaction was monitored by TLC (silica gel/CH_2Cl_2) and after 4 h the reaction was at equilibrium. The mixture was concentrated in vacuo and the residue was placed under vacuum (continuous pumping at ca. 0.3 mm) for 1 h to remove the benzyl bromide. The residue was dissolved in CH_2Cl_2 and the entire process was repeated to give 16.1 g of a dark green oil. Silica gel chromatography gave 7.526 g (62%) of **8b** and 5.66 g (36%) of recovered **8a.** The epimeric mixture of **8b** had UV max 297 nm (ε 3910) and 231 (5750).

Anal. Calcd for $C_{13}H_{15}O_3Br$: C, 52.19; H, 5.05; Br, 26.71. Found: C, 52.37; H, 5.08, Br, 26.81.

The epimeric mixture was separated using medium-pressure liquid chromatography (silica gel H/CH_2Cl_2). The major isomer, ca. 60% of the mixture, was a solid and was crystallized from CH_2Cl_2: mp 78–79 °C; IR (CCl_4) 3584, 2941, 2865, 2833, 1548, 1490, 1284, 1214, 1182, 1036, 939, and 909 cm^{-1}; NMR δ 1.45 (s, 3), 1.73–2.60 (m, 4), 3.58–3.70 (br s, 1), 3.72 (s, 3), 4.37–4.62 (m, 1), and 6.47–6.72 (m, 3). The minor isomer was an oil: IR (CCl_4) 3571, 3425, 2950, 2865, 2833, 1773, 1548, 1490, 1250, 1212, 1135, 1031, 939, and 862 cm^{-1}; NMR δ 1.35 (s, 3), 1.63–2.28 (m, 4), 3.57 (s, 1), 3.73 (s, 3), 3.93–4.30 (br d of d, 1), and 6.48–6.75 (m, 3).

Synthesis of the Tricyclic Ketone, 9. Method A. A stirred suspension of NaH (98%, 0.2 g, 8.33 mmol) in anhydrous ether (15 ml), under a nitrogen atmosphere, was treated with a solution of **8b** (1.5 g, 5.014 mmol) in anhydrous ether (2 ml). After 18 h at room temperature the reaction mixture was filtered through analytical Celite and concentrated to dryness. It was absolutely essential to remove the last traces of ether from the crude product and to exclude any trace of water. The crude yellow oil was purified by silica gel chromatography (anhydrous $CHCl_3$) to yield 1.083 g (99%) of **9** as a colorless oil: IR (CCl_4) 3700–3200 (no absorption), 2941, 2865, 2760, 1770, 1613, 1585, 1488, 1385, 1198, 1042, 1022, 953, and 864 cm^{-1}; UV max 296 nm (ε 3363) and 233 (5698); NMR δ 1.32 (s, 3), 1.58–2.55 (m, 4), 3.65 (s, 3), 3.88–4.18 (d of d, 1), and 6.35–6.68 (m, 3).

Anal. Calcd for $C_{13}H_{14}O_3$: C, 71.54; H, 6.47. Found: C, 71.61; H, 6.51.

Method B. DBN (0.25 g, 2.0 mmol)[10] was added to a stirred solution of 5-bromo-2-methyl-2-(2′-acetoxy-5′-methoxyphenol)cyclopentanone (**13c,** 0.673 g, 1.972 mmol) in anhydrous benzene (10 ml). The solution was stirred for 15 min at room temperature and concentrated in vacuo. The residue was purified by silica gel chromatography (CH_2Cl_2) to yield 0.353 g (82%) of **9.**

5-Hydroxy-2-methyl-2-(2′-hydroxy-5-methoxyphenyl)cyclopentanone (10) and 3,3a-Dihydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran (10′). The ketone **9** was unstable in the presence of water and underwent hydrolytic ring opening to give **10:** IR 3344, 1757 (C=O), 1070, 1036, 1018, 952, 869, 844, and 803 cm^{-1}; NMR ($CDCl_3$) δ 1.42 (s, 3), 1.50–2.70 [m, 6 (2-OH)], 3.82 (s, 3), 4.20–4.33 (m, 1), and 6.60–6.83 (m, 3). Crystallization of **10** from $CHCl_3$ (or CCl_4) afforded the hemiketal **10′:** mp 110.5–111.5 °C; IR ($CHCl_3$, taken quickly after the solution was prepared) 3333, 1079, 1071, 1036, 1010, 957, 923, 879, 853, and 806 cm^{-1}; NMR ($CDCl_3$, taken quickly after the solution was prepared) δ 1.37 (s, 3), 1.77–2.30 (m, 4), 3.20 (s, 1, –OH), 3.63 (s, 1, –OH), 3.83 (s, 3), 4.17–4.30 (m, 1), and 6.80 (s, 3); mass spectrum *m/e* (rel abundance) $M^+ - 236$ (5), 218 (100), 190 (6), 189 (3), 175 (16), 174 (1), 162 (54), 147 (8), and 91 (11).

Anal. Calcd for $C_{13}H_{16}O_4$: C, 66.09; H, 6.83. Found: C, 65.95; H, 6.85.

6,9-Bisnormethyl-8-methoxy-12,13-epoxy-6,8,10-trichothecatriene (11). A stirred mixture of NaH (98%, 0.11 g) in Me_2SO (10 ml, dried and distilled over CaH_2) was heated at 71 °C (N_2 atmosphere) for 7 h. The resultant gray solution, 4.58 mmol of dimethylsulfonium methylide, was cooled to room temperature, THF (10 ml, dried and distilled over $LiAlH_4$) was added, and the solution was cooled to −10 °C. Trimethylsulfonium iodide (0.935 g, 4.58 mmol) dissolved in anhydrous Me_2SO (0.5 ml) was added and the mixture was stirred for 10 min at −10 to −5 °C. The ylide solution was transferred, via a double-tipped 18 gauge 24-in. stainless steel flexible needle (both flasks were equipped with rubber septum inlets), to a stirred solution of **9** (1.0 g, 4.58 mmol) in THF (5 ml, distilled over $LiAlH_4$) which was cooled to −10 °C and kept under a purge of N_2. The inverse addition of the ylide and the washing was completed in ca. 2 min. The mixture was stirred at −5 °C for 1 h, then the temperature was allowed to rise to room temperature. The THF was removed under a stream of N_2, and the Me_2SO solution was diluted with five volumes of H_2O and extracted with ether (3 × 50 ml). The ethereal solution was washed with water (20-ml portions) until the ethereal solution was neutral. The ether was removed in vacuo, and the residue was dissolved in $CHCl_3$ (50 ml) and dried (Na_2CO_3). The solution was concentrated in vacuo to yield 0.851 g of a yellow oil which was purified by silica gel chromatography to yield 0.34 g (33%) of recovered **9** and 0.479 g (46%) of **11:** mp 89.5–90.5 °C; IR ($CHCl_3$) 3050, 2960, 2930, 2865, 2833, 2247, 1622, 1591, 1493, 1468, 1328, 1258, 1209, 1202, 1148, 1044, 1034, 979, and 811 cm^{-1}; UV max 295 nm (ε 3630) and 232 (6453); NMR ($CDCl_3$) δ 1.16 (s, 3), 1.74–2.39 (m, 4), 2.91 (d, J_{AB} = 5 Hz, 1), 3.20 (d, J_{AB} = 5 Hz, 1), 3.73 (s, 3), 4.12 (br s, 1), and 6.55–6.91 (m, 3).

Anal. Calcd for $C_{14}H_{16}O_3$: C, 72.39; H, 6.94. Found: C, 72.41; H, 6.95.

***cis*-3a-Hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran (12).** A suspension of 5% Pd/C (0.60 g) in ethyl acetate (200 ml) was allowed to equilibrate over a hydrogen atmosphere for 2.5 h. A solution of 2-methyl-2-(2′-benzyloxy-5′-methoxyphenyl)cyclopentanone (**7b,** 1.24 g, 3.99 mmol) in ethyl acetate (15 ml) was added to this suspension. Hydrogen uptake ceased after 109.0 ml (4.87 mmol) was absorbed (20 h). The reaction mixture was filtered through Celite and the inorganic residue was washed with ethyl acetate (100 ml). The combined ethyl acetate solution was concentrated in vacuo. The oily residue was dried under high vacuum, and the residue crystallized slowly from the neat oil (either by scratching when chilled at 0 °C or by addition of seed crystals) to quantitatively yield *cis*-3a-hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran (**12**): mp 54.5–57 °C; IR 3390 and 1721 cm^{-1}; UV max 228 nm (ε 3360) and 298 (3130); NMR δ 1.24 (s, 3), 1.30–2.40 (m, 6), 2.93–3.27 (m, 1, OH), 3.67 (s, 3), and 6.50 (s, 3).

Anal. Calcd for $C_{13}H_{16}O_3$: C, 70.89; H, 7.32. Found: C, 70.75; H, 7.35.

***cis*-5-Bromo-3a-hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran.** Crystalline *cis*-3a-hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran (**12,** 110.0 mg, 0.5 mmol) was added to a solution of phenyltrimethylammonium perbromide (188 mg, 0.5 mmol) in methylene chloride (7 ml) with stirring at room temperature. The orange-colored solution became colorless after 4.5 h. The reaction mixture was concentrated in vacuo at temperatures below 50 °C and the residue was extracted with hot anhydrous ether (5 × 25 ml). The ethereal solution was dried (Na_2SO_4) and concentrated in vacuo. The residue was purified by preparative TLC (silica gel–methylene chloride) to give exclusively *cis*-5-bromo-3a-hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran: IR 3436 cm^{-1}; UV max 221 nm (ε 5850) and 304 (4060); NMR δ 1.17–2.63 [m, 9 (CH_3, s, 1.35)], 3.49 (s, 1, OH), 3.77 (s, 1), 6.57 (d, 1 J_m = 3 Hz), and 6.80 (d, 1).

Anal. Calcd for $C_{13}H_{15}BrO_2$: C, 52.16; H, 5.08, Br, 26.61. Found: C, 52.19; H, 5.05; Br, 26.71.

Method A. 2-Methyl-2-(2′-acetoxy-5′-methoxyphenyl)cyclopentanone (13a). A mixture of *cis*-3a-hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran (**12,** 13.4

g, 60.8 mmol) and dry sodium hydride (1.6 g, 67 mmol) in anhydrous ether (125 ml) was stirred under a nitrogen atmosphere at room temperture for 1 h. The dark yellow mixture was cooled to −30 °C and acetyl chloride (9.6 g, 122 mmol) was added with vigorous stirring. Five minutes after the addition was completed the cooling bath was removed and 1% aqueous HCl (100 ml) was added. The ethereal phase was separated and the aqueous phase was washed with ether (2 × 100 ml); the combined ethereal solution was washed with saturated aqueous NaCl solution (50 ml), dried (Na_2SO_4), and concentrated under high vacuum to give an oily solid. The product was crystallized from isopropyl ether to give 13.7 g of **13a**. The mother liquor was concentrated and an additional 1.7 g of **12** was obtained. The yield of **13a** based on recovered starting material was 98%: mp 83–84 °C; IR (CCl_4) 1770 and 1742 cm^{-1}; UV max 239 nm (ε 3390) and 282 (2010); NMR δ 1.27 (s, 3), 1.60–2.42, [m, 9 ($COCH_3$, 3, 2.14)], and 6.47–7.06 (m, 3).

Anal. Calcd for $C_{15}H_{18}O_4$: C, 68.68; H, 6.92. Found: C, 68.67; H, 6.95.

Method B. A solution of **12** (7.0 g, 26.7 mmol) in pyridine (100 ml) was stirred for 30 min, acetic anhydride (20 ml, 212 mmol) was added, and the reaction mixture was stirred for 10 days at room temperature. The mixture was concentrated in vacuo and the residual pyridine was removed by azeotropic distillation with toluene. The residue was dried and crystallized from isopropyl ether to yield 6.95 g (83%) of **13a**.

5,5-Dibromo-2-methyl-2-(2′-acetoxy-5′-methoxyphenyl)cyclopentanone (13b). 2-Methyl-2-(2′-acetoxy-5′-methoxyphenyl)-cyclopentanone (**13a**, 310 mg, 1.10 mmol) was added to a solution of phenyltrimethylammonium perbromide (460 mg, 1.22 mmol) in CH_2Cl_2 (25 ml) with stirring at room temperature. The orange-colored solution became colorless after 3 h. The reaction mixture was concentrated in vacuo at temperature below 35 °C and the residue was extracted with hot anhydrous ether (5 × 25 ml). The ethereal solution was washed with water (50 ml) and saturated NaCl solution (50 ml), dried (Na_2SO_4), and concentrated in vacuo. The residue was found by NMR to contain some starting material and monobrominated product in addition to the major product, the α,α-dibrominated material. The residue was purified by preparative TLC (silica gel, methylene chloride) to give 5,5-dibromo-2-methyl-2-(2′-acetoxy-5′-methoxyphenyl)cyclopentanone (**13b**): IR 1767 cm^{-1}; UV max 232 nm (ε 5580) and 281 (2020); NMR δ 1.47 (s, 3), 1.85–2.52 [m, 5 ($COCH_3$, s, 2.20)], 2.70 (q, 2, $J_{4,3}$ = 6 Hz), 3.70 (s, 3), and 6.52–7.02 (m, 3).

Anal. Calcd for $C_{15}H_{16}Br_2O_4$: C, 42.88; H, 3.84; Br, 38.04. Found: C, 42.90; H, 3.85; Br, 37.94.

5-Bromo-2-methyl-2-(2′-acetoxy-5′-methoxyphenyl)cyclopentanone (13c). A mixture of $CuBr_2$ (3.13 g, 0.014 mol) and 2-methyl-2-(2′-acetoxy-5′-methoxyphenyl)cyclopentanone (**13a**, 2.10 g, 0.008 mol), in ethyl acetate (25 ml) and $CHCl_3$ (25 ml) was heated to reflux. The dark green reaction mixture changed to light amber and the black cupric bromide was converted to white cuprous bromide; after 1.5 h the reaction mixture was cooled and filtered, and the copper salt washed with ethyl acetate (100 ml). The filtrate was concentrated in vacuo (below 50 °C) and the residue was purified by column chromatography (silica gel, methylene chloride) to yield 1.73 g (72%) of 5-bromo-2-(2′-acetoxy-5′-methoxyphenyl)cyclopentanone (**13c** as a mixture of α-bromo epimers): IR 1786 cm^{-1}; UV max 230 nm (ε 3770) and 282 (1330); NMR δ 1.37 (minor epimer, s), 3.77 (s, 3), 4.17–4.73 (m, 1), and 6.00–7.04 (m, 3); mass spectrum *m/e* (rel abundance) M^+ + 2 342 (14), M^+ 340 (14), 300 (96), 298 (100), 219 (16), 218 (9), 201 (13), 191 (11), 177 (21), 175 (9), 165 (9), 164 (76), 162 (15), 161 (11), 149 (14), 91 (18), 55 (77), and 43 (56).

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Registry No.—**2,** 61076-47-9; **3a,** 61076-48-0; **3b,** 61076-49-1; **4,** 61076-50-4; **5,** 61076-51-5; **6,** 61076-52-6; **7a,** 61076-53-7; **7b,** 61076-54-8; **8a,** 61076-55-9; **8b′** isomer 1, 61076-56-0; **8b′** isomer 2, 61117-29-1; **9,** 61076-57-1; **10,** 61076-58-2; **10′,** 61076-59-3; **11,** 61104-49-2; **12b,** 61076-60-6; **13a,** 61076-61-7; **13b,** 61076-62-8; **13c** isomer, 61076-63-9; **13c** isomer 2, 61076-64-0; *p*-methoxyphenol, 150-76-5; 3-chlorocyclopentene, 96-40-2; benzyl bromide, 100-39-0; 2-(2′-benzylcyclopentyl)-4-methoxyphenol, 61076-65-1; *m*-chloroperbenzoic acid, 937-14-4; methyl iodide, 74-88-4; phenyltrimethylammonium perbromide, 4207-56-1; 5,5-dibromo-2-methyl-2-(2′-benzyloxy-5′-methoxyphenyl)cyclopentanone, 61076-66-2; dimethylsulfonium methylide, 6814-64-8; *cis*-5-bromo-3a-hydroxy-7-methoxy-8b-methyl-2,3,3a,8b-tetrahydro-1*H*-cyclopenta[*b*]benzofuran, 61076-67-3; acetyl chloride, 75-36-5; acetic anhydride, 108-24-7.

References and Notes

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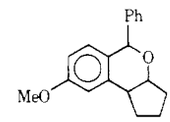
(4) The numbering system adopted for the A-ring aromatic trichothecanes is that which is used for the naturally occurring trichothecanes.

(5) A mixture of KOH, *t*-BuOH, Me_2SO, and H_2O (apparently equivalent to the mixture of KO-*t*-Bu, Me_2SO, and water) was very much inferior in effecting the isomerization of **3b** to **4.**

(6) The isolation of 2-(2′-benzylcyclopentenyl)-4-methoxyphenol from the hydrogenolysis of **5** rules out a structural alternative to **5,** namely i. Formation of i could have been rationalized on the basis of an initial Wittig rearrangement followed by an intramolecular cyclization.



i

(7) (a) W. K. Anderson and T. Veysoglu, *J. Org. Chem.*, **38,** 2267 (1973). (b) Epoxidation of **4** with *m*-chloroperbenzoic acid in dichloromethane over solid sodium carbonate gave <50% of **6** along with a variety of epoxide ring-opened products. Similar poor results were obtained with trifluoroperacetic acid and peracetic acid oxidation of **4.**

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(10) IR spectra of the DBN used in this experiment showed that it contained water.