yellow orange. After complete addition, the solution was warmed to −10 °C for 30 min, then was rechilled to −40 to −50 °C, and finally was carefully quenched in 250 ml of ice water. After complete hydrolysis, the pale yellow organic layer was dissolved in methylene dichloride, dried ($MgSO_4$), and the solvent distilled off. The residual oil crystallized to give 16.5 g (77%) of crude product which was recrystallized from hexane to afford pure **6** (R = Cl): mp 77.5–78 °C; ir (mull) 1805 (C=O), 1597, 1590, 1572 cm^{-1} (C=C); NMR (CCl_4) ^1H δ 7.5–8.1 (m), ^{19}F ϕ −110.5 (s).

Anal. Calcd for $C_{10}H_5ClF_2O$: C, 55.97; H, 2.35; F, 17.71. Found: C, 56.23; H, 2.44; F, 17.64.

References and Notes

(1) (a) N. C. Deno, *Carbonium Ions*, **2**, 783 (1970); (b) G. A. Olah et al., *J. Am. Chem. Soc.*, **97**, 5489 (1975) and references cited therein.
(2) R. West and P. T. Kwitkowski, *J. Am. Chem. Soc.*, **88**, 5280 (1966).
(3) G. A. Olah and Y. K. Mo, *Adv. Fluorine Chem.*, **7**, 109 (1973).
(4) R. D. Chambers, R. S. Matthews, and A. Parkin, *J. Chem. Soc., Chem. Commun.*, 509 (1973).
(5) The NMR line shapes were calculated at various temperatures and exchange rates using a program written by P. Meakin et al. (P. Meakin, E. L. Muetterties, F. N. Tebbe, and J. P. Jesson, *J. Am. Chem. Soc.*, **93**, 4701 (1971)) on a Univac 1108 computer and plotted on Calcomp plotter. The system was treated as a two-site problem with first-order couplings with fluorine atoms and appropriate population ratios and relaxation times.
(6) D. C. F. Law, S. W. Tobey, and R. West, *J. Org. Chem.*, **38**, 768 (1973).
(7) An independent synthesis of perfluorocyclobutenone will be reported in a forthcoming paper (B. E. Smart and C. G. Krespan).
(8) Methoxy-group rotational barriers in neutral systems are typically low, e.g., 2.7 kcal/mol in dimethyl ether (J. G. Astin in "Determination of Organic Structures by Physical Methods", Vol. I, E. A. Braude and F. C. Nachod, Ed., Academic Press, New York, N.Y., 1955, p 525). Although barriers to rotation about the carbonyl carbon–oxygen bond in methylated or protonated aldehydes and ketones are not experimentally known, calculated barriers for the protonated carbonyl species range from a minimum value of 17 kcal/mol (D. M. Brouwer, *Recl. Trav. Chim. Pays-Bas*, **86**, 879 (1967)) to 25–30 kcal/mol (P. Roos, *J. Chem. Phys.*, **49**, 4902 (1968)).
(9) For a discussion of puckered homoaromatic cyclobutenyl cations, see ref 1b.
(10) J. T. Barr et al., *J. Am. Chem. Soc.*, **72**, 4480 (1950).
(11) J. D. Park, C. M. Snow, and J. R. Lacher, *J. Am. Chem. Soc.*, **73**, 2342 (1951).
(12) J. D. Park, S. M. Sharrah, and J. R. Lacher, *J. Am. Chem. Soc.*, **71**, 2337 (1949).

Participation of the Styrene Group as a Terminator of Biomimetic Polyene Cyclizations.[1] Formation of the *trans*-8-Methylhydrindan Ring System

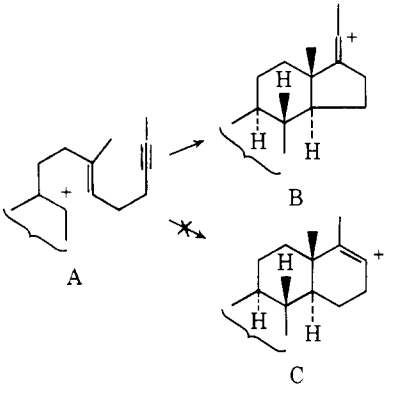
William S. Johnson* and Leonard A. Bunes[2]

Contribution from the Department of Chemistry, Stanford University, Stanford, California 94305.

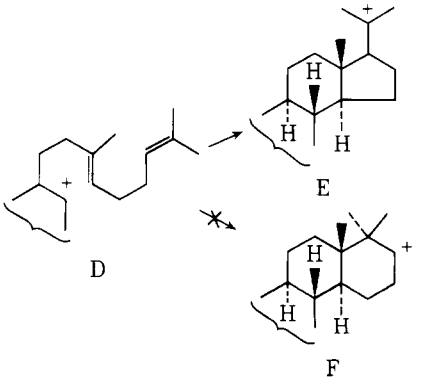
Received February 20, 1976

Abstract: The aim of this study was to examine the styrene group as a cyclization terminator of a biomimetic polyene cyclization, in the hope that it would participate so as to favor formation of a five-membered ring as suggested by the conversion of cation G into H. The model substrate **1** was synthesized from the bromodiene **6** (prepared according to Scheme I) by the sequence outlined in Scheme II. On treatment with stannic chloride in dichloromethane at −78 °C, substrate **1** underwent cyclization to give as the major product a hydrocarbon, presumably **11**, evidently produced from the initially formed benzylic cation by a series of 1,2-hydride and methyl shifts. Cyclization of **1** with trifluoroacetic acid, on the other hand, led to the bicyclic alcohol **12**. The structure and configuration of this product were established by degradation to the diol **18**, which was oxidized to the previously known dione **10**. Reduction of **10** with sodium borohydride gave the isomeric diol **19**, differing from **18** in the orientation of the hydroxyl at C-1.

Up to now the only generally successful method for the stereospecific production of five-membered rings via biomimetic polyene cyclizations has been through the participation of acetylenic bonds in the ring-closure process.[3] This result may be rationalized by postulating that a cation like A would prefer to cyclize so as to give a linear rather than a bent vinyl cation, i.e., B rather than C.



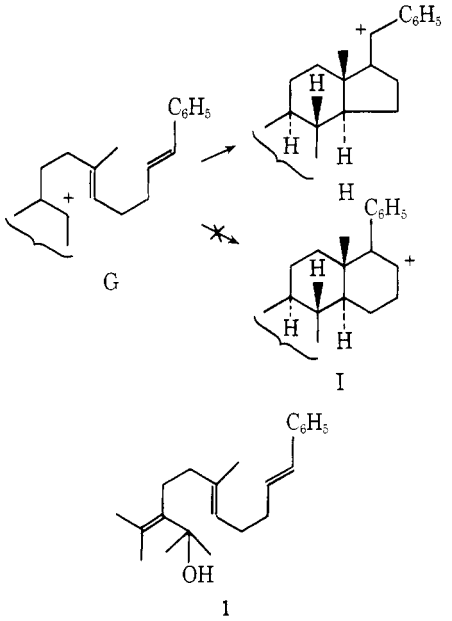
Systems with an appropriately placed isopropylidene terminating group (see cation D) have been shown also to give five- rather than six-membered rings, presumably because of a preference for forming the tertiary cation E over the six-membered ring secondary cation F. Such systems, however,



have not yet been useful in synthesis because cations like E have a susceptibility to undergo backbone rearrangement.[4]

The present paper discloses the first phase of a study of the use of the styrene terminating group which, when incorporated in a molecule as suggested by partial formula G, was envisaged as likely to yield products derived from five-membered ring

closure to form the resonance-stabilized benzylic cation H in preference to the alternative six-membered ring homobenzylic cation I. The styrene terminator has an additional potential advantage in that its olefinic bond is more nucleophilic than an isolated alkene bond; hence it might be a better participant in cyclization.[5] Moreover, the styrene system offers the opportunity of further increasing the nucleophilicity of its olefinic bond by the introduction of appropriate substituents (e.g., p-CH_3) in the aromatic ring. These predictions regarding the behavior of the styrene terminator have been borne out and the

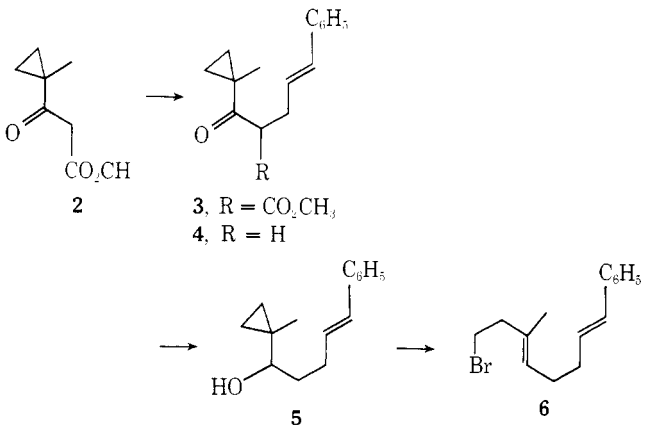


1

present paper describes our initial studies involving the synthesis and cyclization of the trienol **1.**

The allylic alcohol **1** was prepared by modification of a general method reported previously.[3a,6] The required homoallylic bromide **6** was prepared as shown in Scheme I.

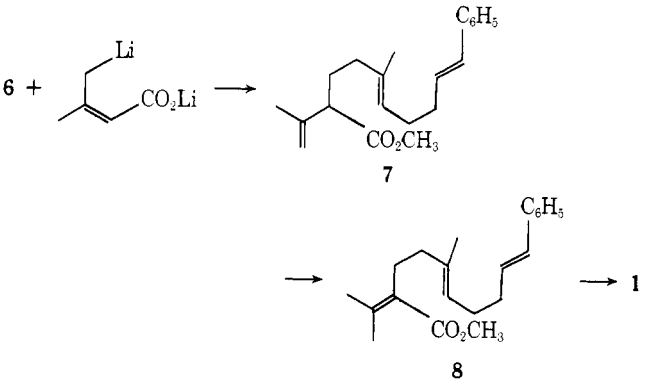
Scheme I



Alkylation of a 20% excess of the sodium enolate of 1-methylcyclopropyl carbomethoxymethyl ketone **2**[7] with *trans*-cinnamyl chloride afforded an 82% yield of alkylation product **3** after distillation. Decarboxylation was smoothly effected by treatment with barium hydroxide in refluxing aqueous ethanol to give the cyclopropyl ketone **4** in 94% yield. The cyclopropyl carbinol **5** was obtained in 99% yield by reduction of **4** with lithium aluminum hydride. Stereoselective rearrangement of alcohol **5** to the *trans*-bromodiene **6** was accomplished by the modified Julia olefin synthesis.[8] Treatment of an ethereal solution of **5** with *s*-collidine and lithium bromide, followed by phosphorus tribromide at −78 °C, gave a mixture of bromides which was directly isomerized with zinc bromide in ether at 0 °C to afford the crude *trans*-bromodiene **6** in 80% yield. This material was contaminated with less than 2% of the corresponding cis isomer.

The dianion formed by treatment of lithium 3-methyl-2-butenoate with diisopropylamine and *n*-butyllithium was alkylated with the bromodiene **6** and the crude product was esterifed with iodomethane and potassium carbonate in acetone[9] to give the β,γ-unsaturated ester **7** (see Scheme II) in

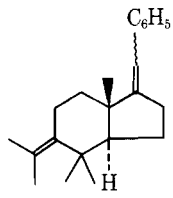
Scheme II



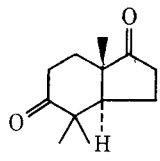
70% yield after chromatography. Equilibration with potassium *tert*-butoxide in *tert*-butyl alcohol resulted in a 96% yield of an 8:92 mixture of the β,γ- and the desired α,β-unsaturated esters **7** and **8**, respectively. Two successive treatments with methyllithium gave in 98% yield the allylic alcohol **1** contaminated with 15% of the corresponding homoallylic alcohol derived from the isomer **7**. The all-trans alcohol **1** could be obtained in greater than 95% purity by chromatography on neutral alumina impregnated with 20% silver nitrate.

Cyclization Studies. Treatment of the substrate **1** (2×10^{-2} M) with 4 mol equiv of stannic chloride in dichloromethane at −78 °C, similar to conditions employed successfully in previous studies,[4] resulted in the formation of considerable high molecular weight material plus a 40% yield of distillable product containing a single hydrocarbon A. The formation of "polymer" was suppressed by conducting the cyclization at a tenfold dilution and the yield of distillable material rose to 75%, 90% of which consisted of hydrocarbon A, as shown by VPC analysis. This hydrocarbon (*m/e* 294), isolated by preparative VPC, was expected to have the structure **9;** however, attempted oxidation with ozone, osmium tetroxide, or ruthenium tetroxide[10] failed to give the known dione **10,**[3a] but led instead to complex mixtures. The NMR spectrum of hydrocarbon A exhibited one-proton singlets at δ 4.51 and 4.80 characteristic of a terminal methylene group and a two-proton singlet at δ 2.60 indicative of a benzylic methylene. A signal for one angular methyl group was observed at δ 0.85. Weak absorptions at 6.14 and 6.25 μ and a strong absorption at 11.23 μ in the ir spectrum suggested a conjugated diene and a terminal vinyl group. Additionally, uv absorptions at 220 (ϵ 4560) and 235–240 mm indicated a noncoplanar conjugated diene and a substituted styrene system, respectively. Taken altogether, this evidence suggested that hydrocarbon A was the rearranged bicyclic substance **11a** or **11b,** which could arise via a series of 1,2-hydride and methyl shifts from the initially formed cation as shown. Seemingly, the driving force for this rearrangement is the formation of a relatively stable allylic cation via successive suprafacial group migrations followed by deprotonation. Similar rearrangements attending biomimetic polyene cyclizations have been observed previously.[4]

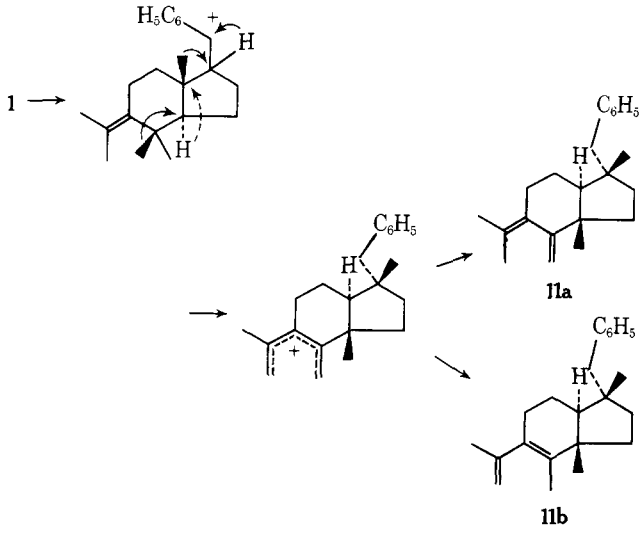
Cyclization of **1** (2×10^{-2} M) in dichloromethane with 4



9



10



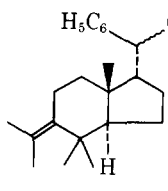
11a

11b

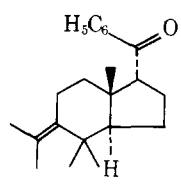
mol equiv of trifluoroacetic acid at −78 °C, followed by hydrolysis of the crude product with potassium carbonate in aqueous methanol, gave a high yield of a cyclized alcohol A contaminated with impurities which could not be removed without a substantial loss of material. The cyclization was complete in less than 8 min, as determined by observing the disappearance of **1** by VPC. An analytical sample of alcohol A was obtained by column chromatography on silica gel followed by evaporative distillation. Oxidation of the crude alcohol with Jones reagent[11] followed by preparative TLC afforded an 87:13 mixture, as shown by VPC, of two phenyl ketones in 79% yield based on the cyclization substrate **1**.

The NMR spectrum of ketone A, the predominant component, exhibited an angular methyl absorption at δ 1.23, while ketone B, the component of higher VPC retention time, exhibited an angular methyl absorption at δ 0.80. Equilibration of the ketone mixture with sodium ethoxide in refluxing ethanol gave a new mixture of ketones A and B in a ratio of 44:56, respectively. Partial purification by dry column chromatography[12] afforded material containing 81% of ketone B. Equilibration of this material resulted in a 47:53 mixture of ketones A and B, respectively, demonstrating that the two ketones are interconvertible epimers.

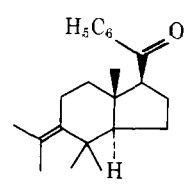
The constitution of alcohol A and ketones A and B was established as **12, 13,** and **14,** respectively, as follows. Attempted



12

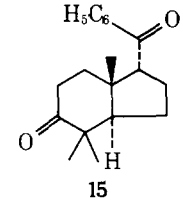


13

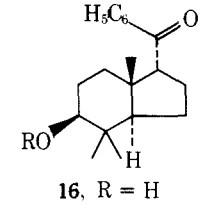


14

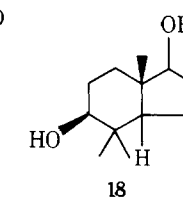
dehydration of alcohol A by a variety of conditions resulted in product mixtures consisting in part of the aforementioned rearranged hydrocarbon **11.** Ozonolysis of the isopropylidene group of ketone A in 1:1 methanol-ethyl acetate at −78 °C afforded the crystalline dione **15,** mp 161–162 °C. Treatment of the dione with sodium borohydride in absolute ethanol[13] at 5–10 °C effected selective reduction to give the hydroxy ketone



15



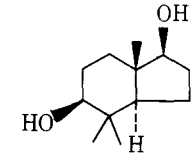
16, R = H
17, R = Ac



18

16, which was converted to the acetate **17.** Baeyer-Villiger oxidation of the keto acetate **17** with peroxytrifluoroacetic acid in the presence of disodium hydrogen phosphate, conditions known to minimize nuclear oxidation of the phenyl ring,[14] followed by hydrolysis afforded the crystalline diol **18,** mp 145–146 °C. Oxidation of this material gave crystalline 4,4,8-trimethyl-*trans*-hydrindan-1,5-dione (**10**), mp 56.5–59.0 °C. The ir spectrum of this material was identical in all respects with that of an authentic specimen of dione **10**[3a] and a mixture melting point was undepressed.

The epimeric phenyl ketone B was degraded in the same manner as described above to afford a second crystalline diol **19,** mp 159.5–161.0 °C, identical in all respects with the diol



19

obtained by reduction of dione **10** with sodium borohydride. By analogy to the course of the borohydride reduction of both C-17 and C-3 keto steroids, which results in β-oriented alcohols, it is assumed that the C-5 hydroxyls of diols **18** and **19,** as well as the C-1 hydroxyl of **19,** are β oriented. Since diols **18** and **19** differ only in the orientation of the hydroxyl at C-1, the C-1 hydroxyl of **18** is considered to be α. Finally, since the Baeyer-Villiger oxidation proceeds with retention of configuration, the α orientation of the benzylic sidechain of alcohol A is established as depicted by structure **12.**

Experimental Section[15]

General Considerations. The prefix "*dl*" has been omitted from the names of all racemic compounds described in this section. Microanalyses were performed by E. H. Meier and J. Consul, Department of Chemistry, Stanford University. Melting points were determined on a Kofler hot-stage microscope. NMR spectra were determined under the supervision of Dr. L. J. Durham on Varian Associates T-60 and XL-100 NMR spectrometers. Unless otherwise stated deuteriochloroform was used as the solvent. Chemical shifts are reported as δ values in parts per million relative to tetramethylsilane = 0. Mass spectra were determined on an A.E.I. MS-9 spectrometer under the supervision of Dr. A. M. Duffield. Infrared (ir) spectra were recorded on a Perkin-Elmer Model 137 spectrometer and ultraviolet (uv) spectra were recorded on a Cary Model 14 spectrometer using 1-cm quartz cells. Vapor-phase chromatographic (VPC) analyses were performed on a Hewlett-Packard HP 402 chromatograph using a ⅛ in. glass column packed with 3.8% SE-30 on Chromosorb W.H.P. (unless otherwise indicated) using helium as the carrier gas. Silica gel HF_{254} (E. Merck A.G.) was used for both analytical and preparative thin-layer chromatography (TLC). Column chromatography was conducted using Florisil (100–200 mesh), silica gel (E. Merck, 7–230 mesh), and neutral alumina (Woelm, activity I). "Evaporative distillation" refers to bulb-to-bulb short-path distillation in which the bulb was heated in a hot-air oven (Buchi Kugelröhrofen). The cited temperatures for these distillations pertain to the oven temperature and are thus not true boiling points.

1-Methylcyclopropyl 1-Carbomethoxy-4-phenyl-*trans*-3-butenyl Ketone (3). A sodium hydride suspension was prepared by washing 2.79 g of a 57% oil dispersion of sodium hydride (0.066 g-atom) with dry pentane (3 × 75 ml) under nitrogen; then 60 ml of dry THF was added. The suspension was cooled to 0 °C and stirred, while a solution

of 9.38 g (0.060 mol) of the cyclopropyl keto ester **2**[7] in 60 ml of dry THF was added over a period of 30 min. The cooling bath was removed and the yellow soution was stirred for 2 h at room temperature, then the solution was filtered through Celite and the filtrate concentrated under reduced pressure to afford a pale yellow solid which was used directly for the alkylation.

A solution of 7.63 g (0.050 mol) of *trans*-cinnamyl chloride in 10 ml of dry THF was added to a mixture of 8.25 g (0.055 mol) of sodium iodide and 10 ml of acetonitrile and the resultant mixture was stirred at 0–5 °C for 45 min under nitrogen. The cooling bath was removed and a solution of the above sodium enolate in 20 ml of acetonitrile and 10 ml of DMF was added over a period of 25 min. The reaction mixture was stirred for 3 h at room temperature, then for 18 h at 60–70 °C. The mixture was cooled to room temperature and poured into 100 ml of 1:1 5% hydrochloric acid–brine. Ether extraction with a base wash[15] afforded 11.14 g (82% yield, 94% pure by VPC) of keto ester **3** as a pale yellow liquid, bp 131–142 °C (0.008 mm). An analytical sample was prepared by two successive evaporative distillations at 125 °C (0.012 mm): ir λ_{max}^{film} 5.73 (ester C=O), 5.91 (C=O), 10.32 (*trans*-CH=CH), 13.41, and 14.45 μ (aromatic); NMR δ 0.57–0.87 (m, 2 H, cyclopropyl CH_2), 1.07–1.40 (m, 2 H, cyclopropyl CH_2), 1.07–1.40 (m, 2 H, cyclopropyl CH_2), 1.33 (s, 3 H, cyclopropyl CH_3), 2.71 (t, J = 7 Hz, 2 H, allylic CH_2), 3.67 (s, 3 H, ester CH_3), 3.77 (t, J = 7 Hz, 1 H, $COCHRCO_2CH_3$), 5.80–6.67 (m, 2 H, CH=CH), and 7.27 (br s, 5 H, aromatic).

Anal. ($C_{17}H_{20}O_3$) C, H.

1-Methylcyclopropyl 4-Phenyl-*trans*-3-butenyl Ketone (4). A solution of 12.9 g (0.0474 mol) of distilled keto ester **3** in 90 ml of 95% ethanol was added to a mixture of 87.5 g (0.277 mol) of barium hydroxide octahydrate and 300 ml of water. The resultant mixture was stirred under nitrogen and heated at reflux for 22 h. The mixture was cooled to room temperature, poured into 180 ml of benzene, acidified to pH 1 with 10% hydrochloric acid, and the total volume adjusted to 900 ml with brine. Extraction with benzene using a base wash (5% aqueous sodium hydroxide solution),[15] followed by evaporative distillation at 123–126 °C (0.025 mm) afforded 9.50 g (94% yield) of the ketone **4** as a colorless liquid, which was >99% pure by VPC (160 °C). An analytical sample was prepared by preparative TLC (R_f 0.67, 4:1 benzene–ethyl acetate) followed by evaporative distillation at 85 °C (0.005 mm): ir λ_{max}^{film} 5.91 (C=O), 10.32 (*trans*-CH=CH), 13.41, and 14.45 μ (aromatic); NMR δ 0.50–0.90 (m, 2 H, cyclopropyl CH_2), 1.07–1.30 (m, 2 H, cyclopropyl CH_2), 1.33 (s, 3 H, cyclopropyl CH_3), 2.33–2.57 (m, 4 H, $-CH_2CH_2-$), 5.80–6.60 (m, 2 H, CH=CH), and 7.27 (br s, 5 H, aromatic).

Anal. ($C_{15}H_{18}O$) C, H: calcd, 8.47; found, 8.90.

1-Methylcyclopropyl-4-phenyl-rans-3-butenylcarbinol (5). A suspension of 2.33 g (0.0614 mol) of lithium aluminum hydride in 225 ml of anhydrous ether was cooled to 0 °C under nitrogen and a solution of 9.31 g (0.0434 mol) of cyclopropyl ketone **4** in 125 ml of anhydrous ether was carefully added. The mixture was stirred at 0 °C for 2 h, then the excess hydride was decomposed by the cautious addition of 5% aqueous sodium hydroxide solution. The supernatant liquid was decanted and the white precipitate was washed with several portions of ether. The combined ethereal solution was dried over sodium sulfate and concentrated at reduced pressure to give 9.35 g (99% yield) of the carbinol **5** as a colorless liquid (>99% pure by VPC, 160 °C). An analytical sample was obtained by three successive evaporative distillations at 95 °C (0.006 mm): ir λ_{max}^{film} 2.90 (OH), 10.32 (*trans*-CH=CH), 13.42, and 14.45 μ (aromatic); NMR δ 0.20–0.43 (m, 4 H, cyclopropyl methylenes), 1.03 (s, 3 H, cyclopropyl CH_3), 1.43–1.90 (m, 3 H, OH and β-CH_2), 2.10–2.50 (m, 2 H, allylic CH_2), 2.87 (t, J = 7 Hz, 1 H, carbinol CH), 5.90–6.63 (m, 2 H, CH=CH), and 7.27 (br s, 5 H, aromatic); TLC R_f 0.43 (4:1 benzene–ethyl acetate).

Anal. ($C_{15}H_{20}O$) C, H.

8-Bromo-6-methyl-1-phenyl-*trans,trans*-1,5-octadiene (6). A modification of a published procedure[8] was employed. A mixture of 8.88 g (0.0410 mol) of carbinol **5** in 200 ml of dry ether, 3.82 g (0.0442 mol) of anhydrous lithium bromide, and 19.4 g (0.160 mol) of *s*-collidine was cooled to −78 °C under nitrogen. A solution of 4.06 ml (11.58 g, 0.0428 mol) of phosphorus tribromide in 150 ml of dry ether was added to the rapidly stirred mixture over a period of 65 min. The reaction mixture was allowed to warm to room temperature and stirred for 20 h; then 10 ml of collidine was added and the mixture was cooled to 0 °C. This was followed by careful addition of 32 ml of water and the resultant clear solution was poured into 250 ml of 50% brine overlaid with 125 ml of pentane. Pentane extraction using an ice-cold acid wash[15] afforded 10.1 g of pale yellow liquid, which was used directly in the rearrangement reaction described below.

A 49.0-g portion (0.217 mol) of zinc bromide was flame-dried under vacuum to a fine, sand-like consistency and 200 ml of dry ether was added. The mixture was cooled to 0 °C under nitrogen and stirred, while a solution of 10.1 g of the above crude bromide in 120 ml of dry ether was added over a period of 1 h. The resultant mixture was stirred at 0 °C for 4 h, then poured into 225 ml of 50% brine overlaid with 225 ml of pentane. Extraction with pentane[15] afforded 9.17 g (80% yield) of the crude bromide **6** as a cloudy yellow liquid. Analytical VPC (150°C) indicated this material to be 86% pure with <2% of the corresponding cis isomer present. An analytical sample was prepared by three successive evaporative distillations at 100 °C (0.007 mm): ir λ_{max}^{film} 6.00 (CHR=CR′R″), 10.39 (*trans*-CH=CH–), and 13.47 and 14.50 μ (aromatic); NMR δ 1.60 (s, 3 H, vinyl CH_3), 2.07–2.30 (m, 4 H, C-3 and C-4 methylenes), 2.50 (t, J = 7 Hz, 2 H, C-7 CH_2), 3.40 (t, J = 7 Hz, 2 H, $-CH_2Br$), 5.25 (br t, $W_{1/2}$ = 7 Hz, 1 H, C-5 vinyl proton), 5.87–6.60 (m, 2 H, CH=CH), and 7.25 (br s, 5 H, aromatic); TLC R_f 0.75 (4:1 benzene–ethyl acetate). The bromide **6** decomposed upon standing, presumably via elimination of hydrogen bromide, as evidenced by the low bromine content of the combustion analysis.

Anal. Calcd for $C_{15}H_{19}Br$: C, 64.52; H, 6.86; Br, 28.62. Found: C, 66.80; H, 7.18; Br, 26.13.

3-Carbomethoxy-2,6-dimethyl-11-phenyl-2-*trans,trans*-6,10-undecatriene (8). A. Alkylation of Lithium 3-Methyl-2-butenoate with Bromide 6. Lithium 3-methyl-2-butenoate was prepared in the following manner. A solution of 10.2 g (0.102 mol) of 3-methyl-2-butenoic acid in 300 ml of dry ether was added over a 20-min period with stirring to a suspension of 0.80 g (0.100 mol) of lithium hydride in 20 ml of dry ether under nitrogen. The mixture was stirred at 23 °C for 22 h and the white precipitate was filtered and washed with ether. The residue was dried in a vacuum desiccator to afford 9.96 g (92% yield) of the acid salt as a white powder.

A solution of 12.56 g (0.124 mol) of *N,N*-diisopropylamine (stored over potassium hydroxide pellets) in 31 ml of dry THF was cooled to 0 °C under nitrogen and 49.0 ml (0.124 mol) of a 2.53 M solution of *n*-butyllithium in hexane was added. The resultant mixture was stirred for 5 min and then added over a period of 10 min to a cold (0 °C) slurry of 13.15 g (0.124 mol) of the above acid salt in 93 ml of dry THF. The resultant suspension was stirred at 0 °C for 30 min and cooled to −78 °C; then a solution of 8.65 g (0.031 mol) of the bromide **6** in 62 ml of dry THF was added over a period of 10 min. The reaction mixture was allowed to warm slowly to room temperature while stirring under nitrogen. Stirring was continued for 25 h; then the mixture was poured into 500 ml of 5% aqueous sodium hydroxide solution and extracted with 1:1 ether–hexane (3 × 250 ml). The combined organic layers were washed with water (2 × 100 ml); then the combined aqueous washings were cooled to 0 °C, acidified to pH 1 with 10% hydrochloric acid, and extracted with benzene (2 × 500 ml) and ether[15] (2 × 250 ml) to yield 13.63 g of yellow liquid consisting of ca. 50% of the alkylated triene acid and 50% of a mixture of unreacted 3-methyl-2-butenoic acid and isophorone, a self-condensation product of 3-methyl-2-butenoic acid.

B. Esterification.[9] A mixture of 13.33 g (ca. 0.10 mol) of the above crude alkylation product, 200 ml of anhydrous acetone, 27.7 g (0.20 mol) of potassium carbonate (dried 16 h at 160 °C), and 28.4 g (0.20 mol) of methyl iodide was stirred and heated at reflux under nitrogen for 1.75 h. The mixture was cooled, diluted with water, and extracted with ether using a 10% aqueous sodium thiosulfate wash.[15] Chromatography of the crude product on 300 g of silica gel (1–3% ether in hexane) afforded 6.82 g (70% yield based on bromide **6**) of the β,γ-unsaturated ester **7**.

C. Equilibration with Potassium *tert*-Butoxide. To a solution of 6.73 g (21.5 mmol) of the above ester **7** in 60 ml of dry *tert*-butyl alcohol was added 30.2 ml (10.8 mmol) of a 5% solution of potassium *tert*-butoxide in dry *tert*-butyl alcohol. The resultant solution was stirred at 23 °C under nitrogen for 5.75 h, then poured into 275 ml of 1:1 10% hydrochloric acid–brine overlaid with 250 ml of pentane. Extraction with pentane[15] followed by evaporative distillation at 150 °C (0.015 mm) gave 6.46 g (96% yield) of a yellow liquid consisting of 92% of the α,β-unsaturated ester **8** and 8% of the β,γ-unsaturated ester **7**, as shown by VPC (190 °C). An analytical sample was obtained by preparative TLC (R_f 0.73, 4:1 benzene–ethyl acetate) followed by evaporative distillation at 146 °C (0.015 mm): ir λ_{max}^{film} 3.30 (CH), 5.85 (α,β-unsaturated ester), 10.39 (*trans*-CH=CH–), and 13.50

and 14.48 μ (aromatic); NMR δ 1.63 (br s, 3 H, C-6 CH_3), 1.78 (s, 3 H, vinyl CH_3), 1.95 (s, 3 H, vinyl CH_3), 2.03–2.57 (m, 8 H, allylic methylenes), 3.70 (s, 3 H, ester CH_3), 5.00–5.37 (m, 1 H at C-7), 5.90–6.63 (m, 2 H, CH=CH), and 7.27 (m, 5 H, aromatic).

Anal. ($C_{21}H_{28}O_2$) C, H.

2-Hydroxy-3-isopropylidene-2,6-dimethyl-11-phenyl-*trans*,*trans*-6,10-undecadiene (1). To a solution of 0.317 g (1.01 mmol) of the α,β-unsaturated ester **8** in 23 ml of dry ether was added 2.0 ml (4.52 mmol) of a 2.26 M solution of methyllithium in hexane. The resultant mixture was stirred for 20 min at 23 °C under nitrogen, then excess methyllithium was decomposed by the careful addition of methanol. The mixture was poured into 20 ml of water and the product, which was isolated by ether extraction,[15] was retreated with methyllithium as described above to afford 0.310 g (98% yield) of pale yellow liquid consisting of 85% of the desired alcohol **1**, 13% of the homoallylic alcohol, and 2% impurities as indicated by analytical VPC (190 °C). Chromatography on 20% silver nitrate-impregnated neutral alumina (ethyl acetate–hexane mixtures) afforded the alcohol **1** in >90% purity as shown by VPC (190 °C): ir λ_{max}^{film} 2.86 (OH), 3.30 (CH), 10.32 (*trans*-CH=CH–), and 13.42 and 14.43 μ (aromatic); NMR δ 1.40 (s, 6 H, $-C(CH_3)_2O-$), 1.67 (br s, 3 H, C-6 CH_3), 1.70 (s, 3 H, isopropylidene CH_3), 1.93 (s, 3 H, isopropylidene CH_3), 2.00–2.33 (m, 8 H, allylic methylenes), 5.07–5.37 (m, 1 H at C-7), 5.93–6.63 (m, 2 H, CH=CH), and 7.28 (m, 5 H, aromatic).

Cyclization of Alcohol 1. A. With Stannic Chloride in Dichloromethane. Isolation of Hydrocarbon A (11). A solution of 100 mg (0.32 mmol) of allylic alcohol **1** in 1 ml of dichloromethane was added via syringe over a period of 8 min to a stirred solution of 0.146 ml (325 mg, 1.25 mmol) of stannic chloride in 115 ml of dichloromethane at −78 °C under nitrogen. The syringe was rinsed with two 1-ml portions of dichloromethane and the reaction mixture was stirred for 1.5 h; then 2 ml of 1:1 diisopropylethylamine–dichloromethane was added. The mixture was stirred for 15 min and poured into 25 ml of 5% hydrochloric acid overlaid with 25 ml of ether. Ether extraction using a base wash[15] afforded 95 mg of yellow liquid consisting of 80% of one component as shown by VPC (190 °C). Chromatography on 5 g of silica gel (hexane) followed by evaporative distillation at 120 °C (0.005 mm) afforded 28 mg of hydrocarbon A (**11**) as a colorless liquid, which was one component by VPC (190 °C): ir λ_{max}^{film} 6.14 (C=C). 6.25 (C=C), and 11.23 μ (C=CH_2); NMR (CCl_4) δ 0.85 (s, 3 H, CH_3), 1.03 (s, 3 H, CH_3), 1.60 (br s, 3 H, vinyl CH_3), 1.71 (br s, 3 H, vinyl CH_3), 2.60 (s, 2 H, benzylic CH_2), 4.51 (br s, 1 H, vinyl proton), 4.80 (br s, 1 H, vinyl proton), and 7.10 (s, 5 H, aromatic); uv $\lambda_{max}^{C_6H_{12}}$ 220 nm (ϵ 4560). The mass spectrum (70 eV) exhibited a molecular ion at *m/e* 294 (68%), a base peak at *m/e* 203 ($M^+ - C_7H_7$), and a major peak at *m/e* 91 (57%).

B. With Trifluoroacetic Acid in Dichloromethane. Isolation of 1α-(α-Hydroxybenzyl)-4,4,8β-trimethyl-5-isopropylidene-9α-hydrindan (12). A solution of 309 mg (2.71 mmol, 3.9 equiv) of trifluoroacetic acid in 2.65 ml of dry dichloromethane was added with stirring via syringe over a period of 3 min to a solution of 242 mg (0.697 mmol, 90% pure as shown by VPC) of alcohol **1** in 35 ml of dry, olefin-free dichloromethane at −78 °C under nitrogen. The resultant mixture was stirred for 8 min at −78 °C and poured into 40 ml of saturated sodium bicarbonate solution overlaid with 40 ml of ether. Extraction with ether[15] afforded 300 mg of pale yellow liquid comprised of 75% of one component as shown by VPC (190 °C).

A mixture of the above crude product, 24 ml of methanol, 9.6 ml of water, and 810 mg of potassium carbonate was stirred under nitrogen for 18 h at 25 °C. The mixture was then concentrated at the rotary evaporator, diluted with water, and extracted with ethyl acetate[15] to yield 246 mg of crude bicyclic alcohol **12**, which appeared to be 90% one component by VPC (190 °C). A specimen of comparable material obtained from a similar experiment was chromatographed on silica gel (ether–hexane mixtures), then evaporatively distilled at 150 °C (0.009 mm) to afford an analytical sample of **12** as a colorless liquid: ir λ_{max}^{film} 2.86 (OH), 3.38 and 3.48 (CH), and 13.08 and 14.29 μ (aromatic); NMR (CCl_4) δ 0.87 (s, 3 H, C-8 CH_3), 1.17 (s, 3 H, C-4 CH_3), 1.20 (s, 3 H, C-4 CH_3), 1.67 (s, 3 H, vinyl CH_3), 1.80 (br s, 3 H, vinyl CH_3), 4.80 (d, J = 2 Hz, 1 H, benzylic proton), and 7.20 (br s, 5 H, aromatic); TLC R_f 0.37 (9:1 hexane–ethyl acetate).

Anal. ($C_{22}H_{32}O$) C, H.

1α-Benzoyl-4,4,8β-trimethyl-5-isopropylidene-9α-hydrindan (13). A modification of a reported procedure[11] was employed. A solution of 0.246 g (90% pure, 0.708 mmol) of crude bicyclic alcohol **12** in 9 ml of acetone was cooled to 5–10 °C under nitrogen and 0.266 ml (0.71 mmol) of 2.67 M Jones reagent[11] was added via syringe over a period of 8 min. The reaction mixture was stirred for an additional 15 min, then the excess oxidant was decomposed by titration with isopropyl alcohol. The mixture was diluted with 20 ml of 50% brine and 10 ml of ether, and stirred for a few minutes. Ether extraction, using a 1:1 5% aqueous sodium hydroxide–brine wash,[15] gave, after preparative TLC (R_f 0.55, 9:1 hexane–ethyl acetate), 0.171 g (79% yield) of pale yellow liquid shown to consist of the phenyl ketones **13** and **14** in a ratio of 87:13 by VPC (190 °C). An analytical sample was obtained from comparable material by preparative TLC (1.5-h elution with 9:1 hexane–ethyl acetate, R_f 0.57) followed by evaporative distillation at 140 °C (0.006 mm): ir λ_{max}^{film} 3.36 (CH), 5.95 (C=O), and 6.25, 6.33, 6.66, and 6.92 μ (aromatic C=C); uv λ_{max}^{EtOH} 244.5 nm (ϵ 11 600); NMR (CCl_4) δ 1.13 (s, 3 H, C-4 CH_3), 1.17 (s, 3 H, C-4 CH_3), 1.23 (s, 3 H, C-8 CH_3), 1.57 (s, 3 H, vinyl CH_3), 1.78 (br s, 3 H, vinyl CH_3), 3.33 (m, 1 H at C-1), 7.30–7.53 (m, 3 H, para and meta aromatic), and 7.73–7.97 ppm (m, 2 H, ortho aromatic).

Anal. ($C_{22}H_{30}O$) C, H.

Equilibration of the Phenyl Ketones 13 and 14. To a solution of 14.5 mg (0.63 mg-atom) of sodium in 9 ml of absolute ethanol was added 390 mg (1.26 mmol) of an 87:13 mixture of bicyclic ketones **13** and **14**. The mixture was heated at reflux for 5 h and the equilibration was followed by VPC analysis of aliquots. After 3 h equilibration appeared to be complete. The solution was cooled, diluted with 90 ml of 1:1 ether–ethyl acetate, then washed with water. The aqueous washings were back-extracted with ethyl acetate and the combined organic layers afforded[15] 378 mg of yellow liquid consisting of the phenyl ketones **13** and **14** in a ratio of 44:56 as shown by VPC (3% XE-60, 190 °C). The crude ketone mixture was applied to a 1 × 12 in. dry column of basic alumina (140 g; Woelm, activity II, containing 0.5% of uv indicator) according to Loev[12] and eluted with carbon tetrachloride. Bands of separated material were visualized by uv and three fractions were cut: fraction a (R_f 0.61) yielded 110 mg of material consisting of 90% **13** and 8.7% **14**; fraction b (R_f 0.43) yielded 150 mg of 20:80 mixture of **13** and **14**; and fraction c (R_f 0.29) yielded 40 mg of an 11:89 mixture of **13** and **14**. Equilibration of a similar mixture of ketones **13** and **14** (16:84) under the conditions described above afforded a 47:53 mixture of **13** and **14**.

1α-Benzoyl-4,4,8β-trimethyl-9α-hydrindan-5-one (15). Ozone was bubbled through a solution of 0.235 g (0.757 mmol) of phenyl ketones **13** and **14** (87:13) in 14 ml of 1:1 ethyl acetate–methanol at −78 °C until a blue color persisted. The solution was flushed with oxygen at −78 °C and 0.5 ml of dimethyl sulfide was added; then the cooling bath was removed and stirring was continued for 1 h. The solvent was evaporated and the product, which was isolated with ether–dichloromethane,[15] amounted to 0.200 g (93% yield) of colorless crystalline solid consisting of the dione **15** contaminated with a trace of the 1β-epimer as indicated by VPC (190 °C). Two recrystallizations from ethyl acetate afforded an analytical sample as flocculent colorless crystals, mp 161–162 °C: ir λ_{max}^{KBr} 3.42 (CH), 5.88 (C=O), and 6.00 μ (benzoyl C=O); NMR (CCl_4) δ 1.05 (s, 3 H, C-4 CH_3), 1.10 (s, 3 H, C-4 CH_3), 1.30 (s, 3 H, C-8 CH_3), 3.63 (m, 1 H at C-1), 7.30–7.57 (m, 3 H, para and meta aromatic), and 7.67–7.97 (m, 2 H, ortho aromatic); TLC R_f 0.59 (4:1 benzene–ethyl acetate).

Anal. ($C_{19}H_{24}O_2$) C, H.

1α-Benzoyl-4,4,8β-trimethyl-9α-hydrindan-5β-ol (16). Selective reduction of the dione **15** was accomplished using a modification of a reported procedure.[13] A solution of 225 mg (0.791 mmol) of the dione **15** (recrystallized from ethyl acetate, >99% pure by VPC) in 20 ml of absolute ethanol and 3 ml of dry THF was cooled to 5–10 °C and 11 mg (0.297 mmol) of sodium borohydride was added in one portion. The mixture was stirred under nitrogen for 5.5 h; then the excess borohydride was decomposed by the addition of a few drops of glacial acetic acid. The mixture was poured into 15 ml of water overlaid with 15 ml of ethyl acetate, and the product was isolated by ethyl acetate extraction using a bicarbonate wash.[15] Thus there was obtained 211 mg of pale yellow liquid consisting of 90% of the hydroxy ketone **16** and 10% of unreacted dione **15** as shown by VPC (190 °C). A specimen of comparable material was recrystallized twice from hexane to afford an analytical sample as colorless microprisms, mp 117.0–118.5 °C: ir λ_{max}^{KBr} 2.94 (OH) and 5.96 μ (C=O); NMR (CCl_4) δ 0.80 (s, 3 H, C-4α CH_3), 1.00 (s, 3 H, C-4β CH_3), 1.27 (s, 3 H, C-8 CH_3), 7.30–7.63 (m, 3 H, para and meta aromatic), and 7.73–7.97 (m, 2 H, ortho aromatic); TLC R_f 0.29 (4:1 benzene–ethy acetate).

Anal. ($C_{19}H_{26}O_2$) C, H.

1α-Benzoyl-4,4,8β-trimethyl-5β-acetoxy-9α-hydrindan (17). To a solution of 211 mg (0.736 mmol) of crude hydroxy ketone **16** in 0.4 ml of dry pyridine was added 0.2 ml of acetic anhydride. The resulting mixture was stirred at room temperature under nitrogen for 29 h; then it was diluted with 5 ml of water and the product isolated by extraction with ethyl acetate using a saturated aqueous copper sulfate wash.[15] Thus there was obtained 211 mg of tan solid consisting of 84% of the keto acetate **17** and 10% of the dione **15** by VPC (190 °C). Recrystallization from methanol afforded 106 mg of the keto acetate as colorless needles. A second crop of 26 mg (total yield = 54%) was obtained from the mother liquor. Two further recrystallizations from methanol provided an analytical sample of **17** as colorless flocculent platelets, mp 129.5–131.0 °C: ir λ_{max}^{KBr} 3.38 (CH), 5.76 (ester C=O), 5.99 (C=O), and 6.25, 6.33, 6.78, and 6.90 μ (aromatic C=C); NMR (CCl_4) δ 0.89 (s, 3 H, C-4 CH_3), 0.91 (s, 3 H, C-4 CH_3), 1.19 (s, 3 H, C-8 CH_3), 1.95 (s, 3 H, acetate CH_3), 3.53 (m, 1 H at C-1), 4.33 (m, 1 H at C-5), 7.33–7.57 (m, 3 H, para and meta aromatic), and 7.71–8.00 (m, 2 H, ortho aromatic); TLC R_f 0.49 (9:1 benzene–ethyl acetate).

Anal. ($C_{21}H_{28}O_3$) C, H.

4,4,8β-Trimethyl-9α-hydrindan-1α,5β-diol (18). A modification of a reported procedure[14] was employed whereby 0.04 ml (ca. 1.5 mmol) of 90% hydrogen peroxide was added via a glass pipette (Caution! Only glass should be used to handle this reagent) to 1 ml of dry dichloromethane at 0 °C. This solution was rapidly stirred while 0.25 ml (1.76 mmol) of trifluoroacetic anhydride was added; then stirring was continued for 0.5 h at 0 °C. This solution was added via syringe over a period of 8 min to a cold (0 °C) mixture of 100 mg (0.305 mmol) of once-crystallized keto acetate **17**, 650 mg (4.47 mmol) of disodium hydrogen phosphate (oven-dried for 48 h at 96 °C), and 2 ml of dry dichloromethane. The mixture was allowed to warm to room temperature, then was stoppered and stirred in the dark for 4 days. A second portion of peracid was prepared as described above and added to the reaction mixture; then the flask was stoppered and stirring was continued for 4 more days in the dark. The mixture was poured into 5 ml of water overlaid with 5 ml of ethyl acetate. Extraction with ethyl acetate[15] yielded 96 mg of yellow liquid consisting of one component by VPC (190 °C).

A mixture of the above crude Baeyer–Villiger product, 1 ml of methanol, and 1 ml of 5% aqueous sodium hydroxide was heated at reflux with stirring for 2 h under nitrogen. The resultant solution was cooled and extracted with ethyl acetate.[15] Chromatography of the product on 1.5 g of Florisil (1:1 ether–hexane; ether) gave 21 mg (35% yield) of the hydrindanediol **18**, which was one component by VPC (190 °C). Recrystallization from cyclohexane yielded 16 mg of colorless platelets. A further recrystallization from benzene afforded 10 mg of the diol **18** as colorless prisms, mp 145–146 °C: ir λ_{max}^{KBr} 2.98 (OH), 3.40, 3.47, 6.90, 7.24, 7.52, 8.77, 9.09, 9.44, 9.75, and 10.06 μ; TLC R_f 0.14 (1:1 benzene–ethyl acetate) and 0.17 (3:1 benzene–acetone).

4,4,8β-Trimethyl-9α-hydrindan-1,5-dione (10). The procedure employed was similar to that described above for the oxidation of alcohol **12**. Thus from 22 mg of the crude diol **18** there was obtained, after chromatography on 1 g of silica gel (1:1 ether–hexane), 4 mg of the hydrindanedione **10**. Two recrystallizations from hexane afforded 1 mg of the dione as colorless needles, mp 56.5–59.0 °C. The ir spectrum of this material, exhibiting absorptions for five- and six-membered ring ketones at 5.75 and 5.86 μ was identical in all respects with the ir spectrum of an authentic specimen of the dione **10**,[3a] mp 59–60 °C. A mixture of the authentic dione and the sample obtained in the present work melted at 55–57 °C.

4,4,8β-Trimethyl-9α-hydrindan-1β,5β-diol (19). A. From Phenyl Ketone 14. The procedures employed were similar to those described above for the conversion of the phenyl ketone **13** to the diol **18**. Thus from 300 mg of a mixture of phenyl ketones **13** and **14** to a ratio of 27:73 there was obtained 175 mg of keto acetate consisting of 21% of **17** and 79% of its 1β-epimer as shown by VPC (190 °C). This keto acetate mixture was oxidized with peroxytrifluoroacetic acid to afford 82 mg of crude ester as a yellow liquid consisting of two components by VPC (190 °C) in a ratio of 5:1.

The crude ester mixture described above was saponified by heating for 2 h under nitrogen in 2 ml of 1:1 methanol–5% aqueous sodium hydroxide solution to give 29 mg of yellow liquid, which appeared to contain 66% of the diol **19** and two unidentified components by VPC (160 °C). The crude product was chromatographed on 1.5 g of Florisil (hexane–ether mixtures) to afford 8 mg of semicrystalline diol **19**. Two recrystallizations from benzene gave 6 mg of diol **19** as colorless prisms, mp 159.5–161.0 °C: ir λ_{max}^{KBr} 2.98 (OH), 3.39 and 3.47 (CH), 6.89 (CH bending of CH_3), 7.57, 9.09, and 9.90 μ; TLC R_f 0.17 (4:1 benzene–acetone).

A mixture of this product with the specimen obtained from the dione **10** (see below) melat 160–161 °C.

B. From the Dione 10. A mixture of 51 mg (0.262 mmol, >99% pure) of authentic dione **10**,[3a] 14.9 mg (0.394 mmol) of sodium borohydride, and 6.5 ml of dry isopropyl alcohol was stirred at room temperature for 8 h under nitrogen. Excess hydride was decomposed by the addition of a few drops of acetic acid and the solvent was removed at reduced pressure. Isolation with ethyl acetate using a base wash[15] yielded 55 mg (106% yield) of diol **19** as a crystalline solid which appeared to be 90% pure by VPC (158 °C). This material was recrystallized from benzene, chromatographed on silica gel, then recrystallized again from benzene to afford diol **19** as colorless prisms, mp 161.5–162.5 °C: NMR δ 0.90 (br s, 6 H, C-4 and C-8 methyls), 0.97 (s, 3 H, C-4 CH_3), and 3.07–3.83 (m, 2 H, C-1 and C-5 protons).

Anal. ($C_{12}H_{22}O_2$) C, H.

Acknowledgment. We wish to thank the National Institutes of Health and the National Science Foundation for support of this research. We are also indebted to Bruce E. Ratcliffe, who gave us much assistance in the preparation of the manuscript of this paper.

References and Notes

(1) For a recent paper in the series on biomimetic cyclizations, see W. R. Bartlett and W. S. Johnson, *Bioorg. Chem.*, in press.
(2) National Science Foundation Predoctoral Fellow, 1970–1973.
(3) (a) W. S. Johnson, M. B. Gravestock, R. J. Parry, R. F. Myers, T. A. Bryson, and D. H. Miles, *J. Am. Chem. Soc.*, **93**, 4330 (1971); (b) W. S. Johnson, M. B. Gravestock, and B. E. McCarry, *ibid.*, **93**, 4332 (1971); (c) B. E. McCarry, R. L. Markezich, and W. S. Johnson, *ibid.*, **95**, 4416 (1973); (d) D. R. Morton, M. B. Gravestock, R. J. Parry, and W. S. Johnson, *ibid.*, **95**, 4417 (1973); (e) D. R. Morton and W. S. Johnson, *ibid.*, **95**, 4419 (1973).
(4) K. A. Parker and W. S. Johnson, *J. Am. Chem. Soc.*, **96**, 2556 (1974).
(5) The weakly nucleophilic terminating group, –CHCl=CH_2, fails to participate at all in polyene cyclizations (B. E. Ratcliffe and W. S. Johnson, unpublished observations). The vinyl terminator is a poor participant, while the even more nucleophilic isopropenyl terminator participates fairly effectively. K. E. Harding, E. J. Leopold, A. M. Hudrlik, and W. S. Johnson, *J. Am. Chem. Soc.*, **96**, 2540 (1974) and R. L. Carney and W. S. Johnson, *J. Am. Chem. Soc.*, **96**, 2549 (1974).
(6) W. S. Johnson and T. K. Schaaf, *Chem. Commun.*, 611 (1969).
(7) Prepared using an adaptation of a published procedure: S. J. Rhodes, J. C. Gilbert, A. W. Decora, T. R. Garland, R. J. Spangler, and M. W. Urbigkit, *Tetrahedron*, **19**, 1625 (1963).
(8) S. F. Brady, M. A. Ilton, and W. S. Johnson, *J. Am. Chem. Soc.*, **90**, 2882 (1968).
(9) This esterification procedure was developed by P. A. Bartlett from a procedure used previously for *O*-alkylation of enols; cf. W. S. Johnson and H. Posvic, *J. Am. Chem. Soc.*, **69**, 1361 (1947).
(10) L. M. Berkowitz and P. N. Rylander, *J. Am. Chem. Soc.*, **80**, 6682 (1958).
(11) K. Bowden, I. M. Heilbron, E. R. H. Jones, and B. C. L. Weedon, *J. Chem. Soc.*, 39 (1946).
(12) B. Loev and M. M. Goodman, *Chem. Ind. (London)*, 2026 (1967).
(13) O. Mancera, H. J. Ringold, C. Djerassi, G. Rosenkranz, and F. Sondheimer, *J. Am. Chem. Soc.*, **75**, 1286 (1953).
(14) M. F. Hawthorne, W. D. Emmons, and K. S. McCallum, *J. Am. Chem. Soc.*, **80**, 6393 (1958).
(15) In cases where products were isolated by solvent extraction, the procedure generally followed was to extract the aqueous layer with several portions of the indicated solvent; then the organic layers were combined and washed with water followed by saturated brine. The organic layer was dried over anhydrous sodium sulfate or magnesium sulfate and filtered and the solvent was evaporated under reduced pressure (water aspirator) using a rotary evaporator. The use of the term "wash" indicates washing the combined organic layers with saturated aqueous sodium bicarbonate solution ("base wash"), with dilute aqueous hydrochloric acid ("acid wash"), or with the indicated solution prior to the aforementioned washing with water.