the specified times: 2.5 hr, 4:38:26:32; 6 hr, 6:42:27:25; 24 hr, 4:38:24:34.

Starting with 1-benzyl-6-methyltetralin (**18**), samples taken after 15, 30, and 60 min of reaction were found to contain 8, 12, and 10% 1-phenyl-5-(*m*-tolyl)pentane (**19**), but no 1-phenyl-5-(*p*-tolyl)pentane (**20**). The rest of the mixture consisted of starting material and unidentified components.

Registry No.—**1**, 1771-65-9; **2a**, 38436-23-6; **2b**, 38436-24-7; **3a**, 38436-25-8; **3b**, 38436-26-9; **4a**, 38436-27-0; **4b**, 38436-28-1; **5a**, 38436-29-2; **5b**, 38436-30-5; **6a**, 38436-31-6; **6b**, 38436-32-7; **7a**, 38436-33-8; **7b**, 38425-19-3; **8a**, 38425-20-6; **8b**, 38425-21-7; **17**, 38425-22-8; **18**, 38425-23-9; **19**, 38425-24-0; **20**, 38425-25-1; pyrotartaric anhydride, 4100-80-5; *p*-methyl-γ-chlorobutyrophenone, 38425-26-2; 1-chloro-4-hydroxy-5-phenyl-4-(*p*-tolyl)pentane, 38425-27-3; 1-hydroxy-5-phenyl-1-(*m*-tolyl)pentane, 38425-28-4; β-*p*-(toluoyl)propionic acid, 4619-20-9; γ-phenyl-γ-tolyl-γ-butyrolactone, 38425-30-8; 5-phenyl-4-(*p*-tolyl)pentanoic acid, 38425-31-9; 4-benzyl-7-methyl-1-tetralone, 38425-32-0; ethyl β-hydroxy-γ-phenyl-(*p*-tolyl)butyrate, 38425-33-1; γ-phenyl-β-(*p*-tolyl)butyric acid, 38425-34-2; 3-(*p*-tolyl)-1-tetralone, 38425-35-3; 3-(*p*-tolyl)-1-tetralone 2,4-dinitrophenylhydrazone, 38425-36-4; 1-hydroxy-1-methyl-3-(*p*-tolyl)tetralin, 38425-37-5; 1-methyl-3-(*p*-tolyl)tetralin, 38425-38-6.

Geometrical Isomerism of 1-Arylidene-2-indanone[1]

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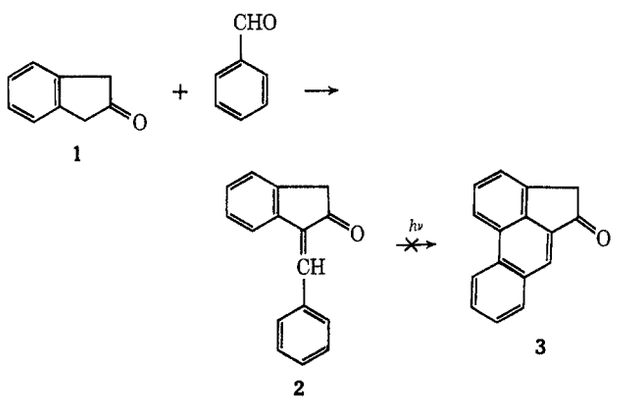
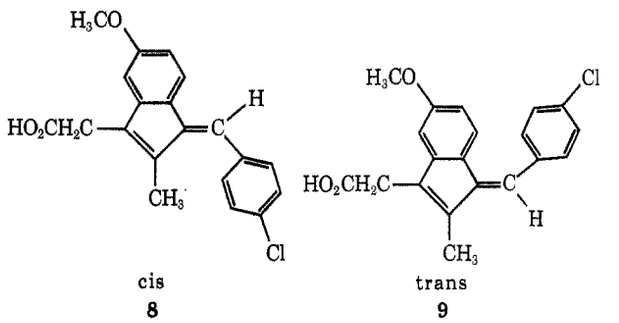
An example of geometrical isomerism in 1-(*p*-bromobenzylidene)-2-indanone is reported. Separation of the cis and trans isomers by dry column chromatography and the assignment of their structures using nmr spectroscopy and the nuclear Overhauser effect is described.

The primary objective of this investigation was to synthesize 5-acephenanthrenone (**3**),[2] an important intermediate in the synthesis of certain phenanthrene amino alcohols as potential antimalarial agents. Our initial approach involving the monocondensation of various aromatic aldehydes with 2-indanone (**1**) followed by photochemical cyclization (Scheme I) was unsuccessful.

SCHEME I



Attempts to effect the condensation of **1** using equimolar amounts of benzaldehyde in the presence of various bases such as sodium ethoxide,[3] potassium hydroxide–aqueous ethanol,[4] piperidine–benzene,[5] etc., were unsuccessful. Similarly, the use of acid catalysis (H_2SO_4–HOAc)[6] failed to give the desired compound **2**. Finally, condensation of 2-(*N*-morpholinyl)indene (**4**)[7] with *p*-bromobenzaldehyde was conducted by refluxing them in the presence of acetic acid for 4 hr.[8,9] Acid hydrolysis of the reaction mixture followed by dry column chromatography over silica gel using a fraction collector afforded a dibenzylidene compound **7** (8.7%) and two isomeric monobenzylidines, one with the *p*-bromophenyl substituent cis, compound **5** (1.3%), and the other with the *p*-bromophenyl substituent trans, compound **6** (36.6%), with respect to the C-2 oxygen (Scheme II). The assignment of **5** and **6** as cis and trans isomers is consistent with the work of Hoogsteen and Trenner[10] on the structure and conformation of the cis compound **8** and trans compound **9**, isomers of 1-(*p*-chlorobenzylidene)-2-methyl-5-methoxyindenylacetic acid. Their structural assignments were based on nmr data and single-crystal X-ray structure determination.



(1) R. E. Harmon, H. N. Subbarao, and S. K. Gupta, Abstracts, 162nd National Meeting of the American Chemical Society, Washington, D. C., Sept 1971, ORGN 112.

(2) R. E. Harmon, M. Mazharuddin, and S. K. Gupta, *J. Chem. Soc.*, in press.

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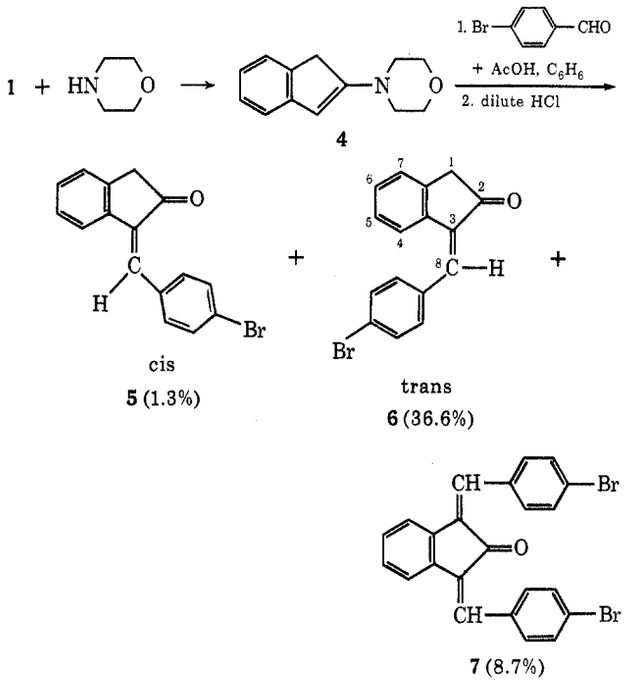
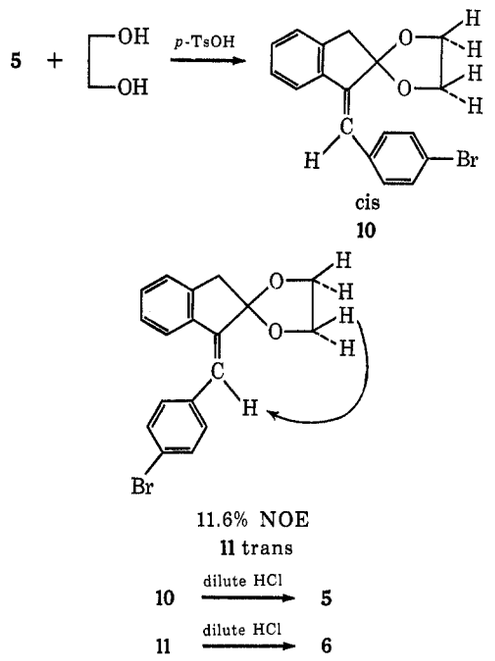
(10) K. Hoogsteen and N. R. Trenner, *ibid.*, **35**, 521 (1970).

SCHEME II



SCHEME III



As compared to the excellent separations of pure cis and trans isomers **5** and **6** achieved by us using dry column chromatography, Hoogsteen and Trenner[10] were able to separate the cis and trans isomers **8** and **9** only in extremely poor yields by fractional crystallization coupled with reverse-phase partition column chromatography.

The structures of compounds **5** and **6** were established as cis and trans isomers of 1-(*p*-bromobenzylidene)-2-indanone on the basis of elemental analyses and ir, nmr, and mass spectral data. The nmr data are given in Table I. Before going into the nmr discussions, it

TABLE I

CHEMICAL SHIFTS IN THE NMR SPECTRA OF COMPOUNDS **5**, **6**, **10**, AND **11**

	Cis **5**	Trans **6**	Cis **10**	Ttrans **11**
Vinyl	7.15	7.43	7.13	6.74
Benzyl	3.55	3.57	3.17	3.20
p-Bromophenyl	7.52, 7.94	7.47, 7.56	7.42	7.33, 7.47
Ketal			3.92, 3.97	4.09, 4.21

should be mentioned that treatment of compound **6** with ethylene glycol in the presence of *p*-toluenesulfonic acid yielded two ketals, **10** (30.6%, mp 125–126°) and **11** (38.3%, mp 118–120°). On the basis of elemental analyses and nmr data discussed below, these ketals were found to be cis and trans isomers. Furthermore, each of them could be independently hydrolyzed with acid to the corresponding monobenzylidene without any significant isomerization (Scheme III).

Nmr Analysis of Compounds 5, 6, 10, and 11.— The nmr data are given in Table I. The structural assignments for compounds **5**, **6**, **10**, and **11** were based on an observed nuclear Overhauser effect (NOE) of 11.6% on the vinyl hydrogen of compound **11** when the ketal hydrogens were irradiated. Compounds **5** and **10** were therefore the cis isomers of compounds **6** and **11**, respectively. A Dreiding model of compound **11** also showed that the vinyl hydrogen in it was very close to the two α-oriented methylene hydrogens.

The NOE did not operate in the opposite direction, nor did the other isomer show an NOE because of multiple relaxation pathways. The paramagnetic shift of the vinyl hydrogen in **10** *vs.* **11** and **5** *vs.* **6** is reasonably attributed to the anisotropy in the plane of the aromatic ring. This is also in agreement with the observations of Hoogsteen and Trenner[10] from the nmr data on compounds **8** and **9**. For instance, the vinyl proton in the cis isomer **8** resonated at δ 7.47, whereas in trans isomer **9** it resonated at δ 7.00. The diamagnetic shift of the ketal hydrogens in **10** *vs.* **11** is attributed to the positive anisotropycone perpendicular to the plane of the *p*-bromophenyl ring. A Dreiding model of **10** indicated that the *p*-bromophenyl ring was rotated out of coplanarity owing to the steric hinderance of the ketal methylenes. The AA′BB′ multiplets of **10** and **11** were analyzed with the LAOCN computer program.[11]

The spectrum of the trans isomer, **11**, was iterated to a fit with an RMS error of 0.353. The spectrum of the cis isomer, **10**, was fitted by adjusting the shifts but using the same coupling constants that were determined for the trans isomer. The plots of the calculated spectra were in agreement with the observed spectra. The results are summarized in Table II.

$J_{A',B'}$ (not shown in Table II) was the same as $J_{A,B}$. At first we were surprised to find $J_{A,B}$ to be -8.17 Hz instead of about -10 Hz as generally expected. To make sure that the computer did not converge to give the wrong fit, we tried to find solutions with $J_{A,B}$ around -10 Hz by varying L and keeping N constant. However, these computed spectra were significantly different from the experimental spectrum. Subsequent literature search revealed other examples of ketals showing $J_{A,B}$ in the -7.5 to -8 Hz region. For in-

(11) G. Slomp, *Appl. Spectrosc.*, **2**, 263 (1969).

TABLE II
ANALYSIS OF THE KETAL AA'BB' MULTIPLETS IN THE NMR SPECTRA OF COMPOUNDS 10 AND 11 USING LAOCN COMPUTER PROGRAM[11]

	11	10
$\delta_{A,A'}$	4.09320	3.91750
$\delta_{B,B'}$	4.21106	3.97259
$J_{A,A'}$	10.271	10.271
$J_{B,B'}$	10.271	10.271
$J_{A,B}$	−8.173	−8.173
$J_{A,B'}$	6.267	6.267

stance in 1965 Abraham[12] reported that in the A_2B_2 proton resonance spectrum of 2-methyl-1,3-dioxolane, J_{gem} was −7.5 Hz. Similarly, Fraser, *et al.*,[13] found that the nmr spectra of a series of substituted dioxolanes showed J_{gem} of −8.3 Hz.

Attempted Photochemical Cyclization of 6.—All of our attempts to achieve the photochemical cyclization of the monobenzylidene **6** to get the desired acephenanthrenone **3** failed. The reactions either yielded multicomponent mixtures or unidentifiable products. The synthesis of compound **3** has now been achieved using an entirely different approach.[2]

Experimental Section

Melting points were determined with a Thomas-Hoover melting point apparatus and are corrected. The elemental analyses were performed by Midwest Microlab, Inc., Indianapolis, Ind. A Beckman IR-8 spectrophotometer was used for recording the ir spectra. A Cary 14 spectrophotometer was used to record the uv spectra. The nmr spectra were obtained on Varian A-60 and Varian HA-100 spectrometers using deuteriochloroform or hexadeuteriodimethyl sulfoxide as solvents using tetramethylsilane (TMS) as an internal standard. Mass spectral data were obtained on an Atlas CH-4 mass spectrometer. Silica gel G from Brinkman Instruments was used for thin layer chromatography (tlc) either on glass slides or 6 × 20 cm² glass plates. Spots on plates were detected by iodine vapor. Column chromatography was carried out on a 5 × 40 cm² glass column packed with silica gel. An Instrument Specialties Co. automatic fraction collector, Model 272, was used to collect the various fractions during column chromatography. 2-Indanone (**1**) was prepared from indene according to the procedure of Horan and Schiessler.[14] Experimental procedures used for the condensation of **1** with substituted benzaldehydes in the presence of NaOEt,[3] KOH–aqueous EtOH,[4] piperidine–benzene,[5] H_2SO_4–HOAc,[6] etc., were essentially similar to those described in the literature for similar aldol condensations. Since none of these procedures gave the desired 1-arylidene-2-indanone, it is not considered worthwhile to give the experimental details of these procedures. 2-(*N*-Morpholinyl)indene (**4**) was prepared by the reaction of **1** with morpholine using the procedure reported by Blomquist and Moriconi.[7]

Condensation of 2-(*N*-Morpholinyl)indene (4) with *p*-Bromobenzaldehyde.—A solution of *p*-bromobenzaldehyde (8.76 g, 0.06 mol) in benzene (100 ml) was added dropwise to a stirred and refluxing solution of **4** (12.06 g, 0.06 mol) in benzene (300 ml) using a Dean-Stark trap and under an atmosphere of nitrogen gas. The addition was completed in about 30 min. After that glacial acetic acid (3.6 g, 0.06 mol) was added to it and the reaction mixture was refluxed for 4 hr. The reaction mixture was hydrolyzed by adding 1:1 HCl–H_2O (100 ml) and refluxing while stirring overnight. The organic layer was separated and the solvent was evaporated under reduced pressure to give 17.4 g of a crude oil which showed several spots on a thin layer chromatogram. This crude mixture was separated into the following components using dry column chromatography over silica gel. An automatic fraction collector was used to collect the various fractions using 10:1 benzene–chloroform as solvents. The yields are based on the enamine **4**.

Combined fraction I, compound **7**, yellow crystals, 2.43 g (8.8% yield), had mp 204–205°. *Anal.* Calcd for $C_{23}H_{14}Br_2O$: C, 59.26; H, 3.02. Found: C, 59.45; H, 3.2.

Combined fraction II, compound **5**, white crystals, 0.23 g (1.3% yield), had mp 115–116°; ir ($CHCl_3$) 1710 cm^{-1} (C=O); nmr ($CDCl_3$) is given in Table I. *Anal.* Calcd for $C_{16}H_{11}BrO$: C, 64.22; H, 3.70; Br, 26.71. Found: C, 64.11; H, 3.66; Br, 26.91.

Combined fraction III, compound **6**, yellow crystals, 6.38 g (36.6% yield), had mp 110–111°; ir ($CHCl_3$) 1725 cm^{-1} (C=O); nmr ($CDCl_3$) is given in Table I. *Anal.* Calcd for $C_{16}H_{11}BrO$: C, 64.22; H, 3.70; Br, 26.71. Found: C, 64.47; H, 3.62; Br, 26.41.

Total yield of monocondensation products **5** and **6** was 37.9%.

Combined fraction IV, compound **1**, colorless crystals, 4.06 g, had mp 55–57°, and was identified as 2-indanone (**1**).

Treatment of 1-(*p*-Bromobenzylidene)-2-indanone (6) with Ethylene Glycol. Preparation of Ketals 10 and 11.[15]—A solution containing compound **6** (2.5 g), *p*-toluenesulfonic acid (200 mg), ethylene glycol (10 ml), and benzene (200 ml) was refluxed for 20 hr. The reaction mixture was cooled and washed first with an aqueous solution of Na_2CO_3 (10%), and then with water. The organic phase was dried (Na_2SO_4) and evaporated to dryness under reduced pressure. The residual oil was subjected to dry column chromatography over silica gel using a fraction collector. The following two fractions were separated. Fraction I, compound **11**, colorless crystals, 1.1 g (yield 38.3%), had mp 118–120°. *Anal.* Calcd for $C_{18}H_{15}BrO_2$: C, 62.99; H, 4.40; Br, 23.28. Found: C, 63.07; H, 4.24; Br, 23.21. The nmr data is given in Table I. Fraction II, compound **10**, colorless crystals, 0.87 g (yield 30.6%), had mp 125–126°. *Anal.* Calcd for $C_{18}H_{15}BrO_2$: C, 62.99; H, 4.40; Br, 23.28. Found: C, 62.95; H, 4.30; Br, 23.30.

Acid Hydrolysis of the Ketals 10 and 11.—A small amount (30 mg) of each of the ketals **10** and **11** was hydrolyzed by shaking it with a solution containing benzene (40 ml), water (10 ml), and concentrated HCl (2 ml) for 1 hr. After that the organic layer was separated and washed first with aqueous Na_2CO_3 and then with water. It was dried (Na_2SO_4) and the solvent was evaporated under reduced pressure. Using this procedure, the hydrolysis of the ketal **10** gave mainly the ketone **5**, whereas the ketal **11**, upon hydrolysis, afforded the corresponding ketone **6** exclusively. The identity of the products was established by melting point, mixture melting point, and superimposable ir spectra.

Registry No.—**1**, 615-13-4; **4**, 23929-00-2; **5**, 33611-18-6; **6**, 33611-17-5; **7**, 33500-65-1; **10**, 33611-20-0; **11**, 33611-19-7; *p*-bromobenzaldehyde, 1122-91-4; ethylene glycol, 107-21-1.

Acknowledgment.—The work at Western Michigan University was supported by the U. S. Army Medical Research and Development Command, Contract No. DADA-17-70-C-0090. The nmr analysis was performed at the Upjohn Co. This is Contribution No. 1050 to the Army Research Program on Malaria.

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