ether. The ether extract was washed with water, dried, and evaporated to an oil. When 100 mL of benzene was added, the crystals that formed were collected and washed with 20 mL of benzene. These crystals, weighing 2.7 g (46%), mp 234–237 °C, after crystallization from C_6H_6–MeOH, gave the pure stereoisomer **5b**, mp 240–243 °C; NMR δ 0.98 (d, $CHCH_3$, J = 7 Hz), 2.67 (m, $CHCH_3$), 2.84 (m, O=CCH), 3.68 (two s, CO_2CH_3), 6.50–7.05 (m, aromatic), 7.92 (s, OH); mass spectrum, *m/e* (relative intensity) 291 (100), 350 (55), 410 (37), 107 (31), 292 (25), 59 (25), 121 (23), 145 (18), 351 (17), 290 (17).

Anal. Calcd for $C_{24}H_{26}O_6$: C, 70.23; H, 6.39. Found: C, 70.06; H, 6.33.

The original benzene filtrate was evaporated, and crystallization of the residue from MeOH–H_2O gave 3.1 g of a mixture which, by both NMR and elemental analysis, appeared to be about 60% product, a mixture of two stereoisomers, and 40% unreacted **3a**. Most of the starting material was removed from the crude product by sublimation at 160 °C, and the residue was crystallized from MeOH–H_2O to give an isomeric mixture, mp 203–204 °C; NMR δ 1.16 (d, $CHCH_3$, J = 7 Hz), 3.00 (m, $CHCH_3$), 3.42 (m, O=CCH), 3.70 (s, CO_2CH_3), 6.50–7.00 (m, aromatic), 7.85 (s, OH); mass spectrum, *m/e* (relative intensity) 350 (100), 121 (49), 291 (41), 351 (39), 410 (32), 107 (23), 244 (17), 59 (16), 292 (10), 276 (10).

Anal. Calcd for $C_{24}H_{26}O_6$: C, 70.23; H, 6.39. Found: C, 70.18; H, 6.41.

Dienestrol–1,4-Naphthoquinone Adduct. A solution of 3 g of **3a** and 3 g of naphthoquinone in 50 mL of xylene was heated at 150 °C for 4 h. The reaction mixture was cooled to give crystals of unreacted **3a**. The filtrate was diluted with hexane to yield a product which, after several crystallizations from dilute EtOH, gave a small amount of yellow crystals which melted with decomposition at 250 °C. No elemental analysis was obtained. The NMR spectrum indicated that the product was a mixture of two stereoisomers and that no residual **3a** was present. NMR δ 0.89 (d, $CHCH_3$, J = 7 Hz), 1.13 (d, $CHCH_3$, J = 7 Hz), 3.15 (s, OH), 3.30–3.58 (m, $CHCH_3$), 3.76–3.90 (m, $CHCH_3$), 6.44–7.05 (m, aromatic on phenolic rings), 7.90 (m, *o*-phenylene).

Photolysis of Adducts. Typically, starting materials were at or near a concentration of 3×10^{-5} M. A Mineralight Model SL (254 nm) 9-W hand lamp was used as the source of UV radiation. Solutions were placed in a 1-cm Teflon-stoppered quartz cuvette (4-mL capacity), irradiated with the lamp flush against the cuvette for intervals timed with a stopwatch, and then scanned directly in the spectrophotometer. No spectral changes were noted during storage in the dark in the absence of irradiation.

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Registry No.—**3a,** 13029-44-2; **3a**–naphthoquinone (isomer I), 64490-43-3; **3a**–naphthoquinone (isomer II), 64521-02-4; **3b,** 24705-62-2; **3c,** 64490-47-7; **5a,** 64490-48-8; **5b** (isomer I), 64490-49-9; **5b** (isomer II), 64550-40-9; **6,** 64490-50-2; **7,** 64490-51-3; **8,** 64490-52-4; **9,** 64490-53-5; maleic anhydride, 108-31-6; phenylurazole, 15988-11-1; dimethyl maleate, 624-48-6; naphthoquinone, 130-15-4; tetracyanoethylene, 670-54-2.

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Facile Synthesis of Hexahydroapoerysopine via Intramolecular Photoarylation of β-Enamino Ketones

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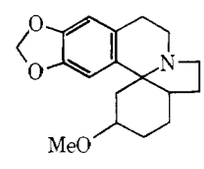
A novel synthesis of hexahydroapoerysopine dimethyl ether (**26**) has been achieved by using photochemical cyclization of β-enamino ketones as a key reaction. The reaction of 3,3a,4,5-tetrahydro-6-methoxy-2*H*-indole (**15**) with 3,4-dimethoxyphenethyl- (**9**) or 2-iodo-4,5-dimethoxyphenethyl iodide (**13**) afforded the corresponding *N*-phenethyl derivatives of 1,2,3,3a,4,5-hexahydro-6*H*-indol-6-one, **17** and **18**, respectively; compound **17** was further brominated to give 7-bromo-1,2,3,3a,4,5-hexahydro-1-(3,4-dimethoxyphenethyl)-6*H*-indol-6-one (**22**). Upon irradiation, the halogenated β-enamino ketones **18** and **22** underwent intramolecular photoarylation and photoreduction, yielding 3,3a-dihydro-2*H*-apoerysopin-1-one dimethyl ether (**21**) and **17**, respectively. Reduction of **21** with $LiAlH_4$ gave the dimethyl ether derivatives of 3,3a,12b,12c-tetrahydro-2*H*-apoerysopin-1-one (**24**) and 2,3,3a,12c-tetrahydroapoerysopine (**25**); the latter was catalytically hydrogenated to 1,2,3,3a,12c,12b-hexahydroapoerysopine dimethyl ether (**26**).

Treatment of tetrahydroerythraline (**1**) under acidic conditions followed by methylation with diazomethane has been reported to yield an optically active base formulated as hexahydroapoerysopine dimethyl ether.[1,2] This reaction has been referred to as the "apo rearrangement".[3] Synthetic routes to such "apo derivatives" possessing the dearomatized ring D are very few in number.[4] We have now devised a new synthesis



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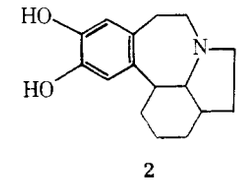

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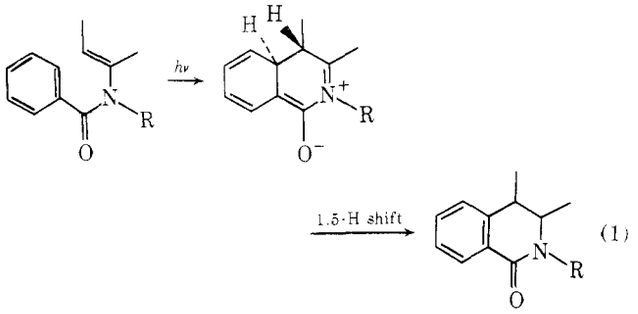
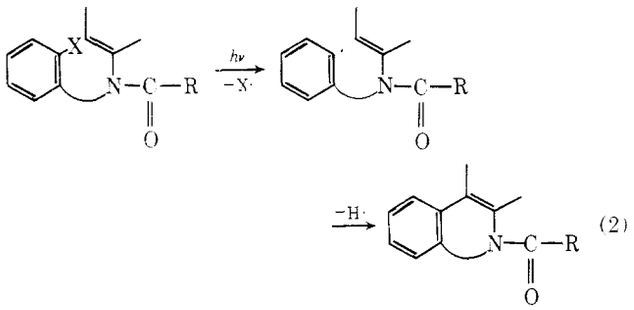
of the title compound from the key intermediate **21** obtained by photolysis of halogen-containing enamino ketones. Our results represent a convenient one-step preparation of β-enamino ketones from the iminoenol ether **15** and new variants of intramolecular arylation.

Intramolecular photoarylations of enamides to heterocyclic ring system have been extensively studied,[5-8] particularly in the field of alkaloid synthesis. The majority of these reactions are regarded as an electrocyclic reaction schematically illustrated by eq 1.[5a,6] Alternatively, a cyclization which takes places via photolysis of halogenoenamides according to eq 2 has been reported in a few cases.[8] Our initial goal was the synthesis of an efficient precursor required for photolysis to form the indolo[7,1-*ab*][3]benzazepine ring system. For this purpose we first attempted to obtain the bromoenamide **5** which, on the basis of eq 2, was expected to undergo photocyclization to the azepine **6**. Thus condensation of the keto acid **3** with the bromophenethylamine **4** was carried out.



(1)



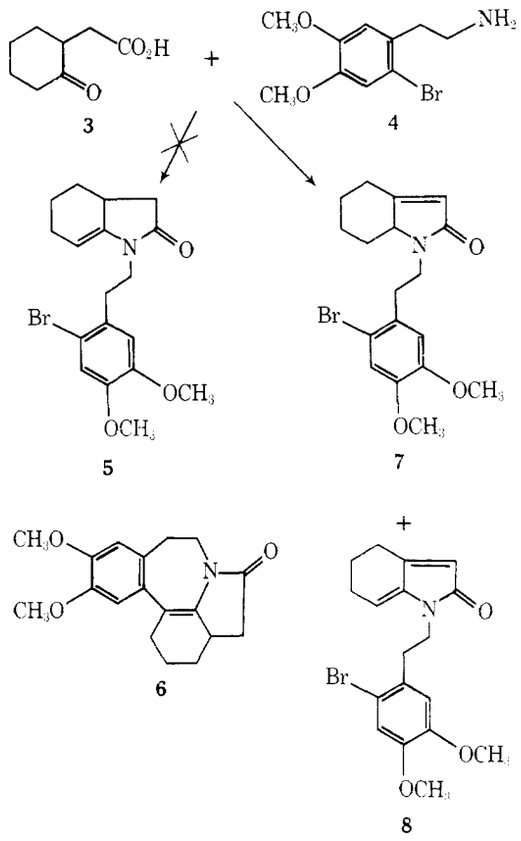
(2)

However, the main product was not the desired enamide **5**, but rather the enamide **7** with the enamine double bond in the endo position to the five-membered ring, along with a minor amount of the more stable oxindole **8** which might arise by oxidation during work-up (Scheme I). Upon irradiation of the latter product **8**, an intractable mixture of unidentified products was obtained.

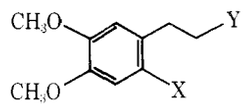
We therefore turned our attention to an alternate suitable substrate needed for photochemical reaction; we planned to fix the enamine double bond in the exo position to five-membered ring by the introduction of a carbonyl group as in the β-enamino ketone **17**. For synthesis of this, we initially explored the use of 1,2,3,3a,4,5-hexahydro-6*H*-indol-6-one (**16**) as a starting material, readily prepared from 6-methoxyindoline (**14**) by the method previously reported (Scheme II),[7] since **16** has already the desired fixed exocyclic enamine double bond to the five-membered ring. Accordingly, reaction of **16** with 3,4-dimethoxyphenethyl iodide (**9**) in the presence of sodium hydride in dimethyl sulfoxide gave the *N*-substituted enamino ketone **17** in 35% yield. Alternatively, when the iodide **9** was heated with the iminoenol ether **15** in benzene, *N*-alkylation and C–O bond cleavage proceeded in situ providing the enamino ketone **17** in 49% yield, which, in very small yield, was further *C*-alkylated to give **19**.

From these results the latter route was conveniently chosen for preparing the required precursor **18** to the indolobenza-

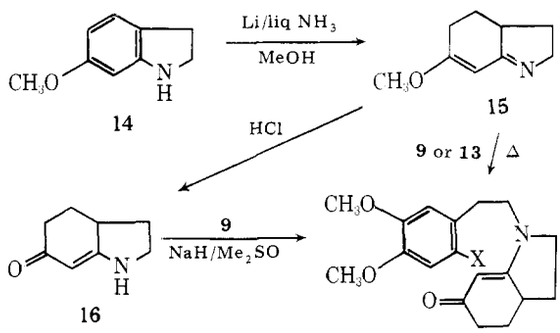
Scheme I



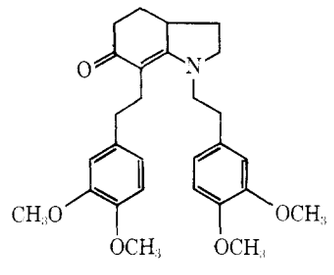
Scheme II



9, X = H; Y = I
10, X = H; Y = OH
11, X = I; Y = OH
12, X = I; Y = Cl
13, X = I; Y = I

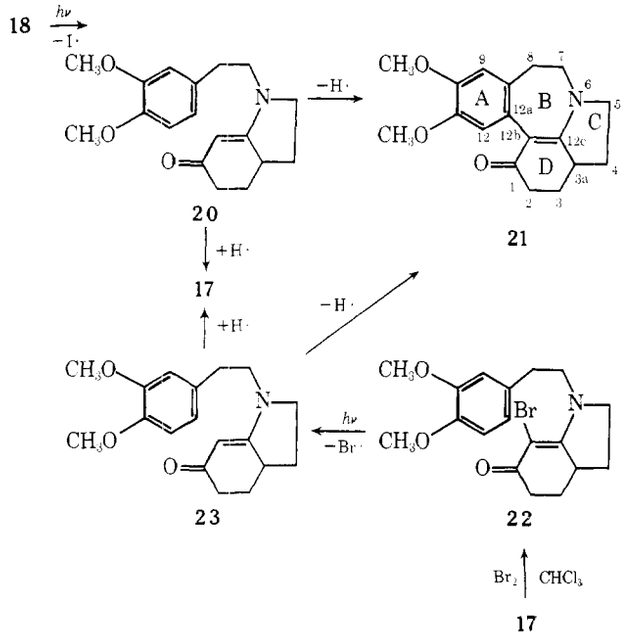


17, X = H
18, X = I

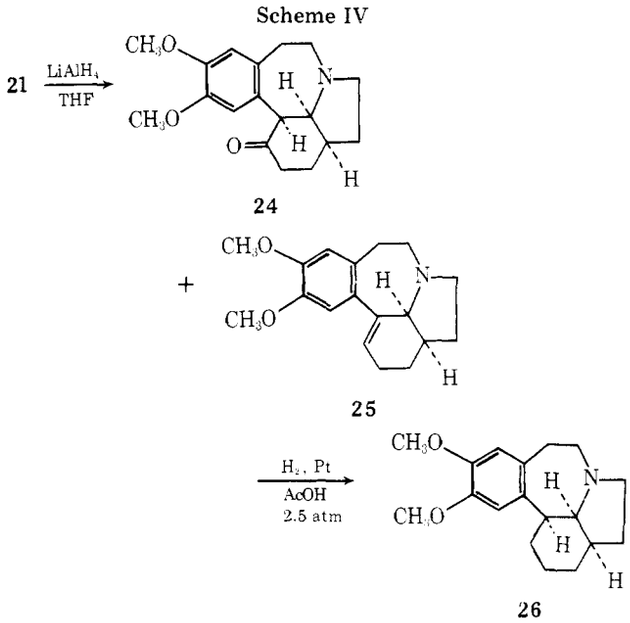


19

Scheme III



Scheme IV



zepine ring system. The synthesis of **18** started with iodination of 3,4-dimethoxyphenethyl alcohol (**10**) in the presence of silver trifluoroacetate in chloroform to afford **11** in 88% yield. Chlorination of **11** with thionyl chloride in the presence of *N,N*-diethylaniline in benzene gave the phenethyl chloride **12**, which was then converted to the corresponding iodide **13** by treatment with sodium iodide–methyl ethyl ketone complex. The diiodide **13** was heated with the iminoenol ether **15** in refluxing toluene to give the requisite iodoenamino ketone **18** in 55% yield.

Pyrex-filtered irradiation of **18** in degassed dioxane containing triethylamine using a 100-W high-pressure mercury lamp produced the tetracyclic azepine **21** in 50% yield. As shown in Scheme III, the ring closure to **21** was accompanied by competitive hydrogen transfer to provide the photoreduction product **17** (30% yield), identical with the above synthesized material, likely through initial generating of a common phenyl radical **20**. The azepine ring formation in **21** was confirmed by its NMR spectrum which showed the disappearance of the vinylic proton. In addition, one of two aromatic proton singlets (δ 6.50 and 7.21) was markedly shifted downfield, indicating that the C-12 proton lies in close proximity to the C-1 carbonyl group.

We were next interested in using an enamino ketone bearing a halogen atom at the α position as an alternative precursor to the azepine ring system. Thus **17**, conveniently prepared from the iminoenol ether **15** as described above, was allowed to react with 1 molecular equiv of bromine in chloroform to give the bromoenamino ketone **22** in 75% yield. Irradiation of **22** in acetonitrile in a manner similar to that described for the iodoenamino ketone **18** led to photocyclization to provide **21** and photoreduction to give **17**, in yields of 38 and 13%, respectively. These products may have arisen from radical **23** (Scheme III).

Intermediate **21** was converted into hexahydroapoerysopine as outlined in Scheme IV. Reduction of **21** with $LiAlH_4$ in tetrahydrofurane afforded the apoerysopinone **24** and the tetrahydroapoerysopine **25** in yields of 10 and 63%, respectively. The stereochemical assignment for **25** was based on its NMR analysis involving decoupling experiments in the following way: saturation of the vinylic resonance at δ 6.50 collapsed a doublet at δ 2.73 with fine splitting to a clear-splitting doublet with coupling constant of 6.5 Hz which indicates that the C/D ring junction is cis. It is known[9] that $LiAlH_4$ reduction of β-enamino ketones usually involves Michael addition of hydride and formation of an enolate which can resist further reduction and thus produce β-amino ketones. In that case, the reduction with $LiAlH_4$ leading to the major product **25** may involve the initial formation of **24**, and therefore **24** likely possesses the cis C/D ring junction in relation to the structure of **25**.[10] Cis stereochemistry was tentatively assigned to the B/C ring system of **24** since even if the C-12b epimer of **24** were formed initially, the serious nonbonded interaction between the C-12 aromatic hydrogen and the C-1 carbonyl oxygen would easily cause epimerization to **24** under alkaline conditions in analogy with previous finding.[11] The C-12b stereochemical assignment above in **24** was most strongly suggested by comparing the chemical shift of the C-12 proton in **24** with those of the C-12 protons in **21** and **25**. The value in **24** (δ 6.64) is close to that in **25** (δ 6.78), where the C-12 proton is free from the deshielding effect due to the C-1 carbonyl group, and is strikingly different from that in **21** (δ 7.21, vide supra). These facts indicate that the C-12b proton in **24** should be α oriented so that the C-12 proton in **24** does not suffer a downfield shift by the C-1 carbonyl group.

Hydrogenation of **25** in acetic acid over Adams catalyst at 2.5 atm yielded what is presumed to be hexahydroapoerysopine dimethyl ether (**26**) in 43% yield by delivery of hydrogen to the less hindered α face thus resulting in a B/D cis fusion, in analogy with our previous work.[7] The pyrrolo[1,2-*a*]azepine ring systems (ring B/C) of these products **24**, **25**, and **26** derived from the photoproduct **21** were all presumably trans fused, based on the strong Bohlmann bands observed in the 2700–2800-cm^{-1} region of their IR spectra.

The IR spectrum ($CHCl_3$) of the picrate of our synthetic hexahydroapoerysopine (**26**) was similar to that of the picrate[12] of the compound obtained on rearrangement of natural tetrahydroerythraline (**1**). The UV spectrum of our free base was almost superimposable on that recorded in the literature[1] for the apo rearranged product but differed significantly from that recorded for unrearranged product[1] which has been formulated as hexahydroerysotrine.[2] Although these observations could not exclude the possibility that the compound obtained on rearrangement of **1** is a stereoisomer of **26**, they show unambigously that **1** is subject to an unusual apo rearrangement on acid treatment to form the azepine ring system.

Experimental Section

Melting points are uncorrected and were determined on a Yanagimoto micro apparatus. IR spectra were recorded on a Hitachi 215

grating spectrophotometer. NMR spectra were taken as $CDCl_3$ solutions on a JOEL JNM-PS-100 spectrometer using $(CH_3)_4Si$ as an internal standard. UV spectra were recorded on a Hitachi 124 spectrometer. Mass spectra were obtained on a Hitachi RMU-7L double-focusing spectrometer at 70 eV. GLC analyses were performed on a Shimadzu GC-6A (flame ionization detector) instrument. Merck precoated silica gel F-254 plates (200 × 200 × 0.5 mm) were used for preparative TLC.

Condensation of Cyclohexanone-2-acetic Acid (3) with 2-Bromo-4,5-dimethoxyphenethylamine (4). A mixture of 1.6 g (0.010 mol) of the keto acid **3**[13] and 2.6 g (0.010 mol) of the bromophenethylamine **4** was heated under stirring at 160–170 °C for 7 h under an atmosphere of nitrogen. After cooling, the solidified reaction mixture was dissolved in chloroform, washed in turn with saturated aqueous $NaHCO_3$, 5% HCl, and water, and dried ($MgSO_4$). After evaporation of the solvent, the residue was chromatographed on a silica gel column. Benzene–chloroform (10:1) eluted an oily mixture which was further chromatographed on preparative TLC plates with ether as developing solvent to give two major components. The faster moving band gave 0.2 g (5%) of 1-(2-bromo-4,5-dimethoxyphenethyl)-5,6-dihydro-4*H*-oxindole (**8**) as an oil: IR ($CHCl_3$) 1670, 1650, 1640 cm^{-1}; NMR δ 3.83 (s, 6 H, 2 OCH_3), 5.60 (t, J = 4 Hz, 1 H, C-7 vinyl H), 5.75 (s, 1 H, C-3 vinyl H), 6.68 (s, 1 H, C-6′ aromatic H), 6.98 (s, 1 H, C-3′ aromatic H); mass spectrum m/e (rel intensity) 379 (3.8, M^+), 377 (4.4, M^+), 298 (68, $M^+ - Br$), 244 (71), 242 (72), 229 (10), 148 (100). The slower moving component was recrystallized from benzene–hexane to give 0.8 g (21%) of 1-(2-bromo-4,5-dimethoxyphenethyl)-5,6,7,7a-tetrahydro-4*H*-oxindole (**7**) as pale yellow prisms: mp 126–128 °C; IR ($CHCl_3$) 1675, 1660; NMR δ 3.84 (s, 6 H, 2 OCH_3), 5.75 (s, 1 H, vinyl H), 6.80 (s, 1 H, C-6′ aromatic H), 7.00 (s, 1 H, C-3′ aromatic H); mass spectrum m/e (rel intensity) 381 (3.4, M^+), 379 (3.7, M^+), 300 (40, $M^+ - Br$), 244 (26), 242 (27), 150 (100). Anal. Calcd for $C_{18}H_{22}BrNO_3$: C, 56.85; H, 5.83; N, 3.18. Found: C, 56.97; H, 5.83; N, 3.30.

1,2,3,3a,4,5-Hexahydro-1-(3,4-dimethoxyphenethyl)-6*H*-indol-6-one (17). Method A. To 5 mL of dimethyl sulfoxide (Me_2SO), 0.2 g of NaH was added and the mixture was stirred at room temperature for 30 min under an atmosphere of nitrogen. To this stirred slurry was added a solution of 0.45 g (3.3 mmol) of **16**, prepared by the method previously reported,[7] in 5 mL of Me_2SO followed by a solution of 0.95 g (3.3 mmol) of 3,4-dimethoxyphenethyl iodide (**9**)[14] in 5 mL of Me_2SO. The stirred mixture was heated at 50 °C for 3.5 h and the solvent was evaporated under reduced pressure. The residue was treated with water and extracted with chloroform. After drying ($MgSO_4$), the solvent was evaporated and the residue was recrystallized from benzene–hexane to give 0.35 g (35%) of **17** as colorless prisms: mp 45 °C; IR ($CHCl_3$) 1610, 1565; NMR δ 2.79 (t, 2 H, J = 7 Hz, CH_2Ph), 3.39 (t, 2 H, J = 7 Hz, NCH_2CH_2Ph), 3.83 (s, 6 H, 2 OCH_3), 5.05 (s, 1 H, vinyl H), 6.61 (s, 1 H, C-2′ aromatic H), 6.64 (d, 1 H, J = 11 Hz, C-5′ aromatic H), 6.73 (dd, 1 H, J = 11 and 0.5 Hz, C-6′ aromatic H); mass spectrum (rel intensity) 301 (13, M^+), 164 (62), 150 (100). Anal. Calcd for $C_{18}H_{23}NO_3$: C, 71.73; H, 7.69; N, 4.65. Found: C, 71.75; H, 7.64; N, 4.57.

Method B. A solution of 1.0 g (6.6 mmol) of the iminoenol ether **15** and 1.9 g (6.5 mmol) of the phenethyl iodide **9** in 20 mL of dry benzene was heated under reflux for 2 h. The solvent was evaporated and the residue was chromatographed on a silica gel column. Initial elution with chloroform afforded 0.03 g (1%) of 1,2,3,3a,4,5-hexahydro-1,7-di(3,4-dimethoxyphenethyl)-6*H*-indol-6-one (**19**), which was recrystallized from ethyl acetate to give colorless prisms: mp 122–124 °C; IR ($CHCl_3$) 1600, 1560, 1555 cm^{-1}; NMR δ 3.75, 3.80, 3.84, and 3.86 (each s, 3 H, OCH_3), 6.60–6.83 (m, 6 H, aromatic H); mass spectrum m/e (rel intensity) 465 (3.0, M^+), 315 (100), 165 (25), 150 (38). Further elution with the same solvent yielded 0.95 g (49%) of **17**, identical with the authentic sample prepared by method A above.

2-Iodo-4,5-dimethoxyphenethyl Alcohol (11). A solution of 6.9 g (0.027 mol) of iodine in an adequent amount of chloroform (ca. 90 mL) was added with stirring to a slurry of 6.0 g (0.027 mol) of silver trifluoroacetate[15] and 7.8 g (0.027 mol) of 3,4-dimethoxyphenethyl alcohol (**10**)[14] in 30 mL of chloroform at room temperature. After addition was complete (1 h), the mixture was stirred for an additional 30 min and insoluble substances were removed by filtration. The filtrate was evaporated to yield a residue which was recrystallized from benzene–hexane to give 7.3 g (88%) of **11** as colorless needles: mp 52–54 °C; IR ($CHCl_3$) 3580 cm^{-1}; NMR δ 2.53 (s, 1 H, OH), 2.95 (t, 2 H, J = 7 Hz, CH_2Ph), 3.89 (s, 6 H, 2 OCH_3), 6.82 (s, 1 H, C-6 aromatic H), 7.24 (s, 1 H, C-3 aromatic H); mass spectrum m/e (rel intensity) 308 (50, M^+), 277 (100), 181 (5.6), 150 (56). Anal. Calcd for $C_{10}H_{13}IO_3$: C, 38.98; H, 4.25. Found: C, 39.21; H, 4.32.

2-Iodo-4,5-dimethoxyphenethyl Chloride (12). To a solution of 6.0 g (0.019 mol) of the phenethyl alcohol **11** in 20 mL of dry benzene containing 2.6 mL of *N,N*-diethylaniline was added 3.5 g (0.035 mol) of thionyl chloride at room temperature during 15 min under stirring. After heating the mixture on a steam bath for 1.5 h, the solvent and the volatile material were removed under reduced pressure. The residue was extracted with benzene, washed with water then 5% Na_2CO_3, and dried ($CaCl_2$). The solvent was evaporated to give a pale yellow oil which upon column chromatography (silica gel, benzene) gave 5.4 g (85%) of **12**, as colorless needles recrystallized from methanol: mp 76–78 °C; NMR δ 3.13 (t, 2 H, J = 8 Hz, CH_2Ph), 3.70 (t, 2 H, J = 8 Hz, CH_2Cl), 3.86 and 3.88 (each s, 3 H, OCH_3), 6.80 (s, 1 H, C-6 aromatic H), 7.24 (s, 1 H, C-3 aromatic H); mass spectrum m/e (rel intensity) 328 (16, M^+), 326 (49, M^+), 277 (100), 164 (12), 150 (12).

2-Iodo-4,5-dimethoxyphenethyl Iodide (13). A suspension of 11.1 g (0.074 mol) of NaI in 84 mL of dry methyl ethyl ketone was heated under reflux for 1.5 h. To this was added a solution of 16 g (0.049 mol) of the phenethyl chloride **12** in 6 mL of dry methyl ethyl ketone and the mixture was heated at reflux for 2 h. After the mixture was cooled, the inorganic substances were removed by filtration and the filtrate was evaporated. The residue was extracted with ether, washed with water, and dried ($CaCl_2$). Removal of the solvent left 15 g of crude material of **13** as a colorless solid which can be used as such for the following reaction. GLC analysis (1.5% SE-30/Chromosorb W, 200 °C) showed that this material contained about 5% unreacted phenethyl chloride. Pure **13** was obtained by several recrystallizations from methanol: mp 55–57 °C; mass spectrum m/e (rel intensity) 418 (37, M^+), 291 (14), 277 (20), 164 (100).

1,2,3,3a,4,5-Hexahydro-1-(2-iodo-4,5-dimethoxyphenethyl)-6*H*-indol-6-one (18). A solution of 0.9 g (6.0 mmol) of the iminoenol ether **15** and 2.5 g (6.0 mmol) of the diiodide **13** in 20 mL of dry toluene was heated at reflux for 2 h. The solvent was evaporated and the residue was chromatographed on a silica gel column. Initial elution with benzene gave 0.9 g (36%) of the unreacted diiodide **13**. Further elution with ethyl acetate gave 1.4 g (55%) of **18** as crystalline material (mp 127–130 °C) which was recrystallized from benzene–hexane to give pure **18** as colorless prisms: mp 129–130 °C; IR ($CHCl_3$) 1600, 1565 cm^{-1}; NMR δ 3.82 (s, 6 H, 2 OCH_3), 5.14 (s, 1 H, vinyl H), 6.64 (s, 1 H, C-6′ aromatic H), 7.18 (s, 1 H, C-3′ aromatic H); mass spectrum m/e (rel intensity 427 (0.7, M^+), 300 (83, $M^+ - I$), 290 (16), 244 (5.0), 164 (7.5), 150 (100). Anal. Calcd for $C_{18}H_{22}INO_3$: C, 50.60; H, 5.19; N, 3.28. Found: C, 50.81; H, 5.12; N, 3.48.

7-Bromo-1,2,3,3a,4,5-hexahydro-1-(3,4-dimethoxyphenethyl)-6*H*-indol-6-one (22). To a stirred solution of 570 mg (1.9 mmol) of **17** in 20 mL of chloroform was added a solution of 310 mg (1.9 mmol) of bromine in 20 mL of chloroform at room temperature in the period of 30 min and stirring was continued for an additional 30 min. The mixture was washed with water and dried ($MgSO_4$). After removal of the solvent, the residue was purified by column chromatography on silica gel using chloroform as eluent and recrystallization from ethyl acetate to yield 540 mg (75%) of **22** as colorless leaves: mp 127–129 °C; IR (Nujol) 1590, 1575, 1555 cm^{-1}; NMR δ 2.94 (t, 2 H, J = 8 Hz, CH_2Ph), 3.86 (s, 6 H, 2 OCH_3), 6.78 (s, 3 H, aromatic H); mass spectrum m/e (rel intensity) 377 (2.4, $M^+ - 2H_2$), 375 (2.5 M^+, $-2H_2$), 301 (29), 277 (28), 164 (100), 150 (94). Anal. Calcd for $C_{18}H_{22}BrNO_3$: C, 56.85; H, 5.83; N, 3.68. Found: C, 57.03; H, 5.87; N, 3.63.

Irradiation of 1,2,3,3a,4,5-Hexahydro-1-(2-iodo-4,5-dimethoxyphenethyl)-6*H*-indol-6-one (18). A solution of 1.90 g (4.45 mmol) of **18** in 75 mL of dioxane containing 4.5 mL of triethylamine was purged with nitrogen for 1 h and irradiated under nitrogen atmosphere through Pyrex with a 100-W high-pressure mercury lamp. After 18 h, when TLC examination indicated consumption of most of the starting material, the mixture was washed with water and dried ($MgSO_4$). The solvent was removed and the residue was chromatographed on a silica gel column using chloroform as eluent. The first fraction contained 0.70 g (50%) of 3,3a-dihydro-2*H*-apoerysopin-1-one dimethyl ether (**21**) as a pale yellow syrup: IR (neat) 1610, 1580 cm^{-1}; NMR δ 3.85 (s, 6 H, 2 OCH_3), 6.50 (s, 1 H, C-9 aromatic H), 7.21 (s, 1 H, C-12 aromatic H); mass spectrum m/e (rel intensity) 299 (100, M^+), 284 (48), 195 (43), 134 (43); mass spectrum (high resolution) calcd for $C_{18}H_{21}NO_3$, 299.1521, and found, 299.1549.

The second fraction contained 0.40 g (30%) of the deiodinated product **17** identical with the material prepared by the above method.

Irradiation of 7-Bromo-1,2,3,3a,4,5-hexahydro-1-(3,4-dimethoxyphenethyl)-6*H*-indol-6-one (22). A solution of 200 mg (0.53 mmol) of **22** in 75 mL of acetonitrile containing 0.5 mL of triethylamine was purged with nitrogen for 1 h then irradiated as described above for **18**. After 20 h of irradiation, the solution was washed

with water and evaporated. The residue was chromatographed in the same manner for 18 to give 60 mg (38%) of **21** and 20 mg (13%) of **17**. Each product was identical with the respective authentic specimen described above.

Reduction of 3,3a-Dihydro-2*H*-apoerysopin-1-one Dimethyl Ether (21) with Lithium Aluminum Hydride. A solution of 200 mg (0.67 mmol) of **21** in 10 mL of dry THF was added slowly to a stirred slurry of 80 mg (2.1 mmol) of $LiAlH_4$ and 20 mL of dry THF with ice–water cooling. The mixture was stirred at room temperature for 1 h, excess hydride was destroyed by addition of 1 mL of ethyl acetate, and the complex was destroyed by addition of 1 mL of water. The mixture was filtered through Celite and the filtrate was evaporated. The residue was extracted with chloroform, washed with water, and dried ($MgSO_4$). After removal of the solvent, the residue was chromatographed on a silica gel column using chloroform as eluent. The first fraction contained 20 mg (9.9%) of 3,3a,12b,12c-tetrahydro-2*H*-apoerysopin-1-one dimethyl ether (**24**) as colorless prisms (mp 143–145 °C): IR (Nujol) 2775 and 2720 (Bohlmann bands), 1710 cm^{-1} (ketone C=O); NMR δ 3.81 and 3.84 (each s, 3 H, OCH_3), 6.54 (s, 1 H, C-9 aromatic H), 6.64 (s, 1 H, C-12 aromatic H); mass spectrum (high resolution) calcd for $C_{18}H_{12}NO_3$, 301.1708, and found, 301.1678. The second fraction yielded 120 mg (63%) of 2,3,3a,12c-tetrahydroapoerysopine dimethyl ether (**25**) as colorless crystals (mp 80–82°C): IR (KBr) 2770 and 2725 cm^{-1} (Bohlmann bands); NMR δ 2.73 (d, 1 H, J = 6.5 Hz, 12c-H), 3.90 (s, 6 H, 2 OCH_3), 6.05 (dd, 1 H, J = 4.5 and 3 Hz, vinyl H), 6.66 (s, 1 H, C-9 aromatic H), 6.78 (s, 1 H, C-12 aromatic H); mass spectrum m/e (rel intensity) 285 (60, M^+), 270 (75), 277 (22), 143 (100); mass spectrum (high resolution) calcd for $C_{18}H_{23}NO_2$, 285.1729, and found, 285.1699.

1,2,3,3a,12b,12c-Hexahydroapoerysopine Dimethyl Ether (26). To a solution of 55 mg (0.19 mmol) of the tetrahydroapoerysopine **25** in 20 mL of acetic acid, 5 mg of PtO_2 was added, and the mixture was hydrogenated at room temperature in a Parr hydrogenator at a starting pressure of 2.5 atm for 12 h. After removal of catalyst by filtration, the filtrate was evaporated under reduced pressure. The residue was extracted with chloroform, washed with 10% Na_2CO_3, and dried ($MgSO_4$). The solvent was evaporated and the residual oil was purified by preparative TLC on silica gel using chloroform–methanol (10:1) as developing solvent to give 24 mg (43%) of **26** as pale yellow liquid: IR (neat) 2775 and 2735 cm^{-1} (Bohlmann bands); UV (EtOH) λ_{max} (log ϵ) 228 (3.86), 283 (3.47) nm; NMR δ 3.84 and 3.87 (each s, 3 H, OCH_3), 6.58 (s, 1 H, C-9 aromatic H), 6.65 (s, 1 H, C-12 aromatic H); mass spectrum m/e (rel intensity) 287 (100, M^+), 272 (51), 259 (20), 244 (28), 165 (38); mass spectrum (high resolution) calcd for $C_{18}H_{25}NO_2$, 287.1885, and found, 287.1859. This material was dissolved in a small amount of methanol and converted to the picrate with an ethereal solution of picric acid. The crystalline product precipitated by standing over night in a refrigerator was collected by filtration and recrystallized from methanol, yielding the pure picrate as yellow needles, mp 233–234 °C. Anal. Calcd for $C_{18}H_{25}NO_2 \cdot C_6H_3N_3O_7$: C, 55.81; H, 5.46; N, 10.85. Found: C, 55.83; H, 5.51; N, 10.87.

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Registry No.—**3,** 1438-96-6; **4,** 63375-81-5; **7,** 64705-35-7; **8,** 64705-36-8; **9,** 64728-23-0; **10,** 7417-21-2; **11,** 64705-37-9; **12,** 64728-24-1; **13,** 64705-38-0; **15,** 59601-27-3; **16,** 64705-39-1; **17,** 64705-40-4; **18,** 64705-41-5; **19,** 64705-42-6; **21,** 64705-43-7; **22,** 64705-44-8; **24,** 64705-45-9; **25,** 64705-46-0; **26,** 64705-47-1; **26** picrate, 64705-48-2.

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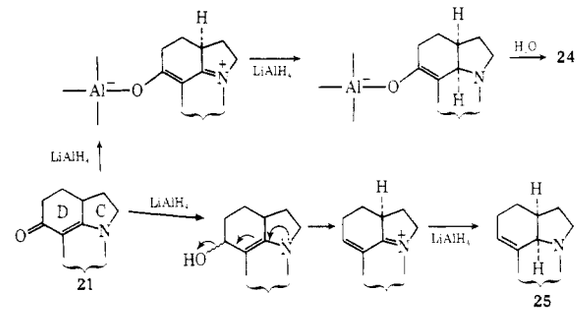

In both processes marked by asterisks the hydride ion could transferred to the least hindered α side of the >C=N⁺< function to give the product with C/D cis ring junction in each case.
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