methyl)cyclopentanone was made basic, a gummy solid was obtained from which no N-(ferrocenylmethyl)pyrrolidine was isolable. If undried solvent was used as solvent in the enamine alkylation, some N-(ferrocenylmethyl)pyrrolidine was obtained at this stage.

## Biindolyls. III. Substituted 2,3'-Biindolyls from 3-Arylacetylindoles[1,2]

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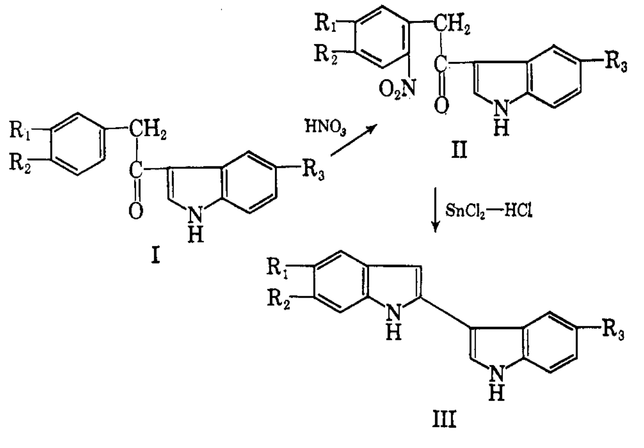
For reasons cited in an earlier paper[4] we have been seeking broadly applicable methods for the synthesis of substituted 2,3'-biindolyls. Although low yields of such compounds have been obtained on reduction of 2-(3-indolyl)-3H-pseudoindol-3-ones,[2] the more successful synthesis of 5,6-dimethoxy-2,3'-biindolyl (IIIa) by reductive cyclization of 3-(4,5-dimethoxy-2-nitrophenylacetyl)indole (IIa)[4] appeared to be more promising as a potentially general route to the desired class of compounds. It has now been found that the accessibility of the 3-(*o*-nitrophenylacetyl)indoles (II) required as starting materials is sharply limited, a deficiency which has confined the over-all method to a few special cases summarized by the sequence of formulas (I to III, a–d).

In this reaction sequence, the crucial introduction of the nitro group at the necessary *ortho* position of the phenyl ring is dependent on the relative reactivities of aryl and indolyl moieties. Although fortuitously favorable in the cases cited (60–95% yield of II), the balance is delicately controlled by all substituents as shown by unsuccessful attempts to nitrate 19 additional 3-arylacetylindoles,[5] most of which were expected to yield the required 3-(*o*-nitroarylacetyl)indoles. For example, 3-methoxy-, 3,4-dichloro-, 3,4-dimethyl-, 2-chloro-3,4-dimethoxy-, 5-chloro-3,4-dimethoxy-, and 2-chloro-4,5-dimethoxyphenylacetylindoles, as well as their 5-bromoindole analogs, were all recovered unchanged from nitric–acetic acid media at room temperature. At higher temperatures, extensive decomposition occurred in all cases. The 2-methylindole analogs of Ia–d, although easily attacked by the same nitrating medium at room temperature, also gave no well-defined mononitration products.



| | R1 | R2 | R3 |
|---|---|---|---|
| a | MeO | MeO | H |
| b | MeO | MeO | Br |
| c | O-CH2-O | | H |
| d | O-CH2-O | | Br |

Reduction of the nitro ketones (IIb–d) with stannous chloride and hydrochloric acid in glacial acetic acid easily afforded the corresponding 2,3'-biindolyls (IIIb–d), albeit in yields of only 10–47%. All of these 2,3'-biindolyls showed ultraviolet absorption spectra similar to that of 2,3'-biindolyl, formed yellow solutions with dilute ethanolic hydrogen chloride, and gave stable blue "rosindoles" with Ehrlich's reagent, thus confirming their structural assignments, as well as those of the precursor nitro compounds (II). A more detailed structure proof for IIa has already been presented.[4]

### Experimental[6]

**Acylation of Indoles. General Procedure.**—A solution of 0.11 mole of indole (or 5-bromoindole) in 50 ml. of anhydrous benzene was added dropwise during 10 min. to a vigorously stirred solution of 0.117 mole of phenylmagnesium bromide, prepared in the usual way, in 100 ml. of anhydrous ether. The resulting mixture was refluxed for 2 hr., then cooled to −10° in a Dry Ice–methanol bath. A solution of 0.100 mole of the arylacetyl chloride in 40 ml. of benzene was then added dropwise during 45 min. while the temperature was maintained at −8 to −10°. The cooling bath was removed; the mixture was stirred an additional 30 min., then hydrolyzed by addition of 50 ml. of 10% aqueous ammonium chloride. The resulting solid product was collected by filtration, washed several times with ether, then air-dried. The products so obtained are described individually in the following paragraphs.

**3-(3,4-Dimethoxyphenylacetyl)-5-bromoindole** (Ib).—The reaction of 5-bromoindolylmagnesium bromide and homoveratroyl chloride[4] gave this product directly on hydrolysis of the reaction mixture in 37% yield. Recrystallization from 95% ethanol afforded white needles, m.p. 228–230°, infrared ($\mu$), 3.16 (N-H) and 6.06 (C=O).

*Anal.* Calcd. for $C_{18}H_{16}BrNO_3$: C, 57.76; H, 4.31; N, 3.74. Found: C, 57.89; H, 4.60; N, 3.67.

**3-(3,4-Methylenedioxyphenylacetyl)indole** (Ic).—Reaction of indolylmagnesium bromide and 3,4-methylenedioxyphenylacetyl chloride[7] yielded 21 g. (95%) of 1,3-di(3,4-methylenedioxyphenylacetyl)indole, which was recrystallized from *n*-propyl alcohol to give white needles, m.p. 145–146°, infrared ($\mu$), 5.76 and 5.95 (C=O).

*Anal.* Calcd. for $C_{26}H_{19}NO_6$: C, 70.74; H, 4.34; N, 3.17. Found: C, 70.95; H, 4.71; N, 3.14.

Two grams of this product was refluxed for 5 min. with a solution of 5 ml. of 10% sodium hydroxide in 20 ml. of 95% ethanol. The resulting hot solution was diluted with 10 ml. of water, filtered, and allowed to cool to room temperature. The resulting crop of crystals was collected, washed with water, then recrystallized from 95% ethanol to give 1.1 g. (88% yield) of Ic, m.p. 194–196°, infrared ($\mu$), 3.01 (N-H) and 6.12 (C=O).

*Anal.* Calcd. for $C_{17}H_{13}NO_3$: C, 73.10; H, 4.69; N, 5.02. Found: C, 73.25; H, 4.80; N, 4.94.

**3-(3,4-Methylenedioxyphenylacetyl)-5-bromoindole** (Id).—Reaction of 5-bromoindolylmagnesium bromide and 3,4-methylenedioxyphenylacetyl chloride yielded 22.8 g. of a crude white solid

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[1] This investigation was supported by Research Grant C-4425 from the National Cancer Institute, National Institutes of Health, U. S. Public Health Service.

[2] Part II: T. E. Young and D. S. Auld, *J. Org. Chem.*, **28**, 418 (1963).

[3] Abstracted from the Ph.D. dissertation of M. F. M., Lehigh University, 1963.

[4] T. E. Young, *J. Org. Chem.*, **27**, 507 (1962).

[5] Syntheses and properties of these compounds will be reported elsewhere.

[6] Melting points are corrected. Infrared spectra were determined in potassium bromide on a Perkin-Elmer Model 21 spectrophotometer. Ultraviolet spectra were run on a Beckman DK-2A instrument. Indole and 5-bromoindole were obtained from Aldrich Chemical Co., Milwaukee, Wis.

[7] C. Mannich and O. Walther, *Arch. Pharm.*, **265**, 7 (1927); *cf. Chem. Zentr.*, 1, 1479 (1927).

which lacked a well-defined melting point and was probably a mixture of 3-acyl and 1,3-diacyl compounds. This mixture was hydrolyzed by brief refluxing with aqueous alcoholic sodium hydroxide as in the preceding example to yield 13.7 g. (38%) of 3-acyl compound (Id), which, after recrystallization from 95% ethanol, had m.p. 256–258°, infrared ($\mu$), 3.13 (N–H) and 6.06 (C=O).

*Anal.* Calcd. for $C_{17}H_{12}BrNO_3$: C, 57.00; H, 3.38; N, 3.91. Found: C, 57.17; H, 3.59; N, 3.96.

**3-(4,5-Dimethoxy-2-nitrophenylacetyl)-5-bromoindole (IIb).**—A solution of 2.24 g. (0.006 mole) of Ib in 160 ml. of boiling glacial acetic acid was cooled to 80° and a solution of 0.54 g. (0.006 mole) of concentrated nitric acid (69.6%) in 10 ml. of glacial acetic acid was added. The yellow solution was allowed to cool, whereby the color deepened and a solid began to separate. The mixture was allowed to stand at room temperature for 3 hr., then the solid was collected on a filter, washed several times with glacial acetic acid, and air-dried. Recrystallization from 95% ethanol gave 2.08 g. (83%) of a pale yellow solid, m.p. 250° dec., infrared ($\mu$), 3.05 (N–H) and 6.05 (C=O).

*Anal.* Calcd. for $C_{18}H_{15}BrN_2O_5$: C, 51.56; H, 3.61; N, 6.68. Found: C, 51.67; H, 3.79; N, 6.41.

**3-(4,5-Methylenedioxy-2-nitrophenylacetyl)indole (IIc).**—Four grams of Ic was nitrated as in the preceding example (4-hr. reaction time) to yield 2.80 g. (60%) of IIc, which recrystallized from glacial acetic acid as fine yellow needles, m.p. 239–240° dec., infrared ($\mu$), 3.08 (N–H) and 6.20 (C=O).

*Anal.* Calcd. for $C_{17}H_{12}N_2O_5$: C, 62.96; H, 3.72; N, 8.64. Found: C, 63.21; H, 3.93; N, 8.28.

**3-(4,5-Methylenedioxy-2-nitrophenylacetyl)-5-bromoindole (IId).**—Nitration of 0.40 g. of Id with 0.11 g. of concentrated nitric acid in 38 ml. of nitromethane for 1 hr. at 60° yielded 0.43 g. (95%) of IId, which crystallized from the reaction mixture. Recrystallization from nitromethane gave pale yellow needles, m.p. 266° dec., infrared ($\mu$), 3.04 (N–H) and 6.18 (C=O).

*Anal.* Calcd. for $C_{17}H_{11}BrN_2O_5$: C, 50.63; H, 2.75; N, 6.94. Found: C, 50.77; H, 2.88; N, 6.65.

**5,6-Dimethoxy-5′-bromo-2,3′-biindolyl (IIIb).**—Two grams (0.0048 mole) of IIb was dissolved in 200 ml. of boiling glacial acetic acid, and a solution of 8.0 g. (0.035 mole) of stannous chloride dihydrate in 15 ml. of concentrated hydrochloric acid was added during 5 min. The solution was then boiled for 10 min. and allowed to stand at room temperature overnight. A yellow solid separated; it was collected on a filter, washed several times with acetic acid, followed by several washings with ether, and air-dried. The yield of orange-yellow powder was 2.2 g. This solid (presumably the hexachlorostannic acid complex) was mixed with 8 ml. of 95% ethanol and enough water to make a stirrable paste, and 5% sodium hydroxide solution was added dropwise until the pH of the mixture was about 7. The reaction mixture changed from red-orange to a pale yellow color at completion of the addition. The cream-colored solid was collected by filtration, washed several times with water, air-dried, then extracted with 50 ml. of boiling 95% ethanol divided roughly into three portions. The combined ethanol extracts were allowed to cool and a small amount of granular white solid which separated was removed by filtration and discarded. The ethanol filtrate was heated to boiling, diluted with 20 ml. of water, and allowed to cool. The slightly colored crystalline solid which separated was collected, then recrystallized twice from aqueous ethanol and twice from aqueous methanol to yield 0.40 g. (22%) of IIIb as off-white feathery needles, m.p. 220–221°; ultraviolet spectrum (95% ethanol): $\lambda_{max}$ m$\mu$ (log $\epsilon$), 247 (4.37), 293 shoulder (4.14), and 323 (4.40). An ethanolic solution of the compound gave a deep blue color with Ehrlich's reagent.

*Anal.* Calcd. for $C_{18}H_{15}BrN_2O_2$: C, 58.23; H, 4.07; N, 7.55. Found: C, 58.50; H, 4.35; N, 7.52.

**5,6-Methylenedioxy-2,3′-biindolyl (IIIc).**—A similar reduction of 2.40 g. (0.0074 mole) of IIc with 5.63 g. (0.025 mole) of stannous chloride dihydrate and 8 ml. of concentrated hydrochloric acid in 200 ml. of glacial acetic acid was effected as in the preceding example except that ethyl acetate was used for the extraction. Evaporation of the extracts followed by sublimation of the residue at 200° (0.4 mm.) afforded 0.20 g. (10% yield) of IIIc which, after one recrystallization from aqueous ethanol and a final sublimation, was obtained as fine white needles, m.p. 222–223° dec.; ultraviolet spectrum (95% ethanol): $\lambda_{max}$ m$\mu$ (log $\epsilon$), 240 (4.44), 279 (4.04), 289 shoulder (4.00), and 335 (4.40). An ethanolic solution of the compound gave a deep blue solution with Ehrlich's reagent.

*Anal.* Calcd. for $C_{17}H_{12}N_2O_2$: C, 73.89; H, 4.37; N, 10.14. Found: C, 74.09; H, 4.41; N, 10.25.

**5,6-Methylenedioxy-5′-bromo-2,3′-biindolyl (IIId).**—A similar reduction of 2.00 g. (0.0050 mole) of IId in 250 ml. of acetic acid with 4.00 g. (0.018 mole) of stannous chloride dihydrate in 6 ml. of concentrated hydrochloric acid, followed by a work-up analogous with that of the preceding example, gave 0.84 g. (47% crude yield) of product, m.p. 212–218° dec. Sublimation at 210–215° (0.08 mm.), accompanied by considerable decomposition of the unsublimed residue, yielded white crystals, m.p. 224–226° dec.; ultraviolet spectrum (95% ethanol): $\lambda_{max}$ m$\mu$ (log $\epsilon$), 248 (4.31), 281 shoulder (4.03), 291 shoulder (4.00), and 333 (4.37); deep blue color with Ehrlich's reagent.

*Anal.* Calcd. for $C_{17}H_{11}BrN_2O_2$: C, 57.48; H, 3.12; N, 7.89. Found: C, 57.39; H, 3.35; N, 7.91.

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## The Photoaddition of Cyclic Ethers to 1-Octene

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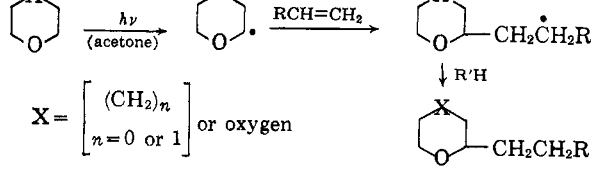
The peroxide-induced reactions of cyclic ethers with 1-octene and maleic anhydride have been reported to produce ketones[1] or $\alpha$-substituted cyclic ethers[2,3] as the major products. Recent investigations on the light-induced reactions of maleic anhydride,[3] 7,7,8,8-tetracyanoquinodimethane, and tetracyanoethylene[4] with tetrahydrofuran have demonstrated that $\alpha$-substituted tetrahydrofurans are the main reaction products, while the same reactions of maleic anhydride with tetrahydropyran and 1,4-dioxane have led to nondistillable mixtures.[3]

These studies prompted us to report the results of a similar investigation involving the photoaddition of cyclic ethers to 1-octene at room temperature which have mainly produced $\alpha$-substituted alkyl ethers. The reaction can be induced directly by light or initiated photochemically by acetone, the latter conditions resulting in higher yields of the alkylated products.

Our results differ from those reported by Wallace and Gritter[1] in that the addition of tetrahydrofuran and tetrahydropyran to 1-octene occurs without ring opening. The formations of 1:1 adducts of tetrahydropyran and 1,4-dioxane with 1-octene are also in contrast to the results obtained by Jacobs and Ecke[3] who have not been able to isolate 1:1 adducts of the same ethers with maleic anhydride.

This addition of cyclic ethers to olefins presumably



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[1] T. J. Wallace and R. J. Gritter, *Tetrahedron*, **19**, 657 (1963), and references cited therein.

[2] T. J. Wallace, R. J. Gritter, and H. G. Walsh, *Nature*, **198**, 284 (1963), and references cited therein.

[3] R. L. Jacobs and G. G. Ecke, *J. Org. Chem.*, **28**, 3036 (1963).

[4] J. Diekmann and C. J. Pedersen, *ibid.*, **28**, 2879 (1963).