remaining 20 mL of solution was added a limiting amount of borohydride (about 3 mol of ketone/mole of hydride), and the mixture was allowed to react at room temperature. After the reaction was quenched with water, most of the solvent was removed by rotary evaporation, and the residue was made up to 20.0 mL with 2-propanol. Five milliliters of this solution was withdrawn and added to 1.0 mL of the *o*-dibromobenzene stock solution. GLC analysis of this sample provide data to establish the number of moles of ketone remaining. Each GLC analysis was performed in duplicate, and each experiment was run in duplicate. Relative reactivities were calculated by eq 4 with the GLC areas and standard curves to establish concentrations of ketone before and after the reaction.

$$\text{rel rate} = k_A/k_B = (\ln [A]_t/[A]_0)/(\ln [B]_t/[B]_0) \quad (4)$$

Preparation of 2-(1-Hydroxyethyl)-6-methyltetrahydropyran (11). An ethanolic solution containing 27.2 g of **9** + **10** and 0.13 g of 5% Pd/C was hydrogenated. After the uptake of hydrogen had ceased, the reaction mixture was filtered, and the filtrate was reduced in volume to give the alcohol mixture. GLC (15% Carbowax) demonstrated very high conversion to the desired product. An analytical sample was obtained by GLC. Anal. Calcd for $C_8H_{16}O_2$: C, 66.67; H, 11.11. Found: C, 66.50; H, 10.98.

Preparation of 2-Acetyl-6-methyltetrahydropyran (12). To 2.1 g of **11** in 20 mL of Et_2O was added, dropwise, 1 equiv of Jones reagent. After being stirred for 2 h at 25 °C, the reaction mixture was neutralized with bicarbonate, and the ether layer was dried and reduced in volume to give the desired ketone. An analytical sample was obtained by GLC. Anal. Calcd for $C_8H_{14}O_2$: C, 67.61; H, 9.86. Found: C, 67.61; H, 10.07.

Acknowledgment. Partial support by the NSF (Grant No. ISP-8011449) is acknowledged. The gift of a generous supply of methyl vinyl ketone from Pfizer is greatly appreciated. The support of the NSF toward acquisition of the 250-MHz NMR spectrometer used in examining materials used in this study is acknowledged.

Registry No. **5**, 823-76-7; **6**, 7353-76-6; **7**, 28450-02-4; **9**, 56057-15-9; **10**, 56057-16-0; **11**, 56057-17-1; **12**, 57015-77-7; **13**, 2043-61-0; **14**, 100-50-5.

Condensation of Naphthoquinones with Polar Ethylenes. A Reexamination

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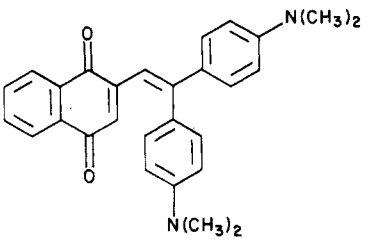
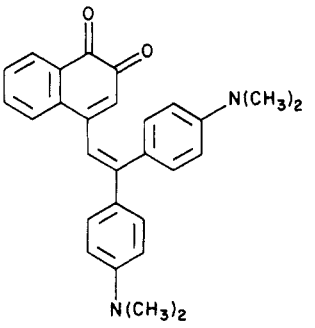
Some years ago I described[1] the condensation of naphthoquinones with polar ethylenes such as 1,1-bis[*p*-(dimethylamino)phenyl]ethylene and 1,1-di-*p*-anisylethylene. The products in the case of the condensation of 1,1-bis[*p*-(dimethylamino)phenyl]ethylene with α-naphthoquinone and β-naphthoquinone, respectively, were formulated as **1** and **2**, resulting from nucleophilic attack of the ethylene on the quinone followed by protolytic and redox equilibration. Structures analogous to **1** were proposed for the condensation products of naphthazarin with 1,1-bis[*p*-(dimethylamino)phenyl]ethylene and of α-naphthoquinone with 1,1-di-*p*-anisylethylene.

A reexamination of these substances with the aid of instrumental techniques unavailable at the time of the original work has para-disubstituted phenyl certain of the





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structural assignments are incorrect. Thus the mass spectrum of the condensation product of 1,1-bis[*p*-(dimethylamino)phenyl]ethylene with α-naphthoquinone shows a parent ion of *m/e* 420; structure **1** requires 422. Similarly, the condensation product of 1,1-di-*p*-anisylethylene and α-naphthoquinone has a parent ion of *m/e* 394, two less than that required by a structure analogous to **1**.

The 400-MHz NMR spectra of these two condensation products show only one AB pattern of the type expected from the para-substituted (dimethylamino)phenyl residues; structure **1** requires two. The second phenyl derived from the ethylene has acquired an additional substituent and appears as an unsymmetrical trisubstituted aromatic ring exhibiting the expected coupling (J_{para} = 0 Hz, J_{ortho} = 9.3–10 Hz, J_{meta} = 2.4–2.9 Hz).

In addition, syntheses of the hydroquinone dimethyl ethers corresponding to structure **1** and its analogue from 1,1-di-*p*-anisylethylene by alternate and unambiguous routes (see Scheme I) gave substances (**6** and **7**) not identical with those produced by reductive methylations of the corresponding quinone condensation products. The NMR spectra of these substances do show two AB patterns.

The condensation products of α-naphthoquinone with 1,1-bis[*p*-(dimethylamino)phenyl]ethylene and with 1,1-di-*p*-anisylethylene must thus be reformulated as **8** and **9**, respectively,[3] consistent with their mass spectra and their 400-MHz NMR spectra.

Likewise the product derived from naphthazarin and 1,1-bis[*p*-(dimethylamino)phenyl]ethylene must be reformulated as **10** since its mass spectrum shows a parent ion of *m/e* 452, and its 400-MHz NMR also exhibits the single AB quartet and trisubstituted aromatic pattern characteristic of **8** and **9**.

(1) Gates, M. *J. Am. Chem. Soc.* **1944**, *66*, 124.

(2) Some quinones show parent ions corresponding to their hydroquinones (Aplin, R. T.; Pike, W. T. *Chem. Ind.* **1966**, 2009, and private communication from Mr. Joseph Wright of the Eastman Kodak Research Laboratories).

(3) That these substances might be the result of additions of the Diels–Alder type was first suggested to me by Dr. George Fawaz, then of the American University in Beirut, in 1946.

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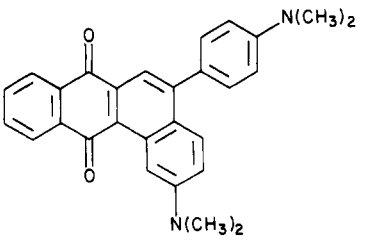

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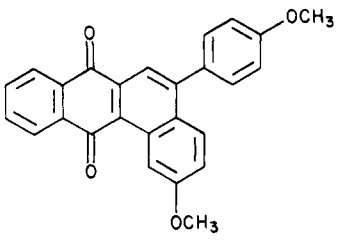

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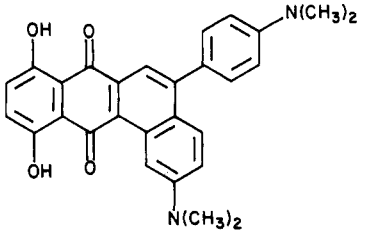

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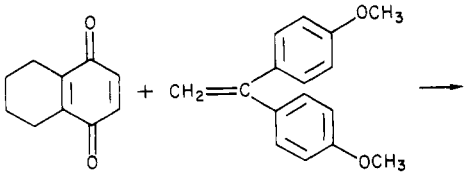
The reaction of the quinone 11 with 1,1-dianisylethylene, not reported in the earlier paper, also gives an analogous tetrahydrobenz[*a*]anthraquinone system (12). Its 400-MHz NMR spectrum is particularly simple and unambiguous, having only eight aromatic hydrogens.



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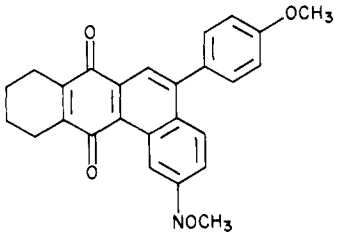

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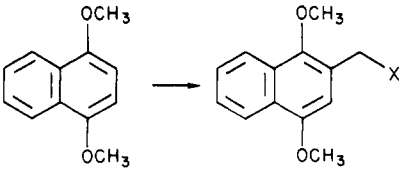
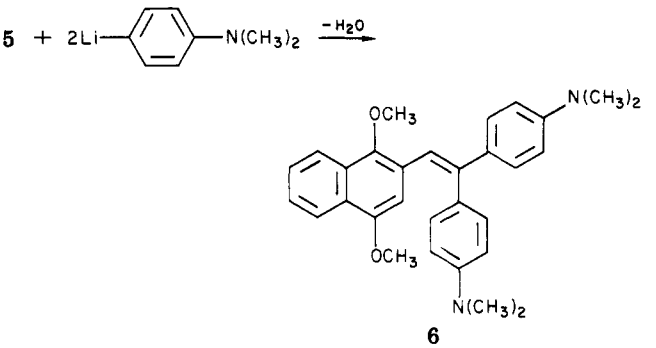
In all of these substances, the one-proton doublet, J_{meta} = 2.4–2.9 Hz (1 H) of the trisubstituted aromatic system, assignable to the 1-position of the benz[*a*]anthracene system, occurs at low fields, δ 9.13–9.19.

In contrast to the products derived from these 1,4-quinones, the condensation product of β-naphthoquinone and 1,1-bis[*p*-(dimethylamino)phenyl]ethylene *does* have the structure originally assigned (2). Its mass spectrum has a parent ion of *m/e* 424, two more than that required by 2,[2] and its 400-MHz NMR shows two AB quartets. Furthermore, reductive methylation of this condensation product yields a dimethyl ether (14) identical in all respects with the substance resulting from the action of [*p*-(dimethylamino)phenyl]lithium on methyl 3,4-dimethoxy-1-naphthaleneacetate (13) followed by dehydration. Both

Scheme I



3, X = Br
4, X = CN
5, X = $COOCH_3$



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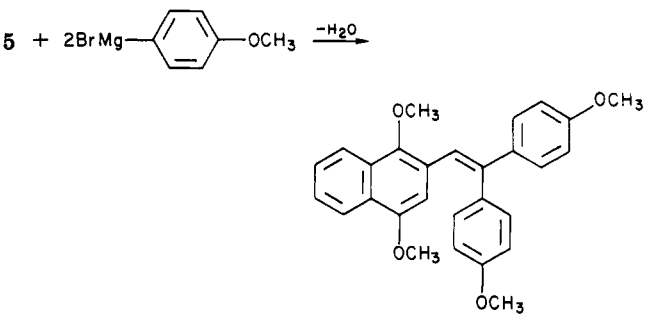

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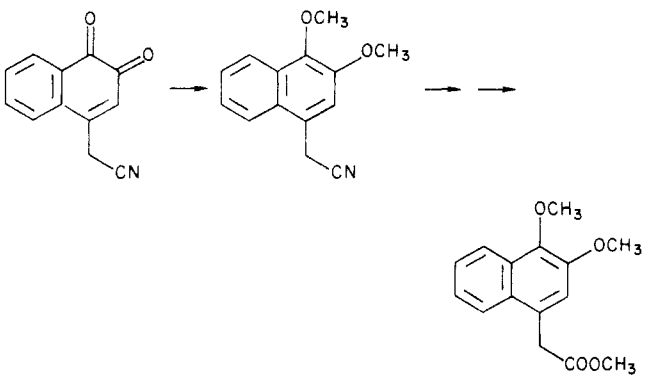
14 and the azine of 2[1] exhibit the expected two AB quartets in their NMR spectra.

A suggestion as to why α-naphthoquinones undergo cycloadditions with these polar ethylenes but β-naphthoquinone undergoes Michael addition can be derived from a comparison of the ^{13}CMR resonances of the C_2 carbon in α-naphthoquinone with that of the C_4 carbon in β-naphthoquinone. Although it is well-known that no general correlation between ^{13}C chemical shifts and electron densities at carbon exists,[4] in closely related series such relationships may be observed, and the values,[5] δ 138.5 for α-naphthoquinone and δ 145.4 for β-naphthoquinone, suggest that carbon 4 of β-naphthoquinone may be more electron deficient than carbon 2 of α-naphthoquinone and may thus be more susceptible to Michael addition.

Experimental Section

IR spectra were recorded on a Beckman Acculab 8 infrared spectrometer or on a Perkin-Elmer 467 grating infrared spectrometer. NMR spectra were recorded on either a Varian EM 390 NMR spectrometer or a Bruker WH 400 NMR spectrometer. Mass spectra were determined on a Du Pont 21490B mass spectrometer, a CEC/Du Pont 21–110 mass spectrometer, or an MAT 731 mass spectrometer. Some of the elemental analyses were carried out by Galbraith Laboratories. All melting points are corrected unless otherwise specified.

(4) Levy, G. C.; Lichter, R. L.; Nelson, G. L. "Carbon-13 Nuclear Magnetic Resonance Spectroscopy"; Wiley-Interscience: New York, 1980; p 102.
(5) McDonald, I. A.; Simpson, T. J.; Sierakowski, A. F. *Aust. J. Chem.* **1977**, *30*, 1727.



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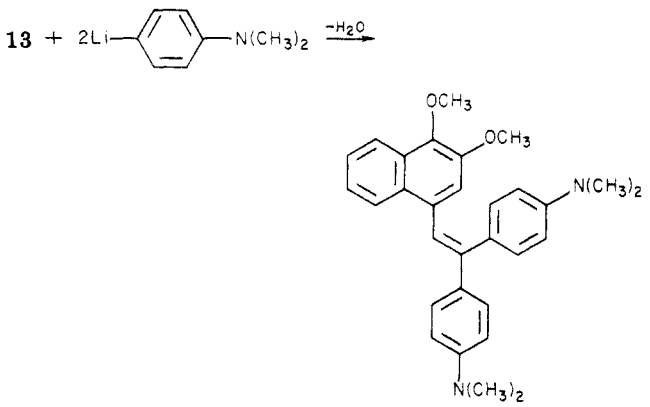

14

Several of the substances reported in the earlier paper[1] have been additionally characterized as follows.

2-(Dimethylamino)-5-[*p*-(dimethylamino)phenyl]benz[*a*]anthracene-7,12-dione (8), originally formulated as 1: mass spectrum, *m/e* 420, 405, 390, 376, 360, 333, 276; NMR (400 MHz) δ 3.05 (s, 6 H), 3.19 (s, 6 H), 6.85, 7.44 (ABq, 4 H, J = 8.3 Hz), 7.18 (d of d, 1 H, J_{meta} = 2.9 Hz, J_{ortho} = 9.3 Hz), 7.98 (d, 1 H, J_{ortho} = 9.3 Hz), 9.13 (d, 1 H, J_{meta} = 2.9 Hz), unsymmetrical trisubstituted aromatic, 7.69 (t, 1 H), 7.76 (t, 1 H), 8.05 (s, 1 H), 8.22 (d, 1 H), 8.31 (d, 1 H).

2-Methoxy-5-(*p*-anisyl)benz[*a*]anthracene-7,12-dione (9), originally formulated as the dimethoxy analogue of 1: mass spectrum, *m/e* 394, 379, 365, 363, 351, 336, 320, 308; NMR (400 MHz) δ 3.92 (s, 3 H), 4.08 (s, 3 H), 7.08, 7.47 (ABq, 4 H, J = 8.8 Hz), 7.24 (d of d, 1 H, J_{meta} = 2.4 Hz, J_{ortho} = 10 Hz), 7.95 (d, 1 H, J_{ortho} = 10 Hz), 9.39 (d, 1 H, J_{meta} = 2.4 Hz), unsymmetrical trisubstituted aromatic, 7.76 (t, 1 H), 7.82 (t, 1 H), 8.20 (s, 1 H), 8.26 (d, 1 H), 8.33 (d, 1 H).

4-[2,2-Bis[*p*-(dimethylamino)phenyl]vinyl]naphthalene-1,2-dione (2): mass spectrum, *m/e* 424, 422, 409, 394, 377, 365, 350, 322, 274, 121; NMR (400 MHz) δ 2.93 (s, 6 H), 2.99 (s, 6 H), 5.99 (s, 1 H), 6.61 (AB), 7.05 (J = 6.9 Hz, 4 H), 6.70 (AB), 7.27 (J = 7.0 Hz, 4 H), 6.71 (s, 1 H), 7.49 (t, 1 H), 7.59 (t, 1 H), 7.79 (d, 1 H), 8.01 (d, 1 H).[6]

8,11-Dihydroxy-2-(dimethylamino)-5-[*p*-(dimethylamino)phenyl]benz[*a*]anthracene-7,12-dione (10), originally formulated as the 5,8-dihydroxy derivative of 1: mass spectrum, *m/e* 452, 226; NMR (400 MHz) δ 3.07 (s, 6 H), 3.22 (s, 6 H), 6.87, 7.46 (ABq, 4 H, J = 8.8 Hz), 7.21 (d of d, 1 H, J_{meta} = 2.9 Hz, J_{ortho} = 10.1 Hz), 8.03 (d, 1 H, J_{ortho} = 10.1 Hz), 9.21 (d, 1 H, J_{meta} = 2.9 Hz), unsymmetrical trisubstituted aromatic, 7.22 (AB), 7.30 (J = 9.6, 2 H), 8.11 (s, 1 H), 12.98 (s, 1 H), 13.72 (s, 1 H), the last two signals disappear on washing the sample with D_2O.

Azine of 2: mass spectrum, *m/e* 494, 479, 463, 450, 432, 405, 374, 358, 330, 329, 277, 239, 164.5, 134, 120, 77; NMR (400 MHz) δ 2.83 (s, 6 H), 3.03 (s, 6 H), 6.47 (AB), 7.06 (J = 9.3 Hz, 4 H), 6.77 (AB), 7.42 (J = 9.3 Hz, 4 H), 7.13 (s, 1 H), 7.66 (s, 1 H), 7.81 (m, 4 H), 8.17 (m, 1 H), 8.32 (m, 2 H), 9.48 (d, 1 H).

8,9,10,11-Tetrahydro-5-(*p*-anisyl)-2-methoxybenz[*a*]anthracene-7,12-dione (12). A solution of 5,6,7,8-tetrahydro-1,4-naphthoquinone (1.62 g) and 1.20 g of 1,1-dianisylethylene in 30 mL of toluene was refluxed for 24 h, during which the color gradually changed light yellow to deep orange. Most of toluene was removed by concentration, and the residue was extracted several times with boiling methanol to remove hydroquinone and starting ethylene. A total of 364 mg of bright-red, methanol-insoluble material, mp 183–185 °C remained. Several crystallizations from benzene–cyclohexane and benzene alone gave ruby-red prisms and red needles: mp 185–186 °C; mass spectrum, *m/e* 398, 394, 383, 370, 355, 339, 291; NMR δ 1.78 (m, 4 H), 2.60 (m, 2 H), 2.66 (m, 2 H), 3.91 (s, 3 H), 4.03 (s, 3 H), 7.05, 7.42 (ABq, J = 8.8 Hz, 4 H), 7.19 (d of d, 1 H, J_{meta} = 2.4 Hz, J_{ortho} = 9.6 Hz), 7.89 (d, 1 H, J_{ortho} = 9.6 Hz), 9.19 (d, 1 H, J_{meta} = 2.4 Hz), unsymmetrical trisubstituted aromatic, 7.98 (s, 1 H).

Anal. Calcd for $C_{26}H_{22}O_4$: C, 78.37; H, 5.57. Found: C, 78.11; H, 5.78.

2-(Bromomethyl)-1,4-dimethoxynaphthalene (3). A solution of 1.40 g of 1,4-dimethoxynaphthalene[7] in 10 mL of glacial acetic acid was treated with 6.00 g of paraformaldehyde and 20 mL of 30% hydrogen bromide in acetic acid and allowed to stand for 4 h at room temperature. After dilution with water, the organic material was taken into ether, filtered to remove paraformaldehyde, washed twice with water, once each with bicarbonate solution, bisulfite solution, brine, then filtered through anhydrous Na_2SO_4, and concentrated. The residue, 2.33 g, crystallized spontaneously. Recrystallization from glacial acetic acid gave 0.72 g, mp 98.5–100 °C. A small sample was crystallized twice more for analysis: mp 99.5–100.5 °C; mass spectrum, *m/e* 282, 280, 267, 265, 201, 186, 171, 170, 127, 114; NMR (100 MHz) δ 3.90 (br s, 6 H), 4.63 (s, 2 H), 6.58 (s, 1 H), 7.43 (m, 2 H), 7.92 (m, 1 H), 8.14 (m, 1 H).

Anal. Calcd for $C_{13}H_{13}O_2Br$: Br, 28.43. Found: Br, 28.05.

In some runs, small amounts of a bis(bromomethyl) compound, mp 123.5–124.5 °C, were obtained.

Anal. Calcd for $C_{14}H_{14}O_2Br_2$: Br, 42.73. Found: Br, 43.68.

2-(Cyanomethyl)-1,4-dimethoxynaphthalene (4). To 200 mL of purified dioxane was added a solution of 4.40 g of potassium cyanide in 80 mL of water. The solution was heated to reflux and 8.82 g of 2-(bromomethyl)-1,4-dimethoxynaphthalene was added. After refluxing 6 h, the solution was slowly poured into a large volume of cold water with stirring, precipitating a solid which was collected and washed with cold methanol, 5.70 g (80%), mp 107–110 °C. Recrystallization from methanol gave 5.16 g, mp 111.5–113 °C. A sample crystallized once more for analysis had the following: mp 112–113 °C; mass spectrum, *m/e* 227, 212, 197, 184, 169, 153, 140, 115; NMR (100 MHz) δ 3.80 (br s, 3 H), 3.90 (br s, 5 H), 6.60 (s, 1 H), 7.43 (m, 2 H), 7.89 (m, 1 H), 8.13 (m, 1 H).

Anal. Calcd for $C_{14}H_{13}NO_2$: C, 73.99; H, 5.76. Found: C, 73.89; H, 6.20.

1,4-Dimethoxynaphthalene-2-acetic acid was produced from 4 (5.12 g) and 25 g of KOH in 35 mL of water and 50 mL of methanol refluxed for 42 h. The mixture was cooled, diluted with water, treated with Norite, filtered, and acidified to Congo Red to yield 5.12 g (92%), mp 122.5–124 °C. A small sample crystallized twice from benzene–petroleum ether for analysis had the following: mp 124.5–125.5 °C; mass spectrum, *m/e* 246, 231, 213, 201, 187, 171, 159, 143, 128, 115; NMR (400 MHz) δ 3.85 (s, 2 H), 3.90 (s, 3 H), 3.95 (s, 3 H), 6.64 (s, 1 H), 7.46 (t with fine structure, 1 H), 7.52 (t with fine structure, 1 H), 8.00 (d 1 H), 8.20 (d, 1 H).

Anal. Calcd for $C_{14}H_{14}O_4$: C, 68.28; H, 5.73. Found: C, 68.48; H, 5.85.

Methyl 1,4-Dimethoxynaphthalene-2-acetate (5). A suspension of 4.85 g of 1,4-dimethoxynaphthalene-2-acetic acid in 50 mL of ether was treated cautiously with an excess of ethereal diazomethane solution[8] prepared from 10 g of nitrosomethylurea. After gas evolution had ceased, the yellow solution was allowed to stand 10 min and then treated with 5% HCl cautiously. After gas evolution had ceased, the ethereal solution was washed with

(6) This spectrum was recorded with tetrahydrofuran-d_8 as the solvent.

(7) Russig, F. *J. Prakt. Chem.* **1900**, *62*, 51.

(8) Arndt, F. "Organic Syntheses", Collect. Vol. 2; Wiley: New York, 1943; p 166.

water twice, then with bicarbonate solution, and then with brine and filtered through anhydrous Na_2SO_4. Concentration of the solution and pumping out of the residue left 4.91 g (96%) of tan viscous oil. A small sample was pumped out at 110 °C (10^{-4} mmHg) for analysis: NMR (100 MHz) δ 3.67 (s, 3 H), 3.80 (br s, 2 H), 3.83 (s, 3 H), 3.90 (s, 3 H), 6.60 (s, 1 H), 7.32 (m, 2 H), 7.97 (m, 1 H), 8.16 (m, 1 H).

Anal. Calcd for $C_{15}H_{16}O_4$: C, 69.21; H, 6.20. Found: C, 69.41; H, 6.48.

Although this material did not crystallize at its preparation, the sample analyzed when inspected 33 years later had crystallized.

Action of [*p*-(Dimethylamino)phenyl]lithium on 5. 1,4-Dimethoxy-2-[2,2-bis[*p*-(dimethylamino)phenyl]vinyl]-naphthalene (6). To the lithium derivative prepared under N_2 from 155 mg of lithium and 1.82 g of *p*-bromo-*N*,*N*-dimethylaniline in ether was added a solution of 1.00 g of methyl ester **5** in ether. About one-third volume of benzene was added, the solution was refluxed for 3 h, then treated with water, and extracted 3 times with 3 N HCl. Neutralization of the acid extracts with dilute KOH gave a deep green-black oil which soon solidified. Trituration with ether in which the material is sparingly soluble removed most of the color, leaving 1.32 g of greyish solid, mp 168–174 °C, which analysis suggested was the carbinol. (Calcd for $C_{30}H_{34}N_2O_3$: C, 76.56; H, 7.28. Found: C, 76.86; H, 7.55. Mp 179–181 °C, recrystallized twice from benzene.) The crude carbinol (0.75 g) in a mixture benzene and methanol was treated with a few drops of acetic acid, producing a brilliant deep blue color. This color faded to a pale greenish yellow when the solution was heated briefly to boiling. The solution was concentrated, diluted with methanol, and allowed to crystallize: 0.69 g; bright yellow prismatic needles, mp 176–177 °C; mixture melting point with the above carbinol, 156–163 °C. A sample for analysis was crystallized from benzene–methanol: mp 177–178 °C; mass spectrum, *m/e* 452, 437, 422, 409, 406, 377, 318; NMR (400 MHz) δ 2.93 (s, 6 H), 2.98 (s, 6 H), 3.39 (s, 3 H), 3.93 (s, 3 H), 6.27 (s, 1 H), 6.69 (AB), 7.33 (J = 8.8 Hz, 4 H), 6.73 (AB), 7.34 (J = 8.8 Hz, 4 H), 7.15 (s, 1 H), 7.37 (t, 1 H), 7.46 (t, 1 H), 8.04 (d, 2 H).

Anal. Calcd for $C_{30}H_{32}N_2O_2$: C, 79.61; H, 7.13. Found: C, 79.34; H, 7.46.

Reductive Methylation of 8. 2-(Dimethylamino)-5-[*p*-(dimethylamino)phenyl]-7,12-dimethoxybenz[*a*]anthracene. A solution of 507 mg of **8** in 10 mL of 10% HCl was treated all at once with 20 mL of Claisen's alkali containing a small scoop of sodium hydrosulfite. Ether was added and the mixture was shaken vigorously until the deep amethyst color of **8** had changed to a bright crimson vat color. The Claisen's alkali was drawn off into a N_2-flushed flask protected from atmospheric oxygen. Three additional extractions with Claisen's alkali containing hydrosulfite (10, 5, and 5 mL) were made.

The combined crimson vat solutions under N_2 were cooled in an ice bath and treated with 5 mL of dimethyl sulfate. The mixture was stirred at 0 °C for 30 min and then allowed to warm to room temperature and stirred for 2 more h. The ocher-colored suspension was diluted with water and the solid was collected and washed with water. For removal of unchanged **8** or its hydroquinone, the solid was dissolved in 10 mL of 10% HCl, treated all at once with an excess of Claisen's alkali containing hydrosulfite and ether, and shaken until vatting was complete. The ether solution was extracted with four additional portions of Claisen's alkali containing hydrosulfite until no more red vat color was produced.

The yellow-ocher ether layer was washed with water and brine, filtered through anhydrous sodium sulfate, and concentrated to give 105 mg of dirty yellow crystalline residue. Recrystallization from benzene–methanol twice gave 64 mg of small yellow-olive prisms: mp 210.5–211.5 °C; mass spectrum, *m/e* 450, 435, 420; NMR (400 MHz) δ 3.06 (s, 6 H), 3.17 (s, 6 H), 4.01 (s, 3 H), 4.08 (s, 3 H), 6.90, 7.50 (ABq, 4 H, J = 8.6 Hz), 7.06 (d of d, 1 H, J_{meta} = 2.5 Hz, J_{ortho} = 9.2 Hz), 7.87 (d, 1 H, J_{ortho} = 8.6 Hz), 9.22 (d, 1 H, J_{meta} = 2.4 Hz), unsymmetrical trisubstituted aromatic, 7.57 (m, 2 H), 7.80 (s, 1 H), 8.30 (t with additional fine structure, 1 H), 8.44 (t with additional fine structure, 1 H).

Anal. Calcd for $C_{30}H_{30}N_2O_2$: C, 79.97; H, 6.71. Found: C, 80.00, H, 6.95.

Action of *p*-Anisylmagnesium Bromide on 5. 1,4-Dimethoxy-2-[(2,2-dianisyl)vinyl]naphthalene (7). To the Grignard reagent prepared from 0.22 g of Mg and 1.59 g of freshly distilled *p*-bromoanisole in ether was added dropwise a solution of 1.00 g of **5** in ether. Benzene (20 mL) was added to increase the solubility of the gummy complex which separated, and the mixture was heated under reflux for 15 min and then decomposed after cooling with an excess of NH_4Cl solution. The organic layer was washed twice with water and then with brine, filtered through anhydrous Na_2SO_4, and concentrated. The viscous oily residue (2.40 g) was dissolved in glacial acetic acid, brought briefly to a boil, and diluted strongly with water, and the precipitated oil was taken into ether, washed with bicarbonate, water, and brine, filtered through anhydrous Na_2SO_4, and concentrated. The oily residue deposited a total of 0.94 g of rosettes of needles, mp 122–125 °C, on standing in ethyl acetate–methanol. Several recrystallizations from glacial acetic acid gave **7** as rosettes of needles: mp 129.5–131 °C; mass spectrum, *m/e* 426, 411, 396, 380, 121; NMR (400 Mz) δ 3.40 (s, 3 H), 3.81 (s, 3 H), 3.85 (s, 3 H), 3.96 (s, 3 H), 6.20 (s, 1 H), 6.86 (AB), 7.17 (J = 8.8 Hz, 4 H), 6.89 (AB), 7.35 (J = 9.2 Hz, 4 H), 7.25 (s, 1 H), 7.44 (t, 1 H), 7.50 (t, 1 H), 8.07 (d, 2 H).

Anal. Calcd for $C_{28}H_{26}O_4$: C, 78.85; H, 6.15. Found: C, 78.86; H, 6.36.

Reductive Methylation of 9. 2,7,12-Trimethoxy-5-(*p*-anisyl)benz[*a*]anthracene. A suspension of **9** (237 mg) in 7 mL of pyridine under N_2 was treated with a spatula full of zinc dust and then dropwise with 2 mL of 6 N HCl. When shaken, the orange solid went into solution and the color faded to a fluorescent greenish yellow. After dilution with ether, the mixture was extracted under N_2 3 times with 15% HCl and then with 15% KOH solution containing a small amount of sodium hydrosulfite. A deep red vat color was produced. The vat solution was drained into a N_2-flushed flask containing 4 mL of dimethyl sulfate. A second alkaline-hydrosulfite extraction gave only a yellow color. The flask was shaken with external cooling; the vat color faded rapidly and a solid replaced the oily second phase. Another 2.5 mL of dimethyl sulfate and more alkali was added. After 15 min shaking, the precipitated light yellow solid was collected and washed well with water. The solution in benzene–methanol was filtered to remove some zinc dust, concentrated, and allowed to crystallize, 180 mg, mp 131–133 °C. After many recrystallizations from benzene–alcohol, ethyl acetate, and carbon tetrachloride, a 56-mg yield, mp 145.5–147 °C, was obtained. The compound was readily soluble in hot benzene or carbon tetrachloride and very slightly soluble in boiling alcohol. Its solutions in benzene or alcohol showed a marked blue fluorescence which is quenched in carbon tetrachloride: mass spectrum, *m/e* 424, 409, 394; NMR (400 MHz) δ 3.92 (s, 3 H), 4.01 (s, 3 H), 4.05 (s, 3 H), 4.09 (s, 3 H), 7.08, 7.52 (ABq, J = 8.6 Hz, 4 H), 7.18 (d of d, J_{meta} = 2.4 Hz, J_{ortho} = 9.2 Hz, 1 H), 7.83 (d, J_{ortho} = 9.2 Hz, 1 H), 9.40 (d, J_{meta} = 2.4 Hz, 1 H), 7.62 (m, 2 H), 7.92 (s, 1 H), 8.33 (m, 1 H), 8.47 (m, 1 H).

Anal. Calcd for $C_{28}H_{24}O_4$: C, 79.22; H, 5.70. Found: C, 78.59; H, 5.55.

1,2-Dimethoxy-4-(cyanomethyl)naphthalene. 4-(Cyanomethyl)-1,2-naphthoquinone[9] (4.30 g) was suspended in 40 mL of methanol and stirred with 1.40 g of $NaBH_4$ for about 70 min. The red-orange color gave way to a pale amethyst. Cautious acidification of the suspension with 60 mL of 3% HCl gave a pale tan suspension, which after being cooled in an ice bath was collected, washed with water, and air-dried, 3.76 g, mp 222–227 °C dec.[10] This hydroquinone was suspended in 60 mL of acetone in a N_2-flushed flask and treated with 10 g of anhydrous K_2CO_3 and 6 mL of dimethyl sulfate. The mixture was stirred at room temperature for 4 h, diluted with 150 mL of water, stirred for 0.5 h, acidified with 10% HCl, and extracted several times with CH_2Cl_2. The extracts were washed with water, filtered through anhydrous Na_2SO_4, and concentrated to give 5.54 g of brown oil (4.65 g, theoretical) which crystallized readily.

A sample from an earlier run was recrystallized several times from benzene–cyclohexane for analysis: mp 74–75 °C, colorless prisms; mass spectrum *m/e* 227, 212, 184, 169, 157, 144, 140, 129, 127, 115, 114; NMR (100 MHz) δ 4.04 (s, 2 H), 4.09 (s, 6 H), 7.48

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(s, 1 H), 7.50 (m, 2 H), 7.80 (complex d, 1 H), 8.32 (complex d, 1 H).

Anal. Calcd for $C_{14}H_{13}NO_2$: C, 73.99; H, 5.77; N, 6.16. Found: C, 74.08; H, 5.87; N, 6.16.

1,2-Dimethoxynaphthalene-4-acetic acid was produced from the cyano compound (5.54 g) by heating to reflux in a solution of 25 g of KOH in 35 mL of water and 50 mL of methanol for 24 h. The cooled solution was filtered, diluted with water, and acidified with dilute HCl. After the solution was cooled in the refrigerator, the precipitated acid was collected and washed with water, and air-dried, 4.21 g, mp 156–158 °C. Recrystallization from ethyl acetate with charcoaling gave 3.09 g of nearly colorless prisms, mp 158.5–161 °C. A small sample was crystallized several time from benzene for analysis: mp 157–159 °C; mass spectrum, *m/e* 246, 231, 201, 189, 185, 157, 144, 128, 115; NMR (100 MHz) δ 3.80 (br s, 8 H), 7.03 (s, 1 H), 7.23 (m, 2 H), 7.70 (br d, 1 H), 7.97 (br d, 1 H).

Anal. Calcd for $C_{14}H_{14}O_4$: C, 68.28; H, 5.73. Found: C, 68.77; H, 5.80.

Methyl 1,2-dimethoxynaphthalene-4-acetate (13) was prepared from the above acid (2.76 g) by treatment of its suspension in ether with the diazomethane solution[8] prepared from 4.50 g of nitrosomethylurea. The acid went into solution slowly and after 10 min the excess diazomethane was destroyed by addition of acetic acid dropwise. The ether was washed with water and brine, filtered through anhydrous Na_2SO_4, concentrated, and pumped out to give 2.98 g of very pale yellow viscous oil: IR strong absorbance at 1724 cm^{-1}, inter alia; mass spectrum, *m/e* 260, 245, 201, 157; NMR (100 MHz) δ 3.70 (s, 3 H), 4.08 (s with some fine structure, 8 H), 7.35 (s, 1 H), 7.53 (m, 2 H), 8.04 (complex d, 1 H), 8.28 (complex d, 1 H).

Anal. Calcd for $C_{15}H_{16}O_4$: C, 69.21; H, 6.20. Found: C, 68.96; H, 6.26.

Action of [*p*-(Dimethylamino)phenyl]lithium on 13. 1,2-Dimethoxy-4-[2,2-bis[*p*-(dimethylamino)phenyl]vinyl]-naphthalene (14). To the lithium derivative prepared from 173 mg of lithium and 2.00 g of *p*-bromo-*N,N*-dimethylaniline in ether was added a solution of 1.00 g of methyl ester **13** in 15 m*l* of benzene. A dark brown color was produced at once. The solution was heated to reflux for 3 h and allowed to stand overnight. The ether benzene solution was extracted 4 times with 10% HCl, and the extracts were made basic with dilute KOH and extracted 4 times with CH_2Cl_2. The extracts were washed with water, filtered through anhydrous Na_2SO_4, and concentrated to give 1.58 g of deep blue-green oil or glass smelling of *N,N*-dimethylaniline.

The ether-benzene solution on concentration gave 0.686 g of brown oily residue, which was refluxed with methanolic KOH and a little water for 15 min, diluted, and filtered, and the filtrate was acidified to give 390 mg of crude 1,2-dimethoxy-4-naphthaleneacetic acid, mp 150–154 °C, corresponding to 415 mg of starting material **13**.

The deep blue-green glass obtained above was heated briefly to boiling in glacial acetic acid (deep blue color), diluted with water, made basic with dilute KOH, and extracted 4 times with CH_2Cl_2. The deep amethyst-purple extracts were washed with water, filtered through anhydrous Na_2SO_4, and concentrated to give 1.48 g of deep green-black oil or glass smelling of *N,N*-dimethylaniline.

Chromatography of this material on alumina gave a total of 393 mg of crude **14** as a yellow crystalline solid. Recrystallization from benzene yielded 336 mg, mp 168–169 °C (33% on the basis of amount of **13** utilized). Several further crystallizations from benzene gave bright yellow prisms: mp 168.5–170 °C; mass spectrum, *m/e* 452, 437, 421, 393, 377, 365, 350, 322, 307, 292, 264, 249, 202, 188, 145, 121; NMR (400 MHz) δ 2.90 (s, 6 H), 3.00 (s, 6 H), 3.50 (s, 3 H), 3.94 (s, 3 H), 6.57 (AB), 7.01 (*J* = 8.0 Hz, 4 H), 6.72 (AB), 7.36 (*J* = 8.4 Hz, 4 H), 6.93 (s, 1 H), 7.23 (s, 1 H), 7.35 (t, 1 H), 7.46 (t, 1 H), 8.12 (d of d, 2 H).

Anal. Calcd for $C_{30}H_{32}N_2O_2$: C, 79.61; H, 7.13; N, 6.19. Found: C, 79.96; H, 7.14; N, 6.13.

Reductive Methylation of 2 (14). A solution of 422 mg of **2** in 25 mL of tetrahydrofuran, freshly distilled from sodium benzophenone ketyl was hydrogenated over 197 mg of $PdCl_2$ on C (10%). Ninety-seven percent of hydrogen (theoretical) was taken up over 40 min. The catalyst was removed by filtration under N_2 with the aid of diatomaceous earth, and the light yellow filtrate was treated with a solution of trimethylphenylammonium ethoxide prepared from 1.23 g of trimethylphenylammonium tosylate and freshly prepared sodium ethoxide solution (169 mg of Na) followed by filtration.

The mixture was heated under a stream of N_2 in a bath maintained at 110 °C for 5.5 h. By 1.5 h essentially all the solvents had evaporated. The cooled, orange-brown solid residue was steam-distilled until no more *N,N*-dimethylaniline came over (odor), cooled, made basic, and extracted 5 times with CH_2Cl_2. The extracts were washed with water, filtered through anhydrous Na_2SO_4, and concentrated to give 332 mg of a green-black residue which crystallized readily. It was chromatographed on a 30 × 30 mm column of Al_2O_3 to remove dark color. Elution with ethyl acetate–CH_2Cl_2 and crystallization from benzene–absolute alcohol gave 234 mg of bright yellow crystalline material, mp 168.5–169.5 °C. Its mixture melting point with **14** prepared from **13** by the action of [*p*-(dimethylamino)phenyl]lithium was 168.5–170 °C, and NMR and IR spectra were indistinguishable from those of that sample.

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Registry No. 2, 79971-22-5; 2-azine, 79971-23-6; **3**, 79971-24-7; **4**, 79971-25-8; **5**, 70313-13-2; **6**, 79971-26-9; 6-carbinol, 79972-39-7; **7**, 79971-27-0; **8**, 79971-28-1; **9**, 72735-91-2; **10**, 79971-29-2; **11**, 7474-90-0; **12**, 79971-30-5; **13**, 79971-31-6; **14**, 79971-32-7; 1,1-dianisylethylene, 4356-69-8; 1,4-dimethoxynaphthalene-2-acetic acid, 79971-33-8; [*p*-(dimethylamino)phenyl]lithium, 13190-50-6; 2-(dimethylamino)-5-[*p*-(dimethylamino)phenyl]-7,12-dimethoxybenz[*a*]anthracene, 79971-34-9; *p*-bromoanisole, 104-92-7; 2,7,12-trimethoxy-5-(*p*-anisyl)benz[*a*]anthracene, 79971-35-0; 1,2-dimethoxy-4-(cyanomethyl)naphthalene, 79971-36-1; 4-(cyanomethyl)-1,2-naphthoquinone, 79971-37-2; 1,2-dimethoxynaphthalene-4-acetic acid, 79971-38-3.

Convenient and Regioselective Synthesis of Substituted 2,3,4,5-Tetrahydro-1*H*-[1,4]diazepino[1,7-*a*]benzimidazoles

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Detailed computer graphic analysis aimed at elucidating structural parameters required for binding to the serotonin receptor suggested that appropriately substituted 2,3,4,5-tetrahydro-1*H*-[1,4]diazepino[1,7-*a*]benzimidazoles (**10**) would be capable of such interactions. This report describes a convenient and regioselective synthetic procedure for preparing derivatives of this novel ring system.

Initial attempts to obtain the parent member of this series paralleled the work of DeSelms,[1] who synthesized the carbocyclic analogue **1**. This route is shown in Scheme I for lactam **3**. Attempted cyclization of chloro amide **2b** under a variety of conditions, including those of DeSelms, gave unacceptable yields of **3**. The highest yield, 12%, was

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