Intramolecular Amination of *p*-Benzoquinones: Formation of 1,2,3,5-Tetrahydrobenzo[1,2-*b*:4,5-*b'*]dipyrroles and 1,2,3,4-Tetrahydropyrido-[2,3-*g*]quinolines

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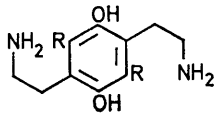
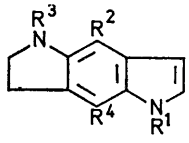
2,5-Bis-(2-aminoethyl)hydroquinones undergo intramolecular condensation in neutral or slightly alkaline aqueous solution in air to form 1,2,3,5-tetrahydrobenzo[1,2-*b*:4,5-*b'*]dipyrroles. Under similar conditions 2,5-bis-(3-aminopropyl)hydroquinones yield 1,2,3,4-tetrahydropyrido[2,3-*g*]quinolines. Tentative structures for some of the intermediates involved in these reactions are discussed in the light of spectroscopic data.

INTERMOLECULAR reactions between 1,4-benzoquinones and aliphatic primary and secondary amines are well known and generally result in di-amination *via* 1,4-addition.[1] Examples of intramolecular amination are more rare. Most of those that have been reported necessarily involve mono-amination only and 1,2-addition is the sole process observed.[2] We have now investigated some fundamental examples of intramolecular di-amination and find that here too 1,2-addition is the preferred mode of attack.



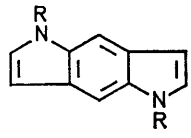
(I)

a; R = H
b; R = D
c; R = Br
d; R = H, NHMe in place of NH_2



(II)

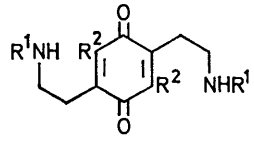
a; $R^1 = R^2 = R^3 = R^4 = H$
b; $R^1 = R^2 = R^4 = H$, R^3 = Ac
c; $R^1 = R^2 = R^3 = H$, $R^4 = D$
d; $R^1 = R^3 = H$, $R^2 = R^4 = D$
e; $R^1 = R^3 = H$, $R^2 = R^4 = Br$
f; $R^1 = R^3$ = Me, $R^2 = R^4 = H$



(III)

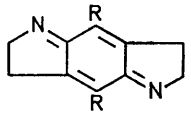
a; R = H
b; R = Me

When the dihydrochloride of the quinol (Ia) was kept in aqueous solution, buffered at pH 7, in the presence of air, it was converted into the benzodipyrrole (IIa). The structure of the latter is supported in part by its i.r. spectrum [$\nu_{max.}$ 3329 and 3130 cm^{-1} (two NH groups)] and its u.v. spectrum ($\lambda_{max.}$ 278 and 315 nm), which is similar to that of 5-aminoindole.[2b] On acetylation it formed a monoacetate formulated as (IIb). On treatment with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone in ether, compound (IIa) underwent dehydrogenation to give compound (IIIa). Support for the latter structure comes from the n.m.r. spectrum which contains, in addition to a singlet (τ 2·48) assigned to the protons of the benzenoid ring, two doublets at τ 2·85 and 3·50 consistent with the presence of α- and β-pyrrolic protons. (IVa) followed by intramolecular 1,2-addition, dehydration, and bond migration. Consistent with this view, the quinone (IVa) formed the dipyrrole (IIa) at pH 7 in the absence of air. Moreover the dideuterioquinol (Ib) formed the dipyrrole (IIc) when kept in aqueous buffer in the presence of air. It is believed that this latter reaction gave initially the dideuterio-derivative (IId), which subsequently underwent exchange with the solvent at position 8. In support of this suggestion, compound (IIc) gave, on stirring with deuterium oxide at room temperature, the dideuterio-derivative (IId), as evidenced by n.m.r. spectroscopy. In benzene solutions of indoles, the n.m.r. signal arising from a system *peri* to the indolic nitrogen is at higher field than in chloroform solutions.[4] The protons at C-4 and C-8 in compound (IIa) resonate at τ 2·98 and



(IV)

a; $R^1 = R^2 = H$
b; $R^1 = H$, $R^2 = Br$
c; R^1 = Me, $R^2 = H$



(V)

a; R = H
b; R = Br

Although examples of this ring system are known [3] this is the first occasion that the parent heterocycle has been obtained.

The formation of compound (IIa) from the quinol (Ia) resembles the oxidative cyclisation of 2-(2,5-dihydroxy)-phenylethylamines to indoles [2a-d,f] and presumably involves aerial oxidation of the quinol to the quinone

[1] D. W. Cameron, P. M. Scott, and Lord Todd, *J. Chem. Soc.*, 1964, 42; D. W. Cameron and P. M. Scott, *ibid.*, p. 5569; J. Kumanotani, F. Kagawa, A. Hikosaka, and K. Sugita, *Bull. Chem. Soc. Japan*, 1968, **41**, 2118; A. Hikosaka, *ibid.*, 1970, **43**, 3928.

[2] (*a*) R. I. T. Cromatie and J. Harley-Mason, *J. Chem. Soc.*, 1952, 2525; (*b*) J. Harley-Mason and A. H. Jackson, *ibid.*, 1954, 1158; (*c*) J. Harley-Mason and A. H. Jackson, *ibid.*, 1954, 1165; (*d*) H. J. Teuber and O. Glosauer, *Chem. Ber.*, 1965, **98**, 2648; (*e*) J. A. Moore and E. C. Capaldi, *J. Org. Chem.*, 1964, **29**, 2860; (*f*) J. Harley-Mason and A. H. Jackson, *J. Chem. Soc.*, 1954, 3651.

[3] O. Piloty, K. Wilke, and A. Blömer, *Annalen*, 1915, **407**, 1; P. Ruggli, B. B. Bussemaker, and W. Muller, *Helv. Chim. Acta*, 1935, **18**, 613; D. A. Kinsey and S. G. P. Plant, *J. Chem. Soc.*, 1958, 1; M. P. Cava and L. Bravo, *Tetrahedron Letters*, 1970, 4631.

[4] J. Ronayne and D. H. Williams, *J. Chem. Soc.* (*B*), 1967, 805.

3·22 in chloroform solution and the signals are superimposed at τ 3·20 in benzene. Thus the signals at τ 2·98 and 3·22 may be assigned to the protons at C-4 and C-8, respectively. In the spectrum of the monodeuteriated compound (IIc) in chloroform the signal at τ 3·22 was of unit intensity whereas that at τ 2·98 was minute.

The dibromoquinol (Ic) and the related quinone (IVb) reacted similarly at pH 7, giving the dibromobenzodipyrrole (IIe).

The course of the foregoing cyclisations could be followed conveniently by u.v. spectroscopy. The initial curve in Figure 1 corresponds to the spectrum of the quinol (Ia) ($\lambda_{max.}$ 291 nm). This maximum undergoes a slight hypsochromic shift to 283 nm with an increase in extinction coefficient which is at a maximum after 15 min. This peak gradually decreases in intensity to be replaced by the spectrum of the dipyrrole (IIa).

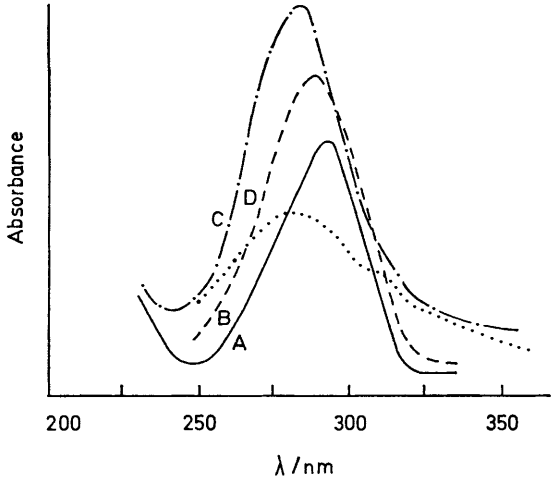
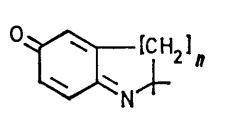


FIGURE 1 Reaction of the quinol (Ia) dihydrobromide at pH 7: A, 1 min; B, 5 min; C, 15 min; D, 90 min

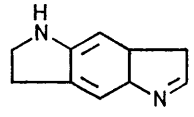
From a related preparative scale reaction an intermediate was isolated by extraction with chloroform. Spectroscopic evidence suggests that this compound may be the quinone di-imine (Va). Thus its n.m.r. spectrum contains multiplets at τ 3·25, 5·81, and 7·22 (relative intensities 1 : 2 : 2) assigned to olefinic protons and C=N·CH_2·CH_2 groups. Its i.r. spectrum exhibits no OH, NH, or carbonyl absorptions. The u.v. spectrum in ethanol contains a single maximum at 293 nm which is consistent with the proposed structure. The cyclic quinone imine (VIa) is reported[5] to have an intense maximum at 272 nm (*cf.* benzoquinone, 246 nm) and it seems reasonable that the presence of a second nitrogen atom and ring will cause a further significant bathochromic shift.

Compound (Va) is unstable; either in solution or in the solid state it is converted into the dipyrrole (IIa). This conversion is effected by acid and heat, and the quinone di-imine is isomerised to compound (IIa) preparatively on attempted sublimation. A possible intermediate in the conversion of (Va) to (IIa) is the 3*H*-indole (VII), but we were unable to detect this compound by n.m.r. spectroscopy when the isomerisation was performed in deuteriochloroform.



(VI)

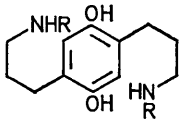
a; $n = 1$
b; $n = 2$



(VII)

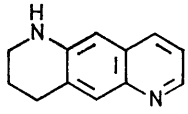
The u.v. spectroscopic behaviour of the quinone (IVa) at pH 7 resembles closely the later stages of the reaction of the related quinol (Ia). Thus the curve obtained immediately upon dissolution ($\lambda_{max.}$ 283 nm) corresponds to that observed after 15 min in the reaction of the quinol. The failure to observe the spectra of the quinone ($\lambda_{max.}$ 252 nm) in the early stages indicates that it must undergo an extremely rapid reaction at pH 7.

Examination of the reaction of the dibromoquinol (Ic) by u.v. spectroscopy showed that it behaved similarly to the quinol (Ia), *viz.* initially the maximum due to the quinol is observed and this band increases in intensity and finally decreases to leave the spectrum of the dibromobenzodipyrrole (IIe). From a preparative scale reaction of the dibromoquinone (IVb) at pH 7 or in 6% borax solution, it was possible to isolate, by chloroform extraction, an intermediate, hereafter called compound (A), which showed $\lambda_{max.}$ 303 nm. The n.m.r. spectrum of this material showed only two broad absorptions, at τ 5·3 and 7·0, which are consistent with structure (Vb). However the analytical data suggested the formula $C_{10}H_8N_2Br_2,0{\cdot}5H_2O$, and the presence of an OH group was supported by i.r. absorption at 3120 cm^{-1}. Thus the structure of compound (A) remains in doubt. On treatment with base compound (A) formed the dipyrrole (IIe).

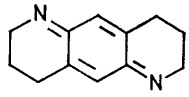


(VIII)

a; R = H
b; R = Me



(IX)



(X)

When the quinol (VIIIa) dihydrochloride was dissolved in water at pH 7, it underwent a rapid reaction which could be followed by u.v. spectroscopy. The initial colourless solution ($\lambda_{max.}$ 296 nm) changed within 3 min to a pale pink solution with significant absorptions at 298 and 330 nm and weaker absorptions in the visible region. These peaks were replaced over a period of 50 min by three other maxima, at 210, 255, and 360 nm. The material giving rise to the final spectrum was isolated and assigned structure (IX). Its i.r. spectrum confirmed the presence of an NH group (3280 cm^{-1}) and the absence of a carbonyl group. Its u.v. spectrum was similar to that of 6-dimethylaminoquinoline; moreover

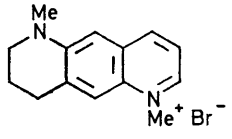
[5] H. J. Teuber and O. Glosauer, *Chem. Ber.*, 1965, **98**, 2939.

the long-wavelength band showed the expected bathochromic shift in acid and hypsochromic shift in base.[6] The n.m.r. spectrum (Experimental section) was consistent with the proposed structure and the coupling constants for the protons of the pyridine ring were of the magnitude usually observed in quinolines.[7] The formation of compound (IX) is presumably analogous to that of compound (IIa) except that an additional oxidative process (aromatisation) is involved, and resembles the oxidative cyclisation of 3-(2,5-dihydroxy)phenylpropylamine to 6-hydroxyquinoline.[2e]

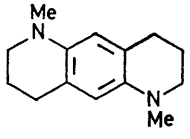
The nature of the intermediate giving rise to the maximum at 298 nm is not certain, but it may be the quinone di-imine (X) [*cf.* the di-imine (Va), $\lambda_{max.}$ 293 nm]. An increase in ring size from five- to six-members would be expected to cause a small bathochromic shift, based on the observation that compound (VIa) absorbs at 272 nm and (VIb) at 274 nm.[5]

The reactions of the quinone (IVc) and the quinols (Id) and (VIIIb) incorporating secondary amino-groups were also studied. It was found that the quinone (IVc) reacted (too rapidly at pH 7 for the reaction to be followed by u.v. spectroscopy) to form the *NN'*-dimethyldipyrrole (IIf). The structure of this product was supported by its spectroscopic properties, and it was dehydrogenated with 2,3-dichloro-5,6-dicyano-1,4-benzoquinone to form compound (IIIb). The quinol (Id) also reacted rapidly at pH 7 to give (IIf), as evidenced by u.v. spectroscopy.

The quinol (VIIIb) reacted at pH 7 to produce a compound absorbing at 218, 283, and 446 nm. From a related reaction in aqueous sodium hydrogen carbonate, the compound responsible for this absorption was isolated by continuous extraction with hot chloroform followed by treatment with hydrogen bromide, and assigned structure (XI). The high field region of its n.m.r. spectrum showed the presence of an *N*-methyl group (τ 6·94), a methyl group attached to a quaternary nitrogen atom (τ 5·53), and three adjacent methylene groups. In the aromatic region two singlets at τ 1·98 and 2·92 were assigned to the protons at positions 7 and 9, and 8, respectively. The observed downfield shift of the pyridine ring proton signals in the salt (XI) compared with the base (IX), as well as the change in the



(XI)



(XII)

magnitude of the coupling constants, are similar to those reported for the quinoline–*N*-methylquinolinium iodide system.[8] The u.v. spectrum of (XI) resembles that of (IX) in dilute acid.

A second product was isolated from the foregoing cyclisation reaction but in too small a quantity for full characterisation. However the available spectral data suggest that it might be the diamine (XII).

In the cyclisation reactions of the quinols (Id) and (VIIIb) and the quinone (IVc) purple solutions were obtained immediately on dissolution in the aqueous buffer. The u.v. spectra of these solutions are shown in Figure 2. Attempts to isolate the purple material by extraction with organic solvents failed. The nature of the coloured species cannot be specified in detail but it seems likely that they are radical cations of the Wurster salt type, which are known to be in equilibrium with molecular species possessing one electron more and one electron less.[9] The u.v. spectrum of the perchlorate salt

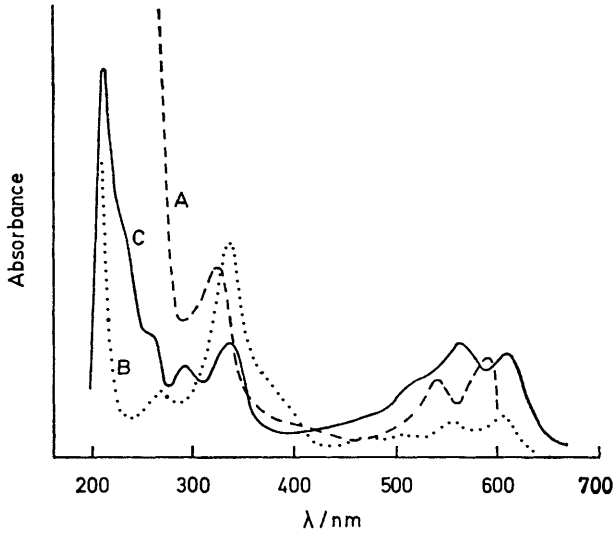


FIGURE 2 U.v. spectra obtained during cyclisation of the quinols (Id) and (VIIIb) at pH 7: A, quinol (Id); B, quinol (VIIIb); C, *NNN'N'*-tetramethyl-*p*-phenylenediamine dihydrochloride

of the radical cation derived from *NNN'N'*-tetramethyl-*p*-phenylenediamine has maxima at 258, 325, 395sh, 520sh, 565, and 605 nm,[10] and we have found that this same spectrum is obtained when *NNN'N'*-tetramethyl-*p*-phenylenediamine dihydrochloride is dissolved in aqueous buffer at pH 7 in the presence of air (see Figure 2).

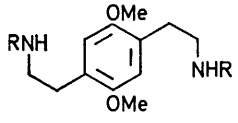
It can be seen from Figure 2 that the relative intensities as well as the position of the maxima in the visible region of the spectra obtained during the reaction of the quinols (Id) and (VIIIb) are similar to those of the model compound.

In the cyclisation of the quinol (VIIIa) and the related quinone, a transient pink solution is obtained which has $\lambda_{max.}$ 519 and 548 nm in the visible region, which approximate well to the reported maxima for the radical cation derived from *NN'*-dimethyl-*p*-phenylenediamine ($\lambda_{max.}$ 508 and 540 nm).[11]

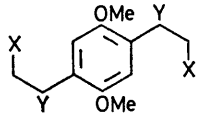
[6] E. A. Steck and G. W. Ewing, *J. Amer. Chem. Soc.*, 1948, **70**, 3397.
[7] T. Schaefer, *Canad. J. Chem.*, 1961, **39**, 1864.
[8] M. H. Palmer and B. Semple, *Chem. and Ind.*, 1965, 1766.
[9] For a discussion see A. R. Forrester, J. M. Hay, and R. H. Thomson, ' Organic Chemistry of Stable Free Radicals,' Academic Press, London, 1968, p. 254.
[10] A. C. Albrecht and W. T. Simpson, *J. Amer. Chem. Soc.*, 1955, **77**, 4454.
[11] L. Michaelis, M. P. Schubert, and S. Granick, *J. Amer. Chem. Soc.*, 1939, **61**, 1981.

The preference for 1,2-addition in all the examples discussed, and particularly those involving secondary amino-groups, is evidently associated with the stabilisation afforded by formation of either indole- or quinoline-based products. This factor is not available in intermolecular amination which is restricted to reversible formation of anils.

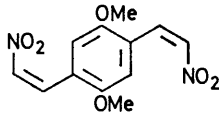
Synthetic Methods.—The dimethoxy-diamine (XIIIa), an important intermediate in the synthesis of the quinones (IVa—c) and related quinols, was prepared from 1,4-dimethoxybenzene by a slight modification of the method of Wood and Gibson.[12] An alternative



(XIII)
a; R = H
b; R = Me
c; R = CHO



(XIV)
a; X = NO_2, Y = OH
b; X = NO_2, Y = H
c; X = NH_2, Y = OH



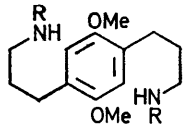
(XV)

route for the synthesis of the diamine (XIIIa) starting from 2,5-dimethoxyterephthalaldehyde[13] was investigated. Condensation of the dialdehyde with nitromethane in the presence of triethylamine gave the nitro-alcohol (XIVa), which was dehydrated with methanesulphonyl chloride in pyridine to give the bis-(β-nitrovinyl) compound (XV). Attempted reduction of this product with either lithium aluminium hydride or hydrogen and platinum did not yield any of the diamine (XIIIa). Reduction to the diamine was achieved by a two-step process, namely, sodium borohydride reduction[14] to the β-nitroethyl compound (XIVb) and catalytic reduction. However the overall yield in this sequence is lower than that of Wood and Gibson[12] and the method was abandoned. An attempt to convert the nitro-alcohol (XIVa) into the amine (XIIIa) by reduction and hydrogenolysis failed, and yielded instead the amino-alcohol (XIVc).

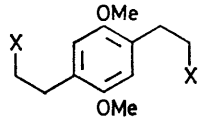
Demethylation of the dimethoxy-diamine (XIIIa) with hydrobromic acid gave the quinol (Ia), isolated as its hydrobromide and characterised as the *NN'*-diacetate and *NN'OO'*-tetra-acetate. Treatment of the quinol (Ia) with bromine in acetic acid gave the dibromoquinol (Ic), which could be oxidised, without isolation, with nitric acid to the quinone (IVb).

For the synthesis of the quinols (VIIIa and b), the diamine (XVIa) was required, and the known diacid (XVIIa) was used as starting material.[15] This diacid was converted into the amide (XVIIb), but reduction of the latter with either lithium aluminium hydride or sodium borohydride in the presence of cobalt chloride[16] did not yield any of the diamine (XVIa). Dehydration of the diamide with phosphorus pentoxide gave the di-nitrile (XVIIc), which was reduced smoothly by lithium aluminium hydride to the diamine (XVIa). Demethylation of the diamine with hydrobromic acid gave the quinol (VIIIa).

A number of routes to the *NN'*-dimethyl amine (XIIIb) were investigated. Methylation of the di-toluene-*p*-sulphonate of the diamine (XIIIa) gave compound (XIIIb; Ts in place of H) but the tosyl groups could not be removed by hydrolysis. Attempted reduction of the diformyl derivative (XIIIc) with lithium aluminium hydride failed. Eventually the application of the Forster–Decker procedure[17] was found to give excellent yields of the desired diamine. The dibenzylidene derivative of the diamine (XIIIa) was methylated with methyl iodide and the resulting quaternary salt was hydrolysed with 80% aqueous ethanol to give the diamine (XIIIb). Oxidative demethylation[18] gave the quinone (IVc) which crystallised as its dihydrochloride. Application of the Forster–Decker procedure to the diamine (XVIa) gave the *NN'*-dimethyl derivative (XVIb), which was demethylated with hydrobromic acid to form the quinol (VIIIb).



(XVI)
a; R = H
b; R = Me



(XVII)
a; X = CO_2H
b; X = $CO{\cdot}NH_2$
c; X = CN

EXPERIMENTAL

Unless otherwise stated u.v. spectra were measured for solutions in 95% ethanol, i.r. spectra for Nujol mulls, and n.m.r. spectra for solutions in deuteriochloroform. All n.m.r. spectra were measured at 100 MHz and all integrations were consistent with the assignments.

2,5-Bis(cyanomethyl)-1,4-dimethoxybenzene.—To a solution of 2,5-bis(chloromethyl)-1,4-dimethoxybenzene (82 g) in dimethyl sulphoxide (750 ml) was added potassium cyanide (68 g) in water (100 ml). The mixture was heated on a water-bath for 20 min, cooled, and diluted with water (3 l). The precipitate was collected and recrystallised from butan-1-ol to yield the dinitrile (71·5 g), m.p. 193—194° (lit.,[12] 198°).

[12] J. H. Wood and R. E. Gibson, *J. Amer. Chem. Soc.*, 1949, **71**, 393.
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2,5-*Bis*-(β-*aminoethyl*)-1,4-*dimethoxybenzene* (XIIIa).—This was prepared from the foregoing dinitrile as described previously.[12] The NN'-*diformyl derivative* (XIIIc) had m.p. 166—172° (from ethanol–water) (Found: C, 59·9; H, 7·3; N, 10·1. $C_{14}H_{20}N_2O_4$ requires C, 60·0; H, 7·2; N, 10·0%). The NN'-*ditoluene*-p-*sulphonate* had m.p. 197—198° (from ethanol) (Found: C, 58·6; H, 6·3; N, 5·4. $C_{26}H_{32}N_2O_6S_2$ requires C, 58·6; H, 6·1; N, 5·3%).

To a refluxing solution of the foregoing ditoluene-*p*-sulphonate (7·4 g) in a mixture of aqueous 3% sodium hydroxide (140 ml) and methanol (250 ml) were added, alternately, in portions, dimethyl sulphate (2·5 ml), and aqueous 10% sodium hydroxide (16 ml). This process was repeated four times. After dilution with water (800 ml), the solid was collected and recrystallised from ethanol to give 2,5-*bis*-[β-(N-*methyl*-p-*tolylsulphonylamino*)*ethyl*]-1,4-*dimethoxybenzene* (6·3 g), m.p. 133—135° (Found: C, 59·7; H, 6·3; N, 4·9. $C_{28}H_{36}N_2O_6S_2$ requires C, 60·0; H, 6·5; N, 5·0%).

2,5-*Bis*-(β-*aminoethyl*)*hydroquinone* (Ia).—A solution of 2,5-bis-(β-aminoethyl)-1,4-dimethoxybenzene (64·5 g) in 48% hydrobromic acid (550 ml) was refluxed under nitrogen for 8 h. On cooling, a solid was deposited, which was collected and washed with cold 48% hydrobromic acid, ethanol, and ether. Further purification was achieved by dissolving the solid in dilute hydrobromic acid, treatment with charcoal, and addition of an equal volume of 48% hydrobromic acid. The *dihydrobromide* (83·2 g) had m.p. 280° (decomp.) (Found: C, 33·8; H, 5·3; N, 7·8; Br, 45·0. $C_{10}H_{18}Br_2N_2O_2$ requires C, 33·6; H, 5·1; N, 7·8; Br, 44·6%); $\lambda_{max.}$ (N-HCl) 291 nm (log ε 3·92); τ [$(CD_3)_2SO$] 1·28br (OH), 2·14br (s, NH), 3·49 (s, ArH), and 7·0—7·45 (m, $CH_2{\cdot}CH_2$). The free base was obtained by treatment of the dihydrobromide with aqueous sodium carbonate as described previously and had m.p. 236—237° (decomp.) (lit.,[12] 234°). The dihydrochloride was prepared as previously.[12]

A mixture of the dihydrochloride (100 mg) and deuterium oxide (4 ml) containing 2 drops of concentrated deuterium chloride was heated on a water-bath for 2 h and evaporated to dryness. This process was repeated three times. Examination of the residue by n.m.r. spectroscopy showed that deuteriation had occurred at positions 3 and 6 (*ca.* 80% incorporation).

2,5-*Bis*-(β-*aminoethyl*)-1,4-*benzoquinone* (IVa).—To a suspension of the foregoing dihydrobromide (2·13 g) in glacial acetic acid (10 ml) was added, with stirring, nitric acid (*d* 1·48; 3 ml). The suspended material quickly dissolved and a heavy precipitate formed. After 3 min, a mixture of ethanol (20 ml) and 48% hydrobromic acid (2 ml) was added and the solution was filtered. The solid was purified by dissolution in the minimum volume of dilute hydrobromic acid and addition of ethanol containing 2% hydrobromic acid. The *dihydrobromide* of the title compound (1·8 g) had m.p. 175—180° (decomp.) (Found: C, 33·8; H, 4·2; N, 7·8. $C_{10}H_{16}Br_2N_2O_2$ requires C, 33·9; H, 4·0; N, 7·9%); $\lambda_{max.}$ (N-HCl) 252 nm (log ε 4·22); $\nu_{max.}$ 3450, 1656, 1525, and 1335 cm^{-1}; τ ($CF_3{\cdot}CO_2H$) 2·9br (NH_3^+), 2·92 (s, CH=C), 6·41 (m, $CH_2{\cdot}N$), and 6·93 (t, *J* 6 Hz, $CH_2{\cdot}CH_2{\cdot}N$).

2,5-*Bis*-(β-*acetamidoethyl*)-1,4-*phenylene Diacetate*.—2,5-Bis-(β-aminoethyl)hydroquinone dihydrobromide (7·56 g) was stirred with ice (50 g) and water (90 ml). Acetic anhydride (8 ml) was added, followed by 20% sodium hydroxide solution until the mixture was yellow (pH *ca.* 9). The addition of 20% sodium hydroxide (8 ml) followed by acetic anhydride (1 ml) was performed three times at 5 min intervals. Finally acetic anhydride (5 ml) was added and the suspension was stirred for 30 min. The precipitate was recrystallised from water to give the *tetra-acetate* (6·01 g), m.p. 203—204° (Found: C, 59·1; H, 6·6; N, 7·9. $C_{18}H_{24}N_2O_6$ requires C, 59·3; H, 6·6; N, 7·7%); $\lambda_{max.}$ 269 and 276 nm (log ε 2·71 and 2·73); $\nu_{max.}$ (KBr) 3320, 1764, and 1657 cm^{-1}.

2,5-*Bis*-(β-*acetamidoethyl*)*hydroquinone*.—A mixture of the foregoing tetra-acetate (1·02 g), sodium hydrogen carbonate (2·2 g), methanol (25 ml), and water (25 ml) was refluxed for 2 h. The cooled suspension was acidified and concentrated to half the original volume, and the solid was collected. Recrystallisation from acidified ethanol–water gave the *hydroquinone* (0·75 g), m.p. 268—269° (decomp.) (Found: C, 60·0; H, 7·1; N, 9·9. $C_{14}H_{20}N_2O_4$ requires C, 60·0; H, 7·2; N, 10·0%); $\lambda_{max.}$ 275 nm (log ε 3·83); $\nu_{max.}$ (KBr) 3330, 3180br, and 1632 cm^{-1}.

1,4-*Dimethoxy*-2,5-*bis*-(β-*methylaminoethyl*)*benzene* (XIIIb).—2,5-Bis-(β-aminoethyl)-1,4-dimethoxybenzene (16·67 g) was refluxed for 30 min with benzaldehyde (16·67 g) in ethanol (50 ml) and the solution was evaporated to dryness. The residual oil crystallised from light petroleum (b.p. 60—80°) to give the *dibenzylidene derivative* (29·9 g), m.p. 102—103° (Found: C, 77·0; H, 7·1; N, 6·5. $C_{26}H_{28}N_2O_2$ requires C, 78·0; H, 7·0; N, 7·0%); $\nu_{max.}$ 1640, 1580, and 1510 cm^{-1}; τ 1·78 (s, CH=N), 2·1—2·7 (m, ArH), 3·24 (s, ArH), 6·15 (t, *J* 7·5 Hz, $N{\cdot}CH_2{\cdot}CH_2$), 6·28 (s, OMe), and 7·01 (t, *J* 7·5 Hz, $ArCH_2{\cdot}CH_2$).

A mixture of the foregoing derivative (19·7 g) and dry methyl iodide (50 ml) was refluxed under nitrogen for 50 h and the solution was evaporated to dryness. The residue was refluxed with 80% aqueous ethanol (110 ml) for 30 min and the solution evaporated. The residue was partitioned between aqueous acid and chloroform and the aqueous layer collected, basified, and extracted with chloroform. Evaporation of the dried extract gave the title amine (14·0 g), m.p. 70—75°, τ 3·27 (s, ArH), 6·24 (s, OMe), 7·22 (s, $CH_2{\cdot}CH_2$), 7·59 (s, NMe), and 8·52br (NH), characterised as its ditosyl derivative, m.p. 133—135° (from ethanol), identical with the material already obtained.

2,5-*Bis*-(β-*methylaminoethyl*)-1,4-*benzoquinone* (IVc).—To a solution of the foregoing amine (10 g) in acetic acid (40 ml) at 0° was added ice-cold nitric acid (20 ml). After 20 s an ice-cold mixture of saturated ethanolic hydrogen chloride (370 ml) and ether (60 ml) was added. The precipitate was collected and purified by dissolution in the minimum volume of dilute hydrochloric acid and precipitation with the ether–ethanolic hydrogen chloride mixtures already specified to give the *dihydrochloride* (6·0 g), m.p. 202° (decomp.) (Found: C, 48·9; H, 7·0; N, 9·3. $C_{12}H_{20}Cl_2N_2O_2$ requires C, 48·8; H, 6·8; N, 9·5%); $\lambda_{max.}$ (0·1N-HCl) 253 nm (log ε 4·23), τ ($CF_3{\cdot}CO_2H$) 2·55br (NH), 2·91 (s, quinone CH), 6·50 (m, $CH_2{\cdot}N^+$), and 6·8—7·1 (m, $ArCH_2$ and $\overset{+}{N}Me$).

2,5-*Bis*-(β-*aminoethyl*)-3,6-*dibromohydroquinone* (Ic).—A suspension of 2,5-bis-(β-aminoethyl)hydroquinone dihydrobromide (0·728 g) in acetic acid (20 ml) containing bromine (850 mg) was refluxed for 8 h. The cooled mixture was filtered and the solid washed with ether. Recrystallisation by dissolution in methanol and addition of ether gave the *dihydrobromide* of the title compound (0·99 g), m.p. 290° (decomp.), presumably as a methanol solvate (Found: C, 24·1, 24·6; H, 3·2, 3·5; Br, 61·7, 58·8; N, 5·5, 5·1.

$C_{10}H_{16}Br_4N_2O_2$ requires C, 23·3; H, 3·1; Br, 62·0; N, 5·4. $C_{10}H_{16}Br_4N_2O_2,CH_3OH$ requires C, 24·1; H, 3·7; Br, 58·3; N, 5·1%); $\lambda_{max.}$ 303 nm (log ε 3·76); $\nu_{max.}$ (KBr) 3395, 1497, 1470, and 1430 cm^{-1}.

2,5-*Bis*-(β-*aminoethyl*)-3,6-*dibromo*-1,4-*benzoquinone* (IVb).—A mixture of the dihydrobromide (Ia) (5·35 g), bromine (6·5 g), iodine (0·75 g), and acetic acid (200 ml) was refluxed for 1·5 h and cooled. Nitric acid (*d* 1·45; 50 ml) was added and after 20 min the precipitate was collected. Purification was achieved by dissolution in 0·2N-hydrochloric acid, filtration, treatment with charcoal, and addition of concentrated nitric acid at 0°. The *dinitrate* (4·0 g) had m.p. 154—155° (Found: C, 25·9; H, 3·1; N, 11·9. $C_{10}H_{14}Br_2N_4O_8$ requires C, 25·1; H, 3·1; N, 11·7%); $\lambda_{max.}$ (0·1N-HCl) 295 nm (log ε 4·25); $\nu_{max.}$ 3195, 1667, 1597, 1520, and 1405 cm^{-1}; τ (D_2O) 6·86 (m, methylene protons).

2,3,6,7-*Tetrahydrobenzo*[1,2-b:4,5-b′]*dipyrrole* (Va).—(*a*) A solution of 2,5-bis-(β-aminoethyl)hydroquinone dihydrobromide (1·25 g) in water (20 ml) was added to a mixture of chloroform (50 ml) and 6% borax solution (50 ml). Air was bubbled through the mixture for 10 min and the organic layer collected. More chloroform was added to the aqueous solution and aeration was continued for 10 min. This process was repeated three times. The combined chloroform extracts were dried ($MgSO_4$) and evaporated to dryness below 40° to give the *dipyrrole* (0·45 g) (Found: C, 75·5; H, 6·5; N, 18·1. $C_{10}H_{10}N_2$ requires C, 73·9; H, 6·4; N, 17·7%); $\lambda_{max.}$ 293 nm (log ε 4·23); $\nu_{max.}$ 1620, 1501, 1415, 1266, 833, 714, and 682 cm^{-1}; τ ($CDCl_3$) 3·25 (t, *J* 1 Hz, C*H*=C–CH_2), 5·81 (m, N=CH_2·CH_2), and 7·22 (m, N=CH_2·CH_2).

(*b*) A similar reaction of 2,5-bis-(β-aminoethyl)-1,4-benzoquinone dihydrobromide (1 g) without bubbling air through the solution gave the dipyrrole (0·4 g). When the reaction mixture was kept overnight, the dipyrrole (IIa) (0·2 g) was obtained (see later).

1,2,3,5-*Tetrahydrobenzo*[1,2-b:4,5-b′]*dipyrrole* (IIa).—(*a*) Sublimation of the foregoing dipyrrole (0·2 g) at 100—120° and 10^{-3} mmHg gave the *dipyrrole* (0·14 g), m.p. 183° (decomp.) (from benzene) (Found: C, 75·9; H, 6·3; N, 17·6. $C_{10}H_{10}N_2$ requires C, 75·9; H, 6·4; N, 17·7%); $\lambda_{max.}$ 278 and 315 nm (log ε 3·78 and 3·70); $\nu_{max.}$ (KBr) 3329, 3130, 1465, and 1347 cm^{-1}; τ 2·98 (s, 4-H), 3·04 (d, *J* 3 Hz, 6-H), 3·22 (s, 8-H), 3·74 (d, *J* 3 Hz, 7-H), 6·53 (t, *J* 7·5 Hz, CH_2·N), and 7·00 (t, *J* 7·5 Hz, CH_2·CH_2·N).

(*b*) A solution of 2,5-bis-(β-aminoethyl)hydroquinone dihydrobromide (0·5 g) in aqueous buffer (300 ml) at pH 7 (Wellcome Buffer Tablets) was kept overnight at room temperature in air and extracted with chloroform. The dried extract ($MgSO_4$) was evaporated to dryness and the residue recrystallised from benzene to give the dipyrrole (0·11 g), m.p. 183° (decomp.).

(*c*) Repetition of the (*b*) using 2,5-bis-(β-aminoethyl)-3,6-dideuteriohydroquinone dihydrochloride (100 mg) gave the monodeuteriated dipyrrole (IIc). The n.m.r. spectrum of this material is discussed in the text.

1-*Acetyl*-1,2,3,5-*tetrahydrobenzo*[1,2-b:4,5-b′]*dipyrrole* (IIb).—(*a*) To the dried chloroform solution (70 ml) obtained from 2,5-bis-(β-aminoethyl)hydroquinone dihydrobromide (0·71 g), as discussed in the preparation of 2,3,6,7-tetrahydrobenzo[1,2-*b*:4,5-*b*′]dipyrrole, were added pyridine (5 ml) and acetic anhydride (2 ml). Next day the solution was concentrated to *ca.* 30 ml and diluted with light petroleum (60 ml; b.p. 40—60°). The precipitate was recrystallised from ethanol–water to give the *acetyl compound* (0·20 g), m.p. 238—240° (Found: C, 71·7; H, 6·5; N, 14·2. $C_{12}H_{12}N_2O$ requires C, 62·0; H, 6·1; N, 14·0%); $\lambda_{max.}$ 247, 305, 311, and 318 nm (log ε 4·43, 3·85, 3·84, and 3·90); $\nu_{max.}$ (KBr) 3295, 1610, and 1477 cm^{-1}; τ [$(CD_3)_2CO$] 1·56 (s, 8-H), 2·77 (m, 4-H and 6-H), 3·59 (m, 7-H), 5·88 (t, *J* 8 Hz, CH_2·N), 6·78 (t, *J* 8 Hz, CH_2·CH_2·N), and 7·83 (s, Ac).

(*b*) To a solution of 1,2,3,5-tetrahydrobenzo[1,2-b:4,5-b′]-dipyrrole (158 mg) in pyridine (5 ml) was added acetic anhydride (0·5 ml), and the mixture was kept overnight. Addition of light petroleum gave the acetyl compound (115 mg), m.p. 238—240° (from ethanol–water).

1,5-*Dihydrobenzo*[1,2-b:4,5-b′]*dipyrrole* (IIIa).—To a solution of the dipyrrole (IIa) (80 mg) in ether (100 ml) was added, with vigorous stirring, a solution of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (145 mg) in ether (100 ml) during 30 min. The solution was filtered to remove a black precipitate and the filtrate extracted successively with aqueous 5% sodium hydrogen carbonate (100 ml) and 0·01N-hydrochloric acid. After drying, the organic layer was evaporated to dryness and the residue sublimed at 200° and 10^{-3} mmHg to give the *dipyrrole* (20 mg), m.p. 195—205° (decomp.) (Found: C, 76·7; H, 5·6; N, 17·3%; M^+, 156. $C_{10}H_8N_2$ requires C, 76·9; H, 5·2; N, 17·9%; *M*, 156); $\lambda_{max.}$ 302, 324, and 333·5 nm (log ε 4·22, 3·96, and 3·96); $\nu_{max.}$ 3387, 1330, 1195, 735, and 675 cm^{-1}; τ 2·48 (s, ArH), 2·83 (d, *J* 3 Hz, CH=C*H*·N), and 3·50 (d, *J* 3 Hz, C*H*=CH·N).

1,2,3,5-*Tetrahydro*-1,5-*dimethylbenzo*[1,2-b:4,5-b′]*dipyrrole* (IIf).—A mixture of 2,5-bis-(β-methylaminoethyl)-1,4-benzoquinone dihydrochloride (5·16 g), aqueous 6% sodium hydrogen carbonate (100 ml), sodium hydroxide (1·4 g), and chloroform (200 ml) was shaken for 5 min. The organic layer was collected, dried, and evaporated to dryness. Trituration of the residue with light petroleum gave a solid which when recrystallised from ethanol–water and then light petroleum gave the *dipyrrole* (1·0 g), m.p. 86—87° (Found: C, 77·3; H, 7·4; N, 15·0. $C_{12}H_{14}N_2$ requires C, 77·4; H, 7·6; N, 15·0%); $\lambda_{max.}$ 283 and 324 nm (log ε 3·80 and 3·65); $\lambda_{max.}$ (acid) 292 and 297 nm (log ε 3·8 and 3·8); $\nu_{max.}$ (KBr) 1620, 1500, 1424, and 1263 cm^{-1}; τ 2·95 (s, 4-H), 3·13 (d, *J* 3 Hz, 6-H), 3·18 (s, 8-H), 3·70 (d, *J* 3 Hz, 7-H), 6·30 (s, 5-Me), 6·74 and 6·89 (2t, *J* 6 Hz, CH_2·CH_2), and 7·23 (s, 1-Me).

1,5-*Dihydro*-1,5-*dimethylbenzo*[1,2-b:4,5-b′]*dipyrrole* (IIIb).—To a stirred solution of the foregoing dipyrrole (463 mg) in benzene (50 ml) was added, dropwise, a solution of 2,3-dichloro-5,6-dicyano-1,4-benzoquinone (556 mg) in benzene (50 ml). After 10 min the solution was filtered and the filtrate extracted with 0·5N-sodium hydroxide solution, 0·1N-hydrochloric acid, and water. Evaporation of the dried organic layer gave a solid which furnished, after recrystallisation from ethanol–water, the *dipyrrole* (238 mg), m.p. 206—209° (Found: C, 78·2; H, 6·5; N, 15·1. $C_{12}H_{12}N_2$ requires C, 78·2; H, 6·6; N, 15·2%); $\lambda_{max.}$ 299, 305, 338, and 348 nm (log ε 4·09, 4·21, 3·97, and 4·12); τ ($CDCl_3$) 2·51 (s, ArH), 2·93 (d, *J* 3 Hz, CH=C*H*–N), 3·46 (d, *J* 3 Hz, C*H*=CH–N), and 6·24 (s, NMe).

Formation of Compound (*A*).—A mixture of 2,5-bis-(β-aminoethyl)-3,6-dibromo-1,4-benzoquinone dinitrate (511 mg), 6% borax solution (40 ml), and chloroform (20 ml) was shaken for 5 min. The organic layer was collected and the aqueous phase extracted with more chloroform (2 × 20 ml). The dried, combined chloroform extracts were concentrated to 5 ml, whereupon crystals were deposited.

Recrystallisation from ethanol gave compound (A) (200 mg), m.p. 155° (decomp.) as a buff-coloured solid (Found: C, 37·1; H, 2·8; Br, 49·5; N, 8·5. Calc. for $C_{10}H_8Br_2N_2,0{\cdot}5H_2O$: C, 37·0; H, 2·8; Br, 49·2; N, 8·6%); $\lambda_{max.}$ 303 nm (log ε 4·10); $\lambda_{max.}$ (acidified EtOH) 282 nm (log ε 4·04), $\lambda_{infl.}$ 295 nm (log ε 3·98). Its mass spectrum was identical with that of the dipyrrole (IIe).

4,8-*Dibromo*-1,2,3,5-*tetrahydrobenzo*[1,2-b:4,5-b′]*dipyrrole* (IIe).—(*a*) To a suspension of compound (A) (200 mg) in methanol (3 ml) was added 10% sodium methoxide in methanol (10 drops). The mixture was boiled for 1 min and cooled in ice. The precipitate was collected and recrystallised from toluene to give the *dipyrrole* (120 mg), m.p. 180° (decomp.) (Found: C, 38·7; H, 2·7; Br, 49·8; N, 8·7. $C_{10}H_8Br_2N_2$ requires C, 38·0; H, 2·6; Br, 50·6; N, 8·9%); $\lambda_{max.}$ 224, 280, and 324 nm (log ε 4·53, 3·97, and 3·71); $\lambda_{max.}$ (acidified EtOH) 295 nm (log ε 4·04); τ [$(CD_3)_2SO$] −1·04 (s, 5-H), 2·80 (m, 6-H), 3·76 (m, 7-H), 4·78 (s, 1-H), 6·49 (m, *J* 7 Hz, CH_2·N), 6·92 (m, *J* 7 Hz, CH_2·CH_2·N).

(*b*) A solution of 2,5-bis-(β-aminoethyl)-3,6-dibromo-1,4-benzoquinone dinitrate (200 mg) in aqueous buffer at pH 7 (100 ml) was kept overnight and extracted with chloroform. The dried extract ($MgSO_4$) was evaporated to dryness and the residue crystallised as before to give the dipyrrole (30 mg), m.p. 180° (decomp.).

(*c*) A solution of 2,5-bis-(β-aminoethyl)-3,6-dibromohydroquinone dihydrobromide (250 mg) in aqueous buffer at pH 7 (100 ml) gave, as described in (*b*), the dipyrrole (30 mg), m.p. 180° (decomp.).

2,5-*Bis*-(β-*carbamoylethyl*)-1,4-*dimethoxybenzene* (XVIIb). A mixture of 2,5-bis-(β-carboxyethyl)-1,4-dimethoxybenzene [15] (10·0 g) and thionyl chloride (22 g) was refluxed for 2 h and evaporated to dryness. The residue was dissolved in ether (50 ml) and the solution stirred while concentrated aqueous ammonium hydroxide (35 ml) was added. The ether was evaporated off and the aqueous solution cooled to yield the *diamide* (6·7 g), m.p. 225—228° (from ethanol) (Found: C, 60·2; H, 7·2; N, 10·2. $C_{14}H_{20}N_2O_4$ requires C, 60·0; H, 7·2; N, 10·0%).

1,4-*Dimethoxy*-2,5-*bis*-(N-*methyl*-β-*carbamoylethyl*)*benzene*.—Prepared similarly from the diacid (4·6 g), thionyl chloride (10 ml), and ethanolic 30% methylamine, the *diamide* (3·3 g) had m.p. 190—191° (from ethanol–water) (Found: C, 62·5; H, 7·6; N, 9·0. $C_{16}H_{24}N_2O_4$ requires C, 62·3; H, 7·8; N, 9·1%).

2,5-*Bis*-(β-*cyanoethyl*)-1,4-*dimethoxybenzene* (XVIIc).—A mixture of the diamide (XVIIb) (3·0 g), phosphorus pentoxide (2·04 g), and mesitylene (150 ml) was refluxed for 2 h with vigorous stirring. The hot supernatant liquid was decanted, concentrated, and cooled to give the *dinitrile* (1·3 g), m.p. 155—156° (from ethanol) (Found: C, 68·6; H, 6·6; N, 11·5. $C_{14}H_{16}N_2O_2$ requires C, 68·9; H, 6·6; N, 11·5%); τ 3·29 (s, ArH), 6·27 (s, OMe), and 7·1 and 7·4 (2t, *J* 7 Hz, CH_2·CH_2·CN).

2,5-*Bis*-(3-*aminopropyl*)-1,4-*dimethoxybenzene* (XVIa).—The foregoing dinitrile (1·6 g) was reduced with lithium aluminum hydride (0·9 g) in tetrahydrofuran (150 ml) (Soxhlet technique). After 24 h water was added and the liquid decanted. The residue was extracted with chloroform. The combined organic extracts were dried and evaporated to give the diamine (1·1 g), b.p. 95—100° at 1×10^{-4} mmHg, $\nu_{max.}$ (film) 3350 and 3300 cm^{-1}; $\lambda_{max.}$ ($CHCl_3$) 295 nm (log ε 3·61); τ ($CDCl_3$–D_2O) 3·36 (s, ArH), 6·26 (s, OMe), 7·36 (m, CH_2·CH_2·CH_2·N), and 8·28 (quintet, *J* 7 Hz, CH_2·CH_2·CH_2). The NN′-*diacetate* had m.p. 188—189° (from ethanol) (Found: C, 63·9; H, 8·4; N, 8·1. $C_{18}H_{28}N_2O_4$ requires C, 64·3; H, 8·4; N, 8·3%); $\nu_{max.}$ 3245 and 1630 cm^{-1}.

2,5-*Bis*-(β-*aminopropyl*)*hydroquinone* (VIIIa).—A mixture of the foregoing amine (0·275 g) and 48% hydrobromic acid (5 ml) was refluxed for 6 h and evaporated to dryness. The residue was dissolved in concentrated hydrochloric acid and the solution evaporated to dryness. This process was repeated several times. Finally, the residue was dissolved in hot ethanol, treated with charcoal, and the solution was filtered and cooled. Additions of ether gave the dihydrochloride (0·27 g), m.p. 267—270°, $\nu_{max.}$ 3300—3100 cm^{-1}, $\lambda_{max.}$ (H_2O) 292 nm (log ε 3·45), τ (D_2O) 3·30 (s, ArH), 7·02 (t, *J* 7 Hz, CH_2·NH_3), 7·40 (t, *J* 7 Hz, ArCH_2), and 8·08 (m, CH_2·CH_2·CH_2). This salt was extremely hygroscopic and no satisfactory analytical data were obtained. The NN′OO′-*tetra-acetate* had m.p. 188—189° (from ethanol–ether) (Found: C, 61·4; H, 7·2; N, 7·2. $C_{20}H_{28}N_2O_6$ requires C, 61·2; H, 7·2; N, 7·1%); $\nu_{max.}$ 3300, 1750, and 1640 cm^{-1}; $\lambda_{max.}$ ($CHCl_3$) 269 and 275 nm (log ε 2·98 and 2·98).

1,2,3,4-*Tetrahydropyrido*[2,3-g]*quinoline* (IX).—Air was passed through a solution of the foregoing dihydrochloride (0·222 g) in aqueous 5% sodium hydrogen carbonate (25 ml) for 3 h. The precipitate obtained sublimed (120° at 10^{-3} mmHg) to give the *quinoline* (0·067 g), m.p. 159—161° (Found: C, 78·4; H, 6·6; N, 15·4%; M^+, 184. $C_{12}H_{12}N_2$ requires C, 78·3; H, 6·5; N, 15·2%; *M*, 184); $\lambda_{max.}$ (EtOH) 213, 260, and 380 nm (log ε 4·50, 4·53, and 3·71); $\lambda_{max.}$ (0·01N-HCl) 215, 274, and 423 nm (log ε 4·49, 4·39, and 3·58); $\lambda_{max.}$ (0·01N-NaOH) 215, 252, and 354 nm (log ε 4·26, 4·34, and 3·50); $\nu_{max.}$ (KBr) 3280, 1640, 1600, and 1500 cm^{-1}; τ 1·48 (dd, *J* 1 and 4 Hz, 7-H), 2·18 (dd, *J* 1 and 8 Hz, 9-H), 2·84 (dd, *J* 4 and 8 Hz, 8-H), 2·28 and 3·40 (2s, 5 and 10-H), 6·64 (t, *J* 6 Hz, CH_2·CH_2·N), 7·04 (t, *J* 6 Hz, PhCH_2·CH_2), and 8·06 (quintet, CH_2·CH_2·CH_2).

1,4-*Dimethoxy*-2,5-*bis*-(3-*methylaminopropyl*)*benzene* (XVIb).—A mixture of 2,5-bis-(3-aminopropyl)-1,4-dimethoxybenzene (1·20 g), freshly distilled benzaldehyde (1·05 g), and absolute ethanol (10 ml) was refluxed for 3 h. The solution was evaporated to dryness, the residue dissolved in the minimum volume of hot light petroleum, and the solution filtered. On cooling, NN′-2,5-*bis*-(3-*benzylidene aminopropyl*)-1,4-*dimethoxybenzene* (0·70 g), m.p. 89—90°, was formed (Found: C, 78·6; H, 7·6; N, 6·3. $C_{28}H_{32}N_2O_2$ required C, 78·5; H, 7·5; N, 6·5%).

A mixture of the foregoing dibenzylidene compound (0·585 g) was refluxed with methyl iodide (50 ml) under nitrogen for 50 h. The solution was evaporated to dryness and the residue refluxed with 80% aqueous ethanol (100 ml) for 1·5 h. The residue obtained after the removal of the solvent was partitioned between toluene and dilute hydrochloric acid. The aqueous phase was collected, basified, and extracted with chloroform. Evaporation of the dried extract ($MgSO_4$) gave the *diamine* (0·225 g) as an oil, b.p. 80—85° at $3{\cdot}2 \times 10^{-2}$ mmHg; $\nu_{max.}$ 3250 cm^{-1}; τ ($CDCl_3$) 3·35 (s, ArH), 6·29 (s, OMe), 7·40 (m, CH_2·CH_2·CH_2·N), 7·61 (s, NMe), 8·24 (m, CH_2·CH_2·CH_2), and 8·48br (s, NH). The *dipicrate* crystallised from ethanol as a solvate, m.p. 136—138° (Found: C, 46·4; H, 5·1; N, 14·3. $C_{28}H_{34}N_8O_{16},C_2H_5OH$ requires C, 46·0; H, 5·1; N, 14·3%).

2,5-*Bis*-(3-*methylaminopropyl*)*hydroquinone* (VIIIb).—A mixture of the foregoing amine (0·276 g) and hydrobromic

acid (6 ml) was refluxed for 4 h. Removal of the solvent under vacuum yielded the *dihydrobromide* (0·349 g), m.p. 195—197° (from ethanol–ether) (Found: C, 40·8; H, 6·1. $C_{14}H_{26}Br_2N_2O_2$ requires C, 40·6; H, 6·3%); M^+, 252; $\lambda_{max.}$ (H_2O) 291 nm (log ε 3·57); $\nu_{max.}$ 3400—3200 cm^{-1}; τ (D_2O) 3·30 (s, ArH), 6·99 (t, *J* 7 Hz, $CH_2{\cdot}CH_2{\cdot}\overset{+}{N}$), 7·32 (s, $\overset{+}{N}Me$), 7·40 (t, *J* 7 Hz, $ArCH_2{\cdot}CH_2$), and 8·08 (m, $CH_2{\cdot}CH_2{\cdot}CH_2$).

Oxidative Cyclisation of the Hydroquinone (VIIIb).—A solution of the foregoing dihydrobromide (0·300 g) in aqueous 5% sodium hydrogen carbonate (30 ml) was aerated for 3 h and kept overnight. The precipitate was collected and sublimed at 40° and 10^{-4} mmHg to give needles (5 mg), tentatively identified as 1,2,3,4,6,7,8,9-octahydro-1,5-dimethylpyrido[2,3-*g*]quinoline, m.p. 65°, M^+ 216; $\nu_{max.}$ ($CHCl_3$) 2920, 2850, 1580, and 1485 cm^{-1}.

The aqueous filtrate was extracted continuously with hot chloroform for 48 h. The extract was filtered through Whatman No. 1 phase separating paper and evaporated to dryness. The residue was dissolved in hydrobromic acid and the solution evaporated to dryness. Recrystallisation of the residue from chloroform–light petroleum gave 1,2,3,4-*tetrahydro*-1,6-*dimethylpyrido*[2,3-g]*quinolinium bromide* (XI) (50 mg), m.p. 246—248° (Found: C, 50·1; H, 5·5; N, 8·1. $C_{14}H_{17}BrN_2$ requires C, 57·1; H, 6·1; N, 9·5. $C_{14}H_{17}BrN_2,0{\cdot}5CHCl_3$ requires C, 49·0; H, 5·0; N, 7·9%), M^+ 213; $\nu_{max.}$ 3375br, 1620, 1580, and 1520 cm^{-1}; $\lambda_{max.}$ (H_2O) 219, 285, and 447 nm (log ε 4·38, 4·34, and 3·69), τ [$(CD_3)_2SO$] 1·09 (d, *J* 6 Hz, H-7), 1·27 (d, *J* 9 Hz, H-9), 2·27 (dd, *J* 6 and 9 Hz, H-8), 1·98 and 2·92 (2s, H-5 and H-10), 5·53 (s, ^+NMe), 6·56 (t, *J* 6 Hz, $PhCH_2{\cdot}CH_2$), 6·94 (s + t, *J* 6 Hz, NMe and $N{\cdot}CH_2{\cdot}CH_2$), and 8·06 (quintet, *J* 6 Hz, $CH_2{\cdot}CH_2{\cdot}CH_2$). A small singlet due to chloroform was observed at τ 1·78.

2,5-*Bis*-(α-*hydroxy*-β-*nitroethyl*)-1,4-*dimethoxybenzene* (XIVa).—A mixture of 2,5-dimethoxyterephthaldehyde [13] (4·51 g), nitromethane (150 ml), and triethylamine (3 ml) was kept overnight at room temperature and the resulting solution evaporated to dryness. Recrystallisation of the residue from ethyl acetate gave the *nitro-compound* (5·36 g), m.p. 210—212° (Found: C, 45·3; H, 5·2; N, 9·0. $C_{12}H_{16}N_2O_8$ requires C, 45·6; H, 5·1; N, 8·9%), $\lambda_{max.}$ 296 nm (log ε 3·70).

1,4-*Dimethoxy*-2,5-*bis*-(β-*nitrovinyl*)*benzene* (XV).—To a solution of the foregoing nitro-compound (4·5 g) in pyridine (40 ml) was added methanesulphonyl chloride (7 g). After 1 day, the precipitate was collected and recrystallised from glacial acetic acid or nitromethane to give the *nitro-compound* (3·6 g), m.p. 300—302° (decomp.) (Found: C, 51·7; H, 4·3; N, 9·9. $C_{12}H_{12}N_2O_6$ requires C, 51·4; H, 4·3; N, 10·0%), $\lambda_{max.}$ 258, 335, and 445 nm (log ε 3·76, 4·22, and 4·10).

1,4-*Dimethoxy*-2,5-*bis*-(β-*nitroethyl*)*benzene* (XIVb).—A solution of the foregoing compound (300 mg) in hot nitromethane (100 ml) was cooled rapidly in order to produce a fine suspension. Sodium borohydride (0·7 g) was added and the mixture stirred at room temperature until the orange colour was discharged. A solution of urea (20 g) in 20% acetic acid (100 ml) was added at 0° until the pH was 6. The organic layer was collected, dried, and evaporated to give the *nitroethane* (220 mg), m.p. 125—133° (from ethanol–water) (Found: C, 50·4; H, 5·4; N, 10·0. $C_{12}H_{16}N_2O_6$ requires C, 50·7; H, 5·7; N, 9·9%); $\lambda_{max.}$ 225 and 297 nm (log ε 4·00 and 3·67); τ (CCl_4) 3·33 (s, ArH), 5·44 (t, *J* 7 Hz, $CH_2{\cdot}NO_2$), 6·25 (s, OMe), and 6·76 (t, *J* 7 Hz, $ArCH_2{\cdot}CH_2$).

2,5-*Bis*-(β-*amino*-α-*hydroxyethyl*)-1,4-*dimethoxybenzene* (XIVc).—A solution of the hydroxy-nitro-compound (XIVb) (210 mg) in glacial acetic acid was stirred under hydrogen in the presence of 10% palladium–charcoal for 6 h (uptake 5·5 mol. equiv.). After filtration, the solution was evaporated to dryness and aqueous sodium hydroxide was added to the residue. A solid formed which could be recrystallised from water to give the *amino-alcohol* (44 mg), m.p. 220—223° (decomp.) (Found: C, 55·8; H, 7·3; N, 10·3. $C_{12}H_{20}N_2O_4$ requires C, 56·2; H, 7·8; N, 10·9%); $\nu_{max.}$ (KBr) 3350, 3280—2500, 1614, and 1500 cm^{-1}, τ [$(CD_3)_2SO$] 3·11 (s, ArH), 3·39 (d, OH), 5·36 (m, $CH{\cdot}OH$), 6·40 (s, OMe), and 7·42 (m, $CH_2{\cdot}CH{\cdot}OH$).

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