**9-(2-Dipropylamino-1-propyl)-10-methyl-10,9-borazarophenanthrene.**—Prepared similarly from IVa (3.1 g.), the **amine IVd** was isolated as an oil (2.14 g., 65%), b.p. 156–158° (0.03 mm.).

*Anal.* Calcd. for $C_{24}H_{25}BN_2$: N, 7.7; B, 3.0. Found: N, 7.3; B, 3.0.

**9-(2-Dibutylamino-1-propyl)-10-methyl-10,9-borazarophenanthrene.**—Prepared similarly from IVa (4.0 g.), the **amine IVe** was isolated as an oil (2.86 g., 62%), b.p. 168–170° (0.04 mm.).

*Anal.* Calcd. for $C_{24}H_{25}BN_2$: N, 7.7; B, 3.0. Found: N, 7.3; B, 3.0.

**9-(2-N-Piperidino-1-propyl)-10-methyl-10,9-borazarophenanthrene.**—Prepared similarly from IVa (1.5 g.), the **amine IVf** crystallized from ethanol in small plates (1.1 g., 72%), m.p. 116–117°, depressed on admixture with IIId.

*Anal.* Calcd. for $C_{21}H_{27}BN$: C, 79.2; H, 8.5; N, 8.8. Found: C, 79.0; H, 8.4; N, 8.6.

**9-(2-N-Morpholino-1-propyl)-10-methyl-10,9-borazarophenanthrene.**—Prepared similarly from IVa (2.0 g.), the **amine IVg** crystallized from ethanol in small plates (1.55 g. 76%), m.p. 129–130°, depressed on admixture with IIIe.

*Anal.* Calcd. for $C_{20}H_{25}BN_2O$: C, 75.0; H, 7.8; N, 8.7. Found: C, 75.2; H, 7.7; N, 8.8.

**9-(2-Cyano-1-propyl)-10-methyl-10,9-borazarophenanthrene.**—A solution of potassium cyanide (0.93 g.) in water (20 ml.) was added to one of IVa (1.5 g.) in ethanol (80 ml.) and the mixture was boiled overnight and then evaporated under vacuum. Ether extraction of the residue gave the **nitrile IVh** which crystallized from ethanol in small prisms (1.00 g., 80%), m.p. 177–178°.

*Anal.* Calcd. for $C_{17}H_{17}BN_2$: C, 78.5; H, 6.5; N, 10.8. Found: C, 78.7; H, 6.2; N, 10.9.

**1,2-Dimethyl-2,1-borazaronaphthalene.**—An ethereal solution of methyllithium, prepared from lithium (1.0 g.) and methyl iodide (6.5 g.), was added dropwise to a vigorously stirred benzene solution of VIa (5.0 g.) under nitrogen at room temperature. A benzene solution of dimethyl sulfate (11 g.) was then added and the mixture was boiled 3 hr. under reflux. Hydrolysis and ether extraction gave **1,2-dimethyl-2,1-borazaronaphthalene (VIc)** as an oil (4.4 g., 80%), b.p. 76–78° (0.5 mm.).

*Anal.* Calcd. for $C_{10}H_{12}BN$: C, 76.4; H, 7.6; N, 8.9; B, 7.0. Found: C, 76.2; H, 7.8; N, 8.9; B, 6.7.

**1-Allyl-2-methyl-2,1-borazaronaphthalene.**—Prepared similarly from allyl bromide (10.8 g.), the **allylmethylborazaronaphthalene (VId)** was isolated as an oil (4.99 g., 78%), b.p. 74° (0.04 mm.).

*Anal.* Calcd. for $C_{12}H_{14}BN$: C, 78.7; H, 7.6; N, 7.6. Found: C, 78.3; H, 7.2; N, 7.8.

**Ethyl 2-Methyl-2,1-borazaronaphthalene-1-carboxylate.**—Prepared similarly from ethyl chloroformate (9.5 g.), the **urethane (VIf)** was isolated as an oil (5.7 g., 76%), b.p. 96–98° (0.4 mm.).

*Anal.* Calcd. for $C_{12}H_{14}BNO_2$: C, 67.0; H, 6.5; N, 6.5. Found: C, 66.7; H, 6.8; N, 6.5.

**1-(3-Chloro-1-propyl)-2-methyl-2,1-borazaronaphthalene.**—Prepared similarly from 1-bromo-3-chloropropane (22.0 g.), the **chloropropyl derivative (VIe)** distilled at 100–102° (2 mm.) as an oil which crystallized, m.p. 70.0°.

*Anal.* Calcd. for $C_{12}H_{15}BClN$: C, 65.6; H, 6.8; N, 6.4; Cl, 16.2; B, 5.0. Found: C, 66.1; H, 7.3; N, 6.4; Cl, 16.0; B, 5.2.

**1-(3-Dimethylamino-1-propyl)-2-methyl-2,1-borazaronaphthalene.**—Prepared in the same way as III from VIe (3.0 g.) and dimethylamine (15.5 g. of 40% aqueous solution), the **amine Va** was isolated as an oil (2.23 g., 72%), b.p. 110° (1.0 mm.), $n^{28}D$ 1.5608.

*Anal.* Calcd. for $C_{14}H_{21}BN_2$: C, 73.7; H, 9.2; B, 4.8. Found: C, 73.5; H, 9.3; B, 4.8.

**1-(3-Dimethylamino-1-propyl)-2-methyl-2,1-borazaronaphthalene.**—Prepared similarly from VIe (3.0 g.), the **amine Vb** formed an oil (2.27 g., 65%), b.p. 119–121° (1.0 mm.), $n^{29}D$ 1.5970.

*Anal.* Calcd. for $C_{16}H_{25}BN_2$: N, 10.9; B, 4.3. Found: N, 10.8; B, 4.3.

**1-(3-N-Piperidino-1-propyl)-2-methyl-2,1-borazaronaphthalene.**—Prepared similarly from VIe (4.0 g.), the **amine Vc** formed an oil (3.38 g., 70%), b.p. 122–124° (0.2 mm.), $n^{29}D$ 1.5670.

*Anal.* Calcd. for $C_{17}H_{25}BN_2$: C, 76.1; H, 9.3; N, 10.4. Found: C, 76.6; H, 9.5; N, 10.1.

**1-(3-N-Morpholino-1-propyl)-2-methyl-2,1-borazaronaphthalene.**—Prepared similarly from VIe (4.0 g.), the **amine Vd** (3.73 g., 76%) had b.p. 130–132° (0.2 mm.), $n^{29}D$ 1.5755.

*Anal.* Calcd. for $C_{16}H_{23}BN_2O$: C, 71.1; H, 8.5; N, 10.4. Found: C, 70.9; H, 8.4; N, 10.2.

**1-(3-Cyano-1-propyl)-2-methyl-2,1-borazaronaphthalene.**—A solution of potassium cyanide (3.6 g.) in water (20 ml.) was added to one of VIe (4.0 g.) in ethanol (125 ml.), and the mixture was boiled under reflux for 6 hr. and then evaporated. Ether extraction of the residue gave the **nitrile Ve** as an oil (2.55 g., 67%), b.p. 140–142° (0.4 mm.).

*Anal.* Calcd. for $C_{13}H_{15}BN_2$: C, 74.3; H, 7.1; B, 5.2. Found: C, 74.9; H, 7.6; B, 5.4.

# New Heteroaromatic Compounds. XXI.[1] Some Tetracyclic Systems[2]

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*Received August 22, 1963*

Several derivatives of 5,4-borazaropyrene, of 9,10-dihydro-5,4-borazaropyrene, and of 6,5-borazarochrysene have been prepared by the general procedures previously described. In the course of this work we have developed an improved synthesis of 4-aminophenanthrene. Attempts to synthesize derivatives of 5,6- and 6,5-borazarobenz[*c*]phenanthrene failed. Limitations on the generality of a recently described[4] new cinnoline synthesis are pointed out.

Previous papers in this series have described a large number of novel heteroaromatic compounds containing boron. These compounds are remarkably stable and show a marked similarity to the related "normal" aromatics in their physical properties; it, therefore, seemed to us that corresponding analogs of carcinogenic hydrocarbons might be of biological interest. The work described here represents a step towards the synthesis of such materials, in particular, analogs of benz[*a*]pyrene.

The obvious route to 5,4-borazaropyrene (I) was by a Friedel–Crafts cyclization of the adduct from 4-aminophenanthrene (II) and boron trichloride.[5] Langenbeck and Weissenborn[6] had reported the preparation of 4-aminophenanthrene by Semmler reaction of the oxime of 4-keto-1,2,3,4-tetrahydrophenanthrene (III); however, one of us (M. J. S. D.) previously had found this reaction capricious and unsatisfactory,[7] and we can confirm that the yields are low and erratic. The

(1) Part XX: M. J. S. Dewar and R. C. Dougherty, *J. Am. Chem. Soc.*, **86**, 433 (1964).

(2) This work was supported by the National Institutes of Health through Grant No. CY-5218.

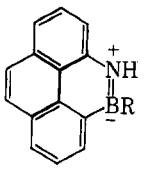
(3) Department of Chemistry, The University of Texas, Austin, Texas 78712.

(4) M. J. S. Dewar and W. H. Poesche, *J. Chem. Soc.*, 2201 (1963).

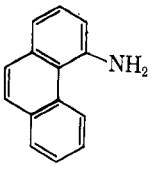
(5) *Cf.* M. J. S. Dewar, V. P. Kubba, and R. Pettit, *ibid.*, 3073 (1958).

(6) W. Langenbeck and K. Weissenborn, *Ber.*, **72**, 726 (1939).

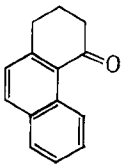
(7) *Cf.* P. M. G. Bavin, Ph.D. thesis, London, 1954.



Ia, R = H
b, R = Cl
c, R = $OCH_3$
d, R = $CH_3$
e, R = 0.5O



II



III

method is quite unsuitable for large-scale preparations and we therefore looked for an alternative route from III to II.

Horning and his collaborators[8,9] have converted cyclohexanone and tetralone azines into aniline and naphthylamine derivatives in one step by refluxing with palladized charcoal in triethylbenzene. When we applied this procedure to the azine of III, II was formed reproducibly in 37% yield. The reaction moreover can be run on a large scale, and the product seemed to be free from 4-amino-1,2,3,4-tetrahydrophenanthrene, judging by the n.m.r. spectrum.

With boron trichloride and aluminum chloride, II was converted[4] to 5-chloro-5,4-borazaropyrene (Ib); this was not isolated but was converted by the methods developed previously[10] into the 5-methoxy (Ic) and 5-methyl (Id) derivatives, and also to 5,4-borazaropyrene (Ia) itself.

These borazaro derivatives are of considerable theoretical interest since they are isoelectronic with normal aromatic hydrocarbons; comparisons of such pairs of closely related compounds provide a useful check of quantum mechanical theories of molecular structure. We therefore measured the ultraviolet spectra (see Table I) of Ia in methylcyclohexane and of

TABLE I

ULTRAVIOLET SPECTRA[a] OF 5,4-BORAZAROPYRENE DERIVATIVES

| Ia (in methylcyclohexane) | Ib (in chloroform) | Id (in chloroform) |
|---|---|---|
| 365 (4.14) | 365 (3.92) | 366 (4.02) |
| 358 (3.54) | 359 s (3.43) | 359 s (3.48) |
| 351 s (3.38) | 348 (3.76) | 348 (3.83) |
| 347 (3.92) | 340 s (3.38) | 341 s (3.38) |
| 340 (3.40) | 331 s (3.54) | 332 s (3.60) |
| 331 (3.54) | 307 (4.05) | 308 (4.10) |
| 320 (4.18) | 295 (3.91) | 296 (3.90) |
| 317 (4.09) | 278 (4.39) | 279 s (4.28) |
| 307 (4.09) | 270 (4.41) | 270 (4.42) |
| 295 (3.88) | 252 (4.60) | 252 (4.61) |
| 267 (4.36) | | |
| 250 (4.57) | | |
| 238 (4.53) | | |

[a] $\lambda_{max}$, m$\mu$ (log $\epsilon$).

Ic and Id in chloroform, and also the charge-transfer bands (see Table II) of the complexes formed by Ia, Ic, and Id with tetracyanoethylene in chloroform.[11] In the case of Ia, alcohol-free chloroform must be used, for in presence of alcohol Ia, like other analogous boron compounds, is oxidized to the 5-ethoxy derivative.[10]

(8) E. C. Horning and M. G. Horning, *J. Am. Chem. Soc.*, **69**, 1907 (1947).
(9) E. C. Horning and E. F. Platt, *ibid.*, **70**, 288 (1948).
(10) M. J. S. Dewar and W. H. Poesche, *ibid.*, **84**, 2253 (1963).
(11) *Cf.* M. J. S. Dewar and H. Rogers, *ibid.*, **84**, 395 (1962).

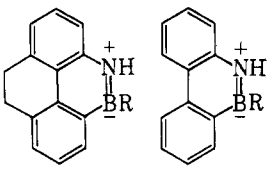
TABLE II

CHARGE-TRANSFER SPECTRA OF COMPLEXES FROM DERIVATIVES OF 5,4-BORAZAROPYRENE AND TETRACYANOETHYLENE IN CHLOROFORM

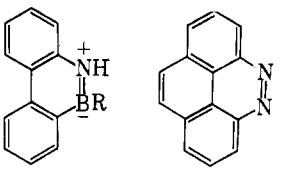
| Compound | $\lambda_{max}$, m$\mu$ |
|---|---|
| Ia[a] | 688, 431 |
| Ic | 695, 565, 408 |
| Id | 706, 542, 404 |

[a] In chloroform free from alcohol.

The difficulties we met initially in preparing II led us to explore an alternative route to I *via* its 9,10-dihydro derivative. The necessary amine could be prepared from 4-nitro-9,10-dihydrophenanthrene, which Krueger and Mosettig[12] obtained in low yield (3–4%) by nitration of 9,10-dihydrophenanthrene and separation from the 2-isomer (obtained in 65% yield). We found it more convenient to reduce the crude mixture of nitro derivatives and to react the resulting amines with boron trichloride and aluminum chloride; hydrolysis of the reaction product gave 5-hydroxy-9,10-dihydro-5,4-borazaropyrene (IVa) as its ether, from which we obtained the corresponding methoxy (IVb) and methyl (IVc) derivatives in the usual way.



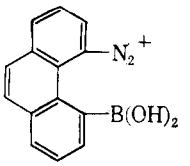
IVa, R = OH
b, R = $OCH_3$
c, R = $CH_3$



Va, R = OH
b, R = $OCH_3$
c, R = $CH_3$



VI



VII

The ether from IVa could be dehydrogenated with palladized charcoal in benzene, using hexene as hydrogen acceptor, under pressure at 260°. The product, formed in good yield, was shown by its conversion to Ic and Id to be the ether Ie. This provides an alternative route to 5,4-borazaropyrenes.

Table III lists the ultraviolet spectra of IVb and IVc in chloroform, and the charge-transfer bands of their complexes with tetracyanoethylene in chloroform. The spectra resemble those of the corresponding derivatives of 10,9-borazarophenanthrene (V), confirming the structure of IV.

TABLE III

ULTRAVIOLET SPECTRA[a] AND CHARGE-TRANSFER COMPLEXES OF 5-METHOXY- AND 5-METHYL-10,9-DIHYDRO-5,4-BORAZAROPYRENE IN CHLOROFORM

| IVb | Vb | IVc | Vc |
|---|---|---|---|
| 327 (3.97) | 325 (4.03) | 330 (4.00) | 324 (4.08) |
| 314 (3.87) | 312 (3.99) | 316 (3.89) | 313 (4.00) |
| 300 (3.69) | 300 s (3.79) | 304 (3.60) | 300 (3.81) |
| 284 (3.97) | 272 (4.23) | 285 s (3.91) | 272 (4.08) |
| 275 (3.97) | 262 (4.23) | 268 s (4.05) | 252 (4.48) |
| | | 257 s (4.32) | |
| Complex with tetracyanoethylene | | | |
| 656 | 635 | 629 | 605 |
| 462 | 515 | 428 | 400 |
| | 425 | | |

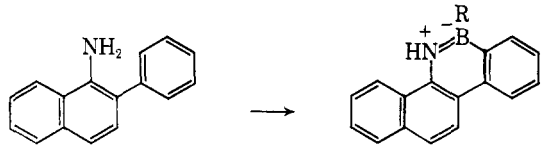
[a] $\lambda_{max}$, m$\mu$ (log $\epsilon$).

We had hoped to obtain 4,5-diazapyrene (VI), which Holt and Hughes have unsuccessfully tried to synthe-

(12) F. W. Krueger and E. Mosettig, *J. Org. Chem.*, **3**, 340 (1938).

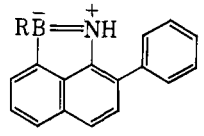
size,[13] by the new cinnoline synthesis which we have lately described.[4] However, while diazotization of 10-hydroxy-10,9-borazarophenanthrene in acetic acid gives benzo[*c*]cinnoline in almost theoretical yield with Ic, only a very small amount of material (*ca.* 2%) was obtained with the properties expected for VI. The main product was a high-melting yellow solid of unknown structure which clung to an alumina column. Attempts to convert IVa into a dihydro derivative of V likewise failed. Presumably the enforced coplanarity of the benzene rings in the intermediate diazonium boronic acid (*e.g.*, VII) hinders cyclization by blocking the approach of the nitrogen moiety to the carbon bearing the boronic acid group. This indicates a limitation on the generality of this cinnoline synthesis.

We also have prepared a series of derivatives of 6,5-borazarochrysene in a similar manner. Condensation[5] of 1-amino-2-phenylnaphthalene (VIII) with boron trichloride in presence of a catalytic amount of aluminum chloride gave 6-chloro-6,5-borazarochrysene (IXa) which was converted without isolation into 6-hydroxy- (IXb) and 6-methyl-6,5-borazarochrysene (IXc), into bis(6,5-borazaro-6-chrysyl) ether (IXd), and into 6,5-borazarochrysene (IXe) itself. The 1-amino-2-phenylnaphthalene was obtained by reduction of 1-nitro-2-phenylnaphthalene, the main nitration product of 2-phenylnaphthalene.[14]

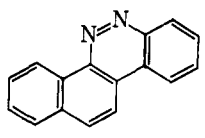


VIII

IXa, R = Cl
b, R = $OCH_3$
c, R = $CH_3$
d, R = 0.5O
e, R = H



X



XI

Conceivably, the 3-phenyl-1,2-borazaroacenaphthylene system (X) might have been formed instead of IX. That this was not the case was shown by the fact that 1-naphthylamine failed to cyclize, and that dibenzo[*c*,*h*]cinnoline (XI) was formed in 35% yield by diazotization of the 6-methoxy derivative in the absence of mineral acid.

Table IV lists ultraviolet spectra of IXe, IXb, and IXc, and also the charge-transfer band of their complexes with tetracyanoethylene.

When the diazotization was carried out in presence of mineral acid, a curious high-melting yellow compound was obtained, with the same empirical formula as IV but subliming only above 300° in a vacuum and soluble only in polar solvents such as dimethylformamide or dimethylsulfoxide.

Dr. E. B. Fleischer has very kindly examined the crystal structure and density of the compound. He found that the unit cell contained the equivalent of four dibenzocinnoline units (mol. wt. 230). A tetrameric structure can be ruled out since the material does sublime in a vacuum above 300°; this could not be the case if it had a molecular weight of 920. It is therefore certain that the compound has approximately the composition of a dimer of dibenzocinnoline, and this was confirmed by a molecular weight determination by freezing point depression of camphorquinone.

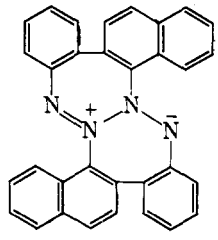
TABLE IV

ULTRAVIOLET MAXIMA AND CHARGE-TRANSFER BANDS OF 6,5-BORAZAROCHRYSENES[a] IN CHLOROFORM

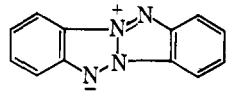
| IXe[b] | IXb | IXc |
|---|---|---|
| 353 (4.04) | 356 (4.05) | 354 (4.11) |
| 337 (3.98) | 339 (4.00) | 338 (4.04) |
| 322 (3.95) | 324 (3.96) | 322 (4.01) |
| 309 (3.98) | 311 (3.97) | 309 (4.01) |
| 276 (4.67) | 278 (4.83) | 277 (4.77) |
| 268 (4.64) | 268 (4.62) | 267 (4.71) |
| | 259 s (4.41) | 258 s (4.51) |
| | 251 (4.31) | |
| 700 | 750 | 730 |
| 495 | 505 | 505 |

[a] $\lambda_{max}$, mμ (log ε). [b] In alcohol-free chloroform.

The structure of this material presents an intriguing problem which one of us (W. H. P.) is at present studying. An attractive possibility is the mesoionic heptalene-like structure (XII), analogous to the pentalene analog (XIII) which Carboni and Castle[15] recently reported.



XII

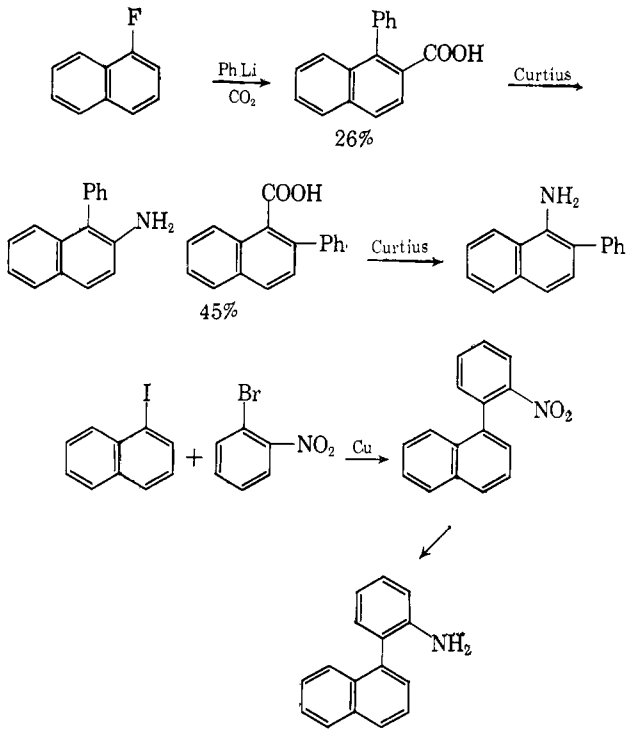


XIII

Our attempts to prepare a borazaro analog of benzo[*c*]phenanthrene met with no success. Apparently cyclization does not take place if the borazarene ring cannot become planar; the phenyl group of 1-phenylnaphthalene is known to be twisted out of the plane of the naphthalene ring[16] (Courtauld models indicate that the angle of twist should be about 40°), and benzo[*c*]phenanthrene is known to be nonplanar.[17]

The routes to the two amines which we tried to cyclize, 1-phenyl-2-naphthylamine and 1-(*o*-aminophenyl)naphthalene, are depicted below. 1-Phenyl-2-naphthylamine had been obtained before by rearrangement of α-phenyl-β-tetralone oxime[18]; it has also been prepared from 2-nitro-1-naphthylamine by a Gomberg reaction[19] and by the action of phenylmagnesium bromide on 1-methoxy-2-benzeneazonaphthalene.[20] 1-(*o*-Aminophenyl)naphthalene is also a known com-

(13) P. F. Holt and A. N. Hughes, *J. Chem. Soc.*, 3218 (1960).
(14) D. H. Hey and S. E. Lawton, *ibid.*, 378 (1940).
(15) R. A. Carboni and J. E. Castle, *J. Am. Chem. Soc.*, **84**, 2453 (1962).
(16) R. A. Friedel, M. Orchin, and L. Reggel, *J. Am. Chem. Soc.*, **70**, 199 (1948); E. Merkel and C. Wiegand, *Naturwissenschaften*, **34**, 122 (1947).
(17) F. H. Herbstein and G. M. J. Schmidt, *J. Chem. Soc.*, 3302 (1954).
(18) H. E. Zaugg, M. Freifelder, and B. W. Horrom, *J. Org. Chem.*, **15**, 1198 (1950); B. Mills and K. Schofield, *J. Chem. Soc.*, 4223 (1956).
(19) D. N. Brown, D. H. Hey, and C. W. Rees, *J. Chem. Soc.*, 3876 (1961).
(20) A. Risaliti, *Ann. Chim.* (Rome), **47**, 1119 (1937); *Chem. Abstr.*, **52**, 6282*f* (1958).




pound.[21] The required nitrophenylnaphthalene was obtained by the method reported recently by Forrest.[22]

## Experimental

**4-Keto-1,2,3,4-tetrahydrophenanthrene Azine.**—A mixture of 4-keto-1,2,3,4-tetrahydrophenanthrene[23] (10 g.), hydrazine hydrate (1.3 ml. of 95%), ethanol (30 ml.), and concentrated hydrochloric acid (3 drops) was refluxed overnight. The red precipitate of the **azine** (*ca.* 100%) was collected, washed with ethanol, and dried, m.p. 195–200°. A sample crystallized from ethyl acetate in small red needles, m.p. 203.5–204.2°.

*Anal.* Calcd. for $C_{28}H_{24}N_2$: C, 86.56; H, 6.23; N, 7.21. Found: C, 86.54; H, 6.38; N, 7.51.

**4-Phenanthrylamine.**—To a solution of 4-keto-1,2,3,4-tetrahydrophenanthrene azine (7.8 g.) in hot triethylbenzene (30 ml.) was added (through the air condenser) palladized charcoal (1.6 g. of 10%); the mixture was refluxed for exactly 30 min. The cold solution was filtered, the residue was extracted with hot benzene (30 ml.) and an equal volume of petroleum ether (b.p. 60–68°) was added to the combined filtrates. The solution was poured on an alumina column (Merck, 60 × 2 cm., deposited in benzene), and the triethylbenzene was washed out with petroleum ether; the column was developed with benzene–petroleum ether, first 1:1 then 3:1, and finally eluted with benzene and benzene–ethyl acetate, fractions being taken. The brown solids obtained on evaporation of the fractions were combined, the red oil in the first fractions being omitted. They were evaporated and the residues were combined and sublimed at 90° (0.1 mm.), giving white 4-aminophenanthrene (2.85 g., 37%), m.p. 60–63° raised by recrystallization from petroleum ether (b.p. 60–68°) to 64.0–64.5° (lit.[7] m.p. 55°). The acetyl derivative after crystallization from petroleum ether (b.p. 90–100°) had m.p. 200–201°, lit.[7] m.p. 203–204°. The compounds were identical (infrared spectrum) with those prepared by the earlier[6,7] procedures.

**5-Methoxy-5,4-borazaropyrene.**—A solution of 4-phenanthrylamine (3.70 g.) in dry xylene (60 ml.) was added slowly with stirring to an ice-cooled solution of boron trichloride (2.5 g.) in dry xylene (15 ml.). Anhydrous aluminum chloride (0.1 g.) was then added, and the temperature was raised over 4 hr. to 140° and held there overnight in a current of dry nitrogen. The cold solution was taken up in a mixture of ether (150 ml.) and benzene (80 ml.), washed with water, dried ($MgSO_4$), and evaporated on a steam bath. The residue was dissolved in hot absolute methanol (200 ml.); the solution was concentrated to *ca.* 50 ml., and kept in a freezer (−15°). The treatment with methanol was repeated (charcoal) giving 2.56 g. (57%) of **5-methoxy-5,4-borazaropyrene** as yellowish leaflets. After a third crystallization in an efficient dry box, it had m.p. 143–145° (evacuated capillary).

*Anal.* Calcd. for $C_{15}H_{12}BNO$: C, 77.29; H, 5.19; N, 6.01. Found: C, 77.22; H, 5.49; N, 5.84.

**5-Methyl-5,4-borazaropyrene.**—Methylmagnesium bromide (15 ml. of 0.6 *M* solution in ether) was added to an ice-cold solution of 5-methoxy-5,4-borazarophenanthrene (1.5 g.) in dry ether (60 ml.). The mixture was stirred for 2 hr., first at 0°, then at room temperature. After the precipitate had settled, the solution was filtered into a sublimator and evaporated. The residue was sublimed at 140° (0.001 mm.), giving **5-methyl-5,4-borazaropyrene** (1.1 g., 79%), m.p. 145°, raised to 155–156.5° by recrystallization (charcoal) from petroleum ether (b.p. 90–100°) as small white plates.

*Anal.* Calcd. for $C_{15}H_{12}BN$: C, 82.99; H, 5.57. Found: C, 82.98; H, 5.73.

**5,4-Borazaropyrene.**—A solution of lithium aluminum hydride (1 mmole) in ether was added to one of 5-methoxy-5,4-borazaropyrene (0.90 g., 3.86 mmoles) in ether (30 ml.) at 0°. Aluminum chloride (0.04 g.) then was added, and the mixture was refluxed for 2 hr. The solution was allowed to stand until the precipitate had settled and then was filtered under nitrogen, evaporated, and the residue sublimed at 120° (0.005 mm.), giving **5,4-borazaropyrene** (0.50 g., 64%) which after resublimation had m.p. 129–130° (sintered at 122°).

*Anal.* Calcd. for $C_{14}H_{10}BN$: C, 82.81; H, 4.96. Found: C, 82.42; H, 4.50.

**Bis(9,10-dihydro-5,4-borazaro-5-pyrenyl) Ether. A. Nitration of 9,10-Dihydrophenanthrene.**—A mixture of fuming nitric acid (110 ml., *d* 1.5) and acetic anhydride (325 ml.) was added dropwise to a stirred solution of 9,10-dihydrophenanthrene (450 g.) in acetic anhydride (2.2 l.) at 25°. After 20 hr., the solution was concentrated *in vacuo* (distillate, 1.5 l.) and added slowly to boiling water (6 l.). The crude product (307 g.) was isolated with benzene and freed from starting material and tar by chromatography from petroleum ether–benzene (1:1) on alumina.

**B. Reduction of the Crude Product.**—Hydrazine hydrate (300 ml.) was added gradually to a boiling solution of the crude product (307 g.) in ethanol (6.3 l.) containing palladized charcoal (3 g. of 10%). After 5 hr., the solution was filtered and distilled giving a mixture of aminodihydrophenanthrenes (176 g.), b.p. 152–65° (0.04 mm.).

**C. Cyclization.**—A solution of the mixed amines (40 g.) in dry xylene (600 ml.) was added slowly to a stirred solution of boron trichloride (28.8 g.) in dry xylene (200 ml.) at 0°. Aluminum chloride (0.1 g.) then was added and dry nitrogen was passed through the mixture while the temperature was raised over 4 hr. to 140° and held there overnight. The cold mixture then was stirred for 24 hr. with dilute hydrochloric acid and the organic layer was washed, dried, and evaporated. The residue was boiled with ethanol and ethyl orthoformate and then distilled in a vacuum. The fraction, b.p. 155° (0.06 mm.), was dissolved in boiling acetic acid and water was added until cloudy; the mixture was allowed to cool to 50°, decanted from the oil, and left to crystallize. The process was repeated with oil and filtrate until no more solid could be isolated. The combined solids were crystallized from petroleum ether (300 ml., b.p. 60–68°) in a Soxhlet, giving **bis(9,10-dihydro-5,4-borazaro-5-pyrenyl) ether** (5.16 g., 11.4% on mixed amines), m.p. 223° after recrystallization from petroleum ether (charcoal, b.p. 90–100°).

*Anal.* Calcd. for $C_{28}H_{22}B_2N_2O$: C, 79.29; H, 5.23; N, 6.61. Found: C, 78.92; H, 5.24; N, 6.67.

**5-Methoxy-9,10-dihydro-5,4-borazaropyrene.**—A solution of bis(9,10-dihydro-5,4-borazaro-5-pyrenyl) ether (3.5 g.) in absolute methanol (200 ml.) was boiled under reflux for 4 hr., then concentrated to *ca.* 100 ml. and kept in a freezer (−20°) overnight. The precipitate was collected and recrystallized from methanol (charcoal), giving **5-methoxy-5,4-borazaropyrene** as leaflets, m.p. 135–136° (evacuated capillary).

*Anal.* Calcd. for $C_{15}H_{14}BNO$: C, 76.63; H, 6.00; N, 5.96. Found: C, 76.39; H, 6.12; N, 6.08.

The combined filtrates were concentrated giving another crop of the compound; the over-all yield was 2.5 g., 65%.

**5-Methyl-9,10-dihydro-5,4-borazaropyrene.**—Methylmagnesium bromide (13 ml. of 0.7 *M* solution in ether) was added to a solution of 5-methoxy-9,10-dihydro-5,4-borazaropyrene (1.45 g.)

(21) J. Forrest and S. H. Tucker, *J. Chem. Soc.*, 1139 (1948).
(22) J. Forrest, *ibid.*, 589 (1960).
(23) R. D. Haworth, *ibid.*, 1129 (1932); E. L. Martin, *J. Am. Chem. Soc.*, **58**, 1441 (1936).

in dry ether (60 ml.) at 0°. After stirring 2 hr., first at 0° and then at room temperature, and then allowing the precipitate to settle, the solution was filtered and evaporated; the residue sublimed at 110° (0.005 mm.), giving **5-methyl-9,10-dihydro-5,4-borazaropyrene** (0.86 g., 60%), m.p. 99.5–101.3° (after resublimation).

*Anal.* Calcd. for $C_{15}H_{14}BN$: C, 82.23; H, 6.44; N, 6.39. Found: C, 82.55; H, 6.52; N, 6.70.

**Bis(5,4-borazaro-5-pyrenyl) Ether.**—A mixture of bis(9,10-dihydro-5,4-borazaro-5-pyrenyl) ether (2.66 g.), palladized charcoal (0.25 g. of 10%), benzene (12.5 ml.), and hexene (25 ml.) was heated in a sealed tube at 265° for 20 hr., giving crude bis(5,4-borazaro-5-pyrenyl) ether (2.34 g., 89%), m.p. *ca.* 240°. Recrystallization from toluene gave colorless leaflets, m.p. 246–247°.

*Anal.* Calcd. for $C_{28}H_{18}B_2N_2O$: C, 80.05; H, 4.32; N, 6.67. Found: C, 79.87; H, 4.50; N, 7.10.

The compound was converted to 5-methoxy-5,4-borazaropyrene, identical (mixture melting point and infrared spectrum) with the material obtained previously by recrystallization from absolute methanol. This in turn was converted as before to 5-methyl-5,4-borazaropyrene, identical (mixture melting point and infrared spectrum) with an authentic sample.

**Action of Nitrous Acid on 5-Hydroxy-5,4-borazaropyrene. A.**—Concentrated hydrochloric acid (2.5 ml.) was added to a hot solution of 5-methoxy-5,4-borazaropyrene (0.47 g.) in acetic acid (10 ml.), and the mixture was cooled to 4°. A solution of sodium nitrite (0.15 g.) in a little water was added below 6° and after 3 hr. a solution of sodium acetate (7.0 g. of $C_2H_3O_2Na \cdot 3H_2O$) in water (15 ml.) was added below 8°. Chromatography of the boron-free precipitate from benzene on alumina gave no 4,5-diazapyrene.

**B.**—The experiment was repeated with the difference that the compound was dissolved in a mixture (1:1, 20 ml.) of acetic and propionic acids, the sodium nitrite was added as a solid, and the sodium acetate was omitted. Chromatography of the product as before gave a small amount (9 mg., 2% calcd. as diazapyrene) of material with an ultraviolet spectrum consistent with 4,5-diazapyrene ($\lambda_{max}$ in chloroform: 385, 367, 305, 289, and 280 s mμ; $\lambda_{max}$ in methylcyclohexane: 379, 372, 355, 350 s, 342 s, 303, 285, 281 s, 276, and 235 mμ). The main product formed a yellow band on the alumina column; this could not be eluted, even with ethyl acetate.

**Action of Nitrous Acid on 5-Hydroxy-9,10-dihydro-5,4-borazaropyrene.**—The reaction, carried out as under B above, failed to give any identifiable product.

**1-Amino-2-phenylnaphthalene.**—Palladized charcoal (2 g. of 10% was added to a solution of 1-nitro-2-phenylnaphthalene[14] (19 g.), m.p. 128.5–130°, lit. m.p. 127°, in boiling ethanol (570 ml.). Hydrazine hydrate (19 ml.) was added slowly and the mixture was boiled 1 hr. After filtering the catalyst and concentrating the solution, the amine (15.7 g., 94%) which separated was collected, washed with water, and dried, m.p. 103.5–105°, lit.[14] m.p. 104°.

**6-Methoxy-6,5-borazarochrysene.**—A solution of 1-amino-2-phenylnaphthalene (15.7 g.) in dry xylene (150 ml.) was added slowly with stirring to an ice-cold solution of boron trichloride (10 g.) in dry xylene (650 ml.). Anhydrous aluminum chloride (0.1 g.) then was added; the temperature was raised during 4 hr. to 140° and held there overnight while the hydrogen chloride that formed was swept away with dry nitrogen. The cold solution was taken up in a mixture of ether (600 ml.) and benzene (250 ml.), washed with water, dried ($MgSO_4$), and evaporated on a steam bath in a hood. The residue was refluxed with absolute methanol (750 ml.) and the solution was concentrated and kept in a freezer (−20°). The treatment with methanol (charcoal) was repeated with the residue, giving **6-methoxy-6,5-borazarochrysene** (9.2 g., 50%), m.p. 106–108°.

A sample was recrystallized from absolute methanol (charcoal), m.p. 108–110°. It was necessary to filter and handle the crystals in a dry box.

*Anal.* Calcd. for $C_{17}H_{14}BNO$: C, 78.80; H, 5.45; N, 5.41. Found: C, 78.84; H, 5.60; N, 5.35.

**Bis(6,5-borazaro-6-chrysyl) Ether.**—The product of another cyclization, instead of being refluxed with methanol, was recrystallized from toluene (charcoal) until the filtrate was colorless, giving the **ether** as a white powder, m.p. 288–290.5°.

*Anal.* Calcd. for $C_{32}H_{22}B_2N_2O$: C, 81.40; H, 4.70; N, 5.93. Found: C, 81.56; H, 5.00; N, 5.89.

**6-Methyl-6,5-borazarochrysene.**—To a stirred solution of 6-methoxy-6,5-borazarochrysene (2.6 g.) in dry ether (100 ml.) was added dropwise at room temperature a solution of methylmagnesium bromide (15 ml. of 1 *M*) in ether. A white precipitate of methoxymagnesium bromide formed immediately. Stirring was continued for 2 hr., and the precipitate then was left to settle, filtered, and washed with dry ether. The filtrate was diluted with ether, shaken with water, and dried ($MgSO_4$); the solvent was removed on a steam bath. The raw product was sublimed at 145° (0.0005 mm.), giving white microcrystals (1.08 g., 45%) of **6-methyl-6,5-borazarochrysene**, decomposing above 150°, depending on the rate of heating.

*Anal.* Calcd. for $C_{17}H_{14}BN$: C, 83.98; H, 5.80. Found: C, 84.08; H, 5.62.

**6,5-Borazarochrysene.**—To a stirred suspension of 6-methoxy-6,5-borazarochrysene (1.00 g., 3.86 mmoles) in dry ether (40 ml.) was added at 0° a solution of lithium aluminum hydride in ether (1.38 mmoles) followed by anhydrous aluminum chloride (0.045 g., 0.45 mmole). The mixture was refluxed for 2 hr., the precipitate was left to settle, and the solution was filtered under dry nitrogen into a sublimator. The ether was distilled and the residue sublimed at 120° (0.005 mm.), giving **6,5-borazarochrysene** (0.54 g., 61%) which after sublimation formed a white powder, m.p. 193–195° dec. (sintered at 170°) with moderately rapid heating.

*Anal.* Calcd. for $C_{16}H_{12}BN$: C, 83.88; H, 5.28. Found: C, 83.87; H, 5.22.

The residue from the second sublimation proved to be bis(6,5-borazaro-6-chrysyl) ether.

**Attempted Synthesis of 1-Chloro-1,2-borazaroacenaphthylene.**—A solution of 1-naphthylamine (15.5 g.) in dry xylene (350 ml.) was added slowly with stirring to an ice-cold solution of boron trichloride (14.4 g.) in dry xylene (100 ml.). Anhydrous aluminum chloride (0.1 g.) then was added and the temperaure was raised over 4 hr. to 140° and held there overnight while the hydrogen chloride formed was swept away with dry nitrogen. The cold reaction mixture was poured into ether–benzene (1500 ml., 2:1) and washed twice with water (3000 ml.) when the precipitate of 1-naphthylamine hydrochloride (identified by infrared spectroscopy) dissolved. The organic layer was dried ($MgSO_4$) and evaporated to dryness on a steam bath in a hood. The residue (4.4 g.) was refluxed with absolute methanol (250 ml.) and the solvent was evaporated. The residue contained no boron and consisted of 1-naphthylamine (identified by infrared spectroscopy).

**Action of Nitrous Acid on 6-Methoxy-6,5-borazarochrysene. A.**—Concentrated hydrochloric acid (5 ml.) was added to a solution of 6-methoxy-6,5-borazarochrysene (1 g.) in hot acetic acid (20 ml.) and the mixture was cooled to 4° with vigorous stirring to produce a fine precipitate. Sodium nitrite (0.30 g.) in a little water was added with stirring below 6°, and the dark green solution was kept at 0° overnight, when the color disappeared. Sodium acetate (14 g. of trihydrate) in water (30 ml.) was added below 8°, stirring was continued for 1 hr., and the precipitate then was filtered. Extraction with carbon tetrachloride gave a yellow-brown residue (0.52 g. 56% calcd. as dimer) which after crystallization from dimethylformamide had m.p. >300°; ultraviolet–visible spectrum, $\lambda_{max}$ (log ε) in EtOH: 380 (3.75), 361 s (3.90), 343 (4.05), 306 (3.85), 276 s (4.52), 264 (4.69), and 257 mμ (4.65); in $H_2SO_4$: 449 (4.42), 354 (3.85), and 268 mμ (4.98); infrared spectrum, ν (cm.$^{-1}$): 695 w, 708 w, 766 s, 770 s, 782 s, 790 m, 277 m, 925 w, 1015 w, 1082 m, 1093 w, 1120 w, 1140 m, 1275 m, 1322 m, 1358 m, 1380 m, 1407 m, 1440 w, 1460 w, 1550 s, 1508 m, 1575 m, and 3070 m.

*Anal.* Calcd. for $C_{32}H_{20}N_4$: C, 83.45; H, 4.38; N, 12.17. Found: C, 83.43; H, 4.27; N, 12.42; mol. wt., *ca.* 400 (in camphorquinone).

The compound could be recrystallized from dimethylformamide, dimethyl sulfoxide, or ethylene glycol; in the last solvent it was very sparingly soluble, but separated in tiny yellow plates, monoclinic, $a = 22.02$, $b = 6.36$, $c = 7.40$, $\beta = 98°45'$, density (measured) = 1.49 g./cm.$^3$, mol. wt. (calculated)/unit cell 919.

**B.** A solution of 6-methoxy-6,5-borazarochrysene (1 g.) in a hot mixture of acetic acid (10 ml.) and propionic acid (10 ml.) was cooled to 4° with stirring and solid sodium nitrite (0.30 g.) was added. Next day water was added and the solid (0.895 g.) was collected, dried, and extracted with benzene. The extract was chromatographed on alumina, the bands being eluted with benzene–ethyl acetate, first 9:1, then 7:1, and finally 5:1. The second (greenish yellow) band consisted of dibenzo[*c,h*]cinnoline (0.31 g., 34%), identified by melting point, mixture melting

point, and comparison of the infrared spectrum with that of an authentic sample prepared by electrolytic reduction[4] of *o*-(nitrophenyl)-1-nitronaphthalene. The residue from the extraction was identical with the main product obtained under A.

**1-Phenyl-2-naphthoylhydrazide.**—Methyl 1-phenyl-2-naphthoate (24.64 g.)[24] was refluxed with hydrazine hydrate (36 ml.) for 24 hr. with stirring. The resulting **hydrazide** crystallized from ethanol as a white powder (19.4 g., 79%) which after recrystallization had m.p. 189–190.5°.

*Anal.* Calcd. for $C_{17}H_{14}N_2O$: C, 77.84; H, 5.38; N, 10.69. Found: C, 77.99; H, 5.50; N, 10.90.

**Ethyl 2-(1-Phenylnaphthyl)carbamate.**—1-Phenyl-2-naphthoylhydrazide (19.6 g.) was added portionwise over 2 hr. at 5° to a stirred solution of nitrosyl chloride (4.9 g.) in dry ethanol (330 ml.). The solution was stirred at 5° for another hour, then refluxed overnight. Water (35 ml.) was added and the hot solution was left to cool in a freezer (−15°) when crystals of the **carbamate** (17.8 g., 81%) separated. After two recrystallizations from 90% ethanol it had m.p. 112–6–112.8°.

(24) R. Huisgen and H. Rist, *Ann.*, **594**, 151 (1955).

*Anal.* Calcd. for $C_{19}H_{17}NO_2$: C, 78.33; H, 5.88. Found: C, 78.20; H, 6.05.

**1-Phenyl-2-naphthylamine.**—Ethyl 2-(1-phenylnaphthyl)-carbamate (17.8 g.) was refluxed for 10 hr. with alcoholic potassium hydroxide (260 ml. of ethanol, 8.4 g. of potassium hydroxide). The amine was precipitated by addition to water (1 l.) affording 13.4 g. (100%) of a product with m.p. 94–102°. Recrystallization (charcoal) from petroleum ether (b.p. 60–68°) gave the pure amine, m.p. 95–96°, lit.[10-12] m.p. 94 and 96°.

**Attempted Preparation of 5-Chloro-5,6-borazarobenzo[*c*]-phenanthrene.**—The cyclization of 1-phenyl-2-aminonaphthalene was attempted in the same way and with the same lack of success as that of 1-naphthylamine.

**Attempted Preparation of 6-Chloro-6,5-borazarobenzo[*c*]phenanthrene.**—1-(*o*-Nitrophenyl)naphthalene was prepared from 1-iodonaphthalene and *o*-bromonitrobenzene,[22] m.p. 94–96°, lit.[21] m.p. 90–92° and 93–94°. 1-(*o*-Aminophenyl)naphthalene was obtained from the nitro compound (21.5 g.) by catalytic (palladium-charcoal 10%) reduction in absolute ethanol (475 ml.) under 50 lb./sq. in. initial pressure, m.p. *ca.* 62°, lit.[21] m.p. 65°. The cyclization of 1-(*o*-aminophenyl)naphthalene was attempted in the same way, and with the same lack of success, as that of 1-naphthylamine.

# Pyrimidines. III. A Novel Rearrangement in the Syntheses of Imidazo- or Pyrimido[1,2-*c*]pyrimidines[1]

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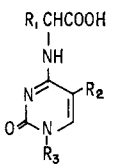
Pyrimidinylamino acids [*e.g.*, N-(1H-2-oxo-4-pyrimidinyl)-β-alanine (**1**)], when treated with acetic anhydride, cyclize with rearrangement to 2-oxopyrimido- or 2-oxoimidazo[1,2-*c*]pyrimidines (*e.g.*, **2**, **15**, **23**, and **30**). This novel rearrangement occurs with pyrimidinyl-α or -β simple amino acid derivatives. A mechanism is given which involves the cleavage of the $C^2$–$N^3$ linkage of the pyrimidine ring of **1** with the formation of an amide linkage between the carboxyl group of the amino acid moiety and $N^3$ to form B. Recyclization occurs between $C^2$ and $N^4$ of intermediate B to furnish **2**. The presence of a hydrogen on $N^1$ of the pyrimidinyl amino acids is essential for the rearrangement. $N^1$-Alkylated pyrimidinyl amino acids do not undergo the rearrangement; instead other reactions predominate. γ-Amino acid derivatives yield N-4-pyrimidinylbutyrolactams (**35**).

In a previous paper in another series,[2] the preparation of a number of pyrimidinylamino acids and their nucleosides of the general structure shown in Chart I

CHART I




was reported as part of our program in the synthesis of compounds of potential biochemical interest. During this investigation, the reactions of the β-alanyl derivative **1** with several reagents, particularly with acetic anhydride, were studied. The present paper deals with an interesting rearrangement which led to a general investigation into the reactions of pyrimidinylamino acids with acetic anhydride.

Treatment of N-(1H-2-oxo-4-pyrimidinyl)-β-alanine (**1**) with acetic anhydride could yield several possible products, among them the $N^4$-acetyl derivative of the mixed anhydride of **1** (Chart II). Such a compound would be expected to cyclize with the loss of acetic acid to form **3**, 1H-1,2,3,4-tetrahydro-4,6-dioxopyrimido[1,2-*c*]pyrimidine or its $N^1$-acetyl derivative. When **1** was refluxed with acetic anhydride, a 70% yield was obtained of a product with an elemental analysis in accord with **3**. The ultraviolet spectrum of this product differed from **1**, as expected. If this product is **3**, hydrolysis with acid or alkali should regenerate **1**, since it has been reported that ring acylated purines[3] or pyrimidines[4,5] (*e.g.*, 1,3,4-tribenzoylcytosine)[4] regenerate to their parent compounds under hydrolytic conditions.

Mild acid or alkaline hydrolysis of the product obtained from the reaction of **1** with acetic anhydride did not regenerate **1**. Instead, a new product was obtained which was proved to be 3-(2-carboxyethyl)cytosine (**4**) by ultraviolet absorption studies[6,7] (similarity to 3-methylcytosines) and by further alkaline hydrolysis of **4**

(1) This investigation was supported in part by funds from the National Cancer Institute, National Institutes of Health, U. S. Public Health Service (Grant No. CA 03190-07). A preliminary report of this work has appeared in the Abstracts of the 144th National Meeting of the American Chemical Society, Los Angeles, Calif., April, 1963, p. 39L. For part II of this series, see I. Wempen and J. J. Fox, *J. Med. Chem.*, **7**, 207 (1964).

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