appears at m/e 52 corresponding to $C_4H_4^+$. In the mass spectrum of IV, however, the m/e peak of 52 appears as the strongest peak. This peak is absent from the spectrum of N-methyl 2-pyridone (which evidently fragments to N-methylpyrrole and cyclopropenyl cations). The species $C_4H_4^+$ produced from IV by electron impact could well be the cyclobutadiene radical cation.

TABLE I

Compound	m/e (relative intensity)[a]
I	96(25), 68(58), 39(100), 29(25)
IV	109(15), 81(35), 52(100), 42(35), 39(30), 15(25)
N-Methyl-2-pyridone	109(100), 81(65), 42(38), 39(48)

[a] Intensity of strongest peak taken as 100; only peaks of intensity 25 are included.

The possibility of internal photoaddition reactions of 2-pyrones and 2-pyridones evidently has not been investigated seriously even though irradiations of both types of compounds have been reported.[10,11] We are currently extending these studies to related systems in addition to the heterocycles discussed above.[12]

(10) The irradiation of 4,6-dimethyl-2-pyrone in methanol solution affords methyl β-acetonylcrotonate, a reaction which has been interpreted as a cycloelimination proceeding *via* a ketene intermediate [P. de Mayo, "Advances in Organic Chemistry," Vol. II, Interscience Publishers, New York, N. Y., 1960, p. 394]. The intermediacy of a bicycle β-lactone would seem to be a reasonable alternative in view of our results.

(11) For the photodimerization of N-methyl-2-pyridone see: (a) E. C. Taylor and R. O. Kan, *J. Am. Chem. Soc.*, **85**, 776 (1963); (b) L. A. Paquette and G. Slomp, *ibid.*, **85**, 795 (1963); (c) W. A. Ayer, R. Hayatsu, P. de Mayo, and J. B. Stothers, *Tetrahedron Letters*, **No. 18**, 648 (1961); and (d) earlier papers by these authors.

(12) This work was supported by the National Institutes of Health.

(13) N. A. T. O. Postdoctoral Research Fellow.

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The Reductive Alkylation of Quinones with Trialkylboranes

Sir:

In the past, alkyl hydroquinones have been prepared through routes which involved the reaction of quinones with acyl peroxides[1] or electrophilic acylation[2] and alkylation[3,4] of hydroquinones. We wish to report a new method for the preparation of alkyl hydroquinones from 1,4-benzoquinone and the corresponding trialkylboranes. The latter materials may be conveniently prepared by the hydroboration of alkenes.[5] The reductive alkylation reactions are strongly exothermic and virtually quantitative. Triphenylborane did not react with 1,4-benzoquinone and triarylboranes may prove to be generally ineffective.

In all cases 0.10 mole of 1,4-benzoquinone dissolved in diethyl ether was added under nitrogen to a solution of 0.11 mole of trialkylborane in the same solvent at the reflux temperature. The trialkylboranes employed were crude products obtained by hydroboration[5] of the proper olefin. Following the addition (30 min.) the reaction mixture was maintained at the reflux temperature for 30 min. The reaction mixture was then steam distilled to remove solvent, boronic and borinic acids, and unused reagents. On cooling, the alkyl hydroquinone separated as a crystalline mass in the steam distillation flask. Each hydroquinone was characterized by conversion to the dibenzoate and corresponding 2-alky-1,4-benzoquinone. New compounds gave satisfactory elemental analyses. Yields and characterization data are presented in Table I.

TABLE I

Alkyl group	Crude yield, %	Hydroquinone, m.p., °C.	Quinone, m.p., °C.	Dibenzoate, m.p., °C.
1-Butyl	86	87–87.5[b]	34–35	97–98
1-Hexyl	98.5	84–84.5[b]	48–49	53–54
Cyclohexyl	99	163–165 (0.4)[a]	53–54[c]	106–108
2-Methylpropyl	91	111.5–112	35–36	120.5–121
2-Butyl	94	100–101	66 (1.0)[a]	92–93
Cyclooctyl	91	160–160.5	43.5–44.5	123–126
Benzyl	90	101–103[d]		151–153

[a] B.p. (mm.), °C. [b] J. Renz [*Helv. Chim. Acta*, **30**, 124 (1947)] reports m.p. 84–85° (1-butyl) and m.p. 79–80° (1-hexyl). [c] L. F. Fieser [*J. Am. Chem. Soc.*, **70**, 3165 (1948)] reports m.p. 53.5–54.5°. [d] R. Stolle and W. Moring [*Ber.*, **37**, 3486 (1904)] report m.p. 105°.

The reactions of representative trialkylboranes with other quinones and a mechanism study will be reported elsewhere.

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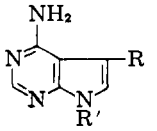
Synthesis of 4-Amino-5-cyanopyrrolo[2,3-*d*]pyrimidine, the Aglycone of Toyocamycin[1]

Sir:

Two closely related antibiotics, Tubercidin (Ia) and Toyocamycin (IIa), have recently been reported from Japan and are the first naturally occurring derivatives of the pyrrolo[2,3-*d*]pyrimidine (7-deazapurine)



Ia, R = H; R′ = β-D-ribose
Ib, R = R′ = H
IIa, R = CN; R′ = D-ribose
IIb, R = CN, R′ = H

ring system. Tubercidin, first isolated by Anzai, Nakamura, and Suzuki,[2] was shown to possess structure Ia on the basis of degradation studies,[3–6] which led to the known 4-aminopyrrolo[2,3-*d*]pyrimidine (Ib).[7] It is active against *Mycobacterium tuberculosis* B.C.G. and *Candida albicans* and is reported to have strong antitumor activity.[2] Toyocamycin, isolated in crystalline form from a species of *Streptomyces*[8] and from the

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(5) Y. Mizuno, M. Ikehara, K. Watanabe, and S. Suzaki, *Chem. Pharm. Bull.* (Tokyo), **11**, 1091 (1963).

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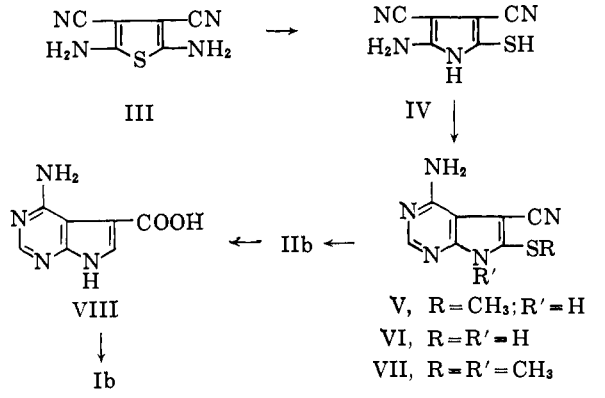
soil near Fuji City, Shizuoka Prefecture,[9] is reported to be active against *Mycobacterium tuberculosis* $H_{37}Rv$ and *Candida albicans*.[8] It has been shown to have structure IIa on the basis of spectral evidence and degradation.[9,10] Tubercidin has not been synthesized,[5,11] even though its aglycone Ib is a known compound.[7] The aglycone IIb of Toyocamycin is not known; it was not prepared from the antibiotic and has not been synthesized, presumably because the only previously available synthetic route to pyrrolo[2,3-*d*]pyrimidines, that discussed by Davoll[7] *via* pyrimidine intermediates, is not applicable to the preparation of 4-amino-5-cyanopyrrolo[2,3-*d*]pyrimidine (IIb).

We wish to describe in this communication a simple synthesis of the pyrrolo[2,3-*d*]pyrimidine ring system utilizing *pyrrole* intermediates which has permitted the preparation of the aglycones Ib and IIb of both antibiotics.[12]

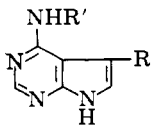
Tetracyanoethylene was converted by the action of hydrogen sulfide to 2,5-diamino-3,4-dicyanothiophene (III), which was rearranged with alkali to 5-amino-3,4-dicyano-2-mercaptopyrrole (IV) as described by Middleton, *et al.*[13] Treatment of IV with methyl orthoformate followed by alcoholic ammonia gave 4-amino-5-cyano-6-methylmercaptopyrrolo[2,3-*d*]pyrimidine[14] [V, m.p. 317–318° dec., 57% yield, $\lambda_{max}^{C_2H_5OH}$ 231 mμ (ε 16,500) and 301 (17,600); infrared, CN band at 2225 cm.$^{-1}$]. Desulfurization of V with Raney nickel[15] in aqueous ammonium hydroxide then gave 4-amino-5-cyanopyrrolo[2,3-*d*]pyrimidine [IIb, m.p. > 360°, 35% yield; $\lambda_{max}^{C_2H_5OH}$ 226 mμ (ε 10,700), 277 (13,700), 287 (9750)[16]; infrared, CN band at 2225 cm.$^{-1}$], the aglycone of Toyocamycin.

Alternatively, refluxing IV with formamidine acetate[17] in 2-ethoxyethanol gave 4-amino-5-cyano-6-mercaptopyrrolo[2,3-*d*]pyrimidine (VI), which was characterized as its 6,7-dimethyl derivative (VII, m.p. 315–317° dec.) by treatment with methyl iodide and alkali. Analogous methylation of V also gave VII. Raney nickel desulfurization of VI then gave IIb.

Confirmation of the structure of IIb was obtained by hydrolysis with 6 *N* hydrochloric acid to the corresponding 5-carboxylic acid [VIII, m.p. (as hydrochloride salt) 286–287° dec.; $\lambda_{max}^{0.1\ N\ HCl}$ 228 mμ (ε 10,380), 240 sh. (9050), 274 (11,120); $\lambda_{max}^{0.1\ N\ NaOH}$ 226 mμ (ε 10,280), 259 (9480), 280 (10,950)], followed by decarboxylation of its copper salt in quinoline[18] at 210° to give the known 4-aminopyrrolo[2,3-*d*]pyrimidine (Ib),[4,7] the aglycone of Tubercidin. This degradation of IIb thus constitutes an independent synthesis of Ib.



We wish to report at this time another but related pyrrolo[2,3-*d*]pyrimidine synthesis *via* pyrrole intermediates. The condensation of aminoacetone and of ω-aminoacetophenone (as representative examples of α-aminoketones) with malononitrile to give 5-amino-4-cyano-3-methyl- and 3-phenylpyrrole has recently been reported by Gewald.[19] We have found that these *o*-aminonitriles can be converted to 4-amino-5-methylpyrrolo[2,3-*d*]pyrimidine (IX, m.p. 257–258°, 50% yield) and 4-amino-5-phenylpyrrolo[2,3-*d*]pyrimidine (X, m.p. 259–261°, 35% yield), respectively, by initial reaction with ethyl orthoformate to give the 5-ethoxymethyleneamino derivatives, followed by treatment with alcoholic ammonia to give the 4-cyano-5-formamidino derivatives and final cyclization with sodium methoxide in methanol. Several 4-substituted amino derivatives of 5-methyl- and 5-phenylpyrrolo-[2,3-*d*]pyrimidine were prepared directly by reaction of the above 5-ethoxymethyleneamino intermediates with primary amines[20] (XI, m.p. 250–251.5°, 35% yield; XII, m.p. 124–127°, 19% yield; XIII, m.p. 286.5–288°, 38% yield). It would appear that appropriate combinations of the above two synthetic routes should make readily available a wide variety of 4-aminopyrrolo[2,3-*d*]pyrimidines structurally related to Tubercidin and Toyocamycin.



IX, R = CH_3; R' = H
X, R = C_6H_5; R' = H
XI, R = R' = CH_3
XII, R = CH_3; R' = $(CH_2)_3N(CH_3)_2$
XIII, R = C_6H_5, R' = CH_3

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Free-Radical Phenylation of Ferricenium Ion

Sir:

Although it is generally conceded that phenyl radicals are produced during interaction of ferrocene and benzenediazonium salts[1–5] there is a diversity of opinion as to the precise mechanism of the phenylation reaction. Several groups of workers[2,4,6] have supported Pauson's suggestion[1] that ferricenium ion and phenyl radicals are formed by an electron-transfer reaction as follows (FcH = ferrocene).

$$FcH + PhN_2^+ \longrightarrow FcH^+ + PhN_2\cdot \quad (1)$$

$$PhN_2\cdot \longrightarrow Ph\cdot + N_2 \quad (2)$$

However, the accompanying hypothesis[1] that free

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