1158. *The Structure and Reactions of Some Pyrrolin-2-ones.*

By J. H. Atkinson, R. S. Atkinson, and A. W. Johnson.

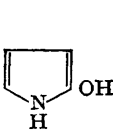
The spectra, particularly nuclear magnetic resonance spectra, of the alkylpyrrolin-2-ones confirm that they contain a Δ^3-double bond but that the 4-ethoxycarbonylpyrrolin-2-ones have the double bond in the Δ^4-position. Several of the earlier structures suggested for the halogenation products of the pyrrolin-2-ones have been revised. A number of condensation reactions of the pyrrolin-2-ones and of the halogenation products are described.

The structure and chemistry of the pyrrolinones has attracted interest for some time as they form the terminal rings of the bile pigments and they have been used extensively in syntheses of bile pigments and related compounds.[1] Hans Fischer[2] regarded the compounds as 2-hydroxypyrroles (I) and nearly all compounds containing this ring system were formulated

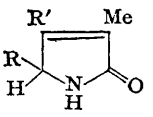
[1] H. Fischer and H. Orth, "Die Chemie des Pyrrols," Akademische Verlag, Leipzig, 1937, vol. II Part I, p. 621; H. Fischer and H. Plieninger, *Z. physiol. Chem.*, 1942, **274**, 231.
[2] H. Fischer and H. Orth, "Die Chemie des Pyrrols," 1937, vol. I, p. 124.

in this manner, although he clearly recognised the possibility of tautomerism and indeed used the cyclic amide structures to formulate certain phases in the Gmelin reaction of bile pigments.[3] Since the war, an overwhelming weight of evidence has been adduced for the existence of the terminal rings of the bile pigments in the pyrrolinone form.[4]

Parallel studies on the simple monocyclic pyrrolinones or 2-hydroxypyrroles have left little doubt that they, too, exist very largely in the cyclic amide form, although the remaining endocyclic double bond can assume either the Δ^3- or the Δ^4-position. The pyrrolinones known at the present time are mainly of two types: those containing only alkyl substituents, in which the double bond appears to exist in the Δ^3-position (*e.g.* II; R and R′ = alkyl) and those containing an ester or other electron-withdrawing group in the 4-position, in which case the double bond takes up the Δ^4-position (III; R and R′ = alkyl). We have examined both types of pyrrolinones in order to assess the possibility of using them as intermediates in the syntheses of macrocyclic rings related to corrin[5] (IV), the parent ring system of vitamin B_{12}, and corrole[6] (V) and some preliminary experiments are now described.



(I)



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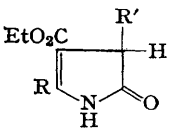

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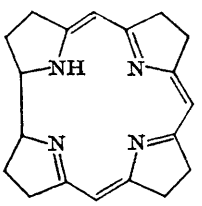
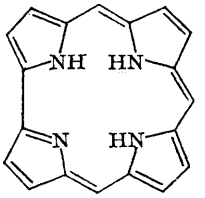


(IV)



(V)

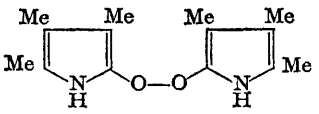
Several good methods exist for the preparation of alkyl-2-pyrrolinones lacking an electron-withdrawing group, of which the simplest is the oxidation of pyrroles containing one free α-position with hydrogen peroxide in presence of pyridine.[7] Alternative methods include the hydrolysis of 2-bromopyrroles,[8] the hydrogen peroxide oxidation of 2-formylpyrroles,[9] and ring-synthetic approaches.[10]

Fischer formulated the products as 2-hydroxypyrroles but Plieninger, Decker, and Katritzky[11] have studied the n.m.r. spectra of the 3,4-dialkyl compounds (which they obtained by ring-synthetic methods) and have shown that these products are 3,4-dialkyl-3-pyrrolin-2-ones. By oxidation of 3,4-dimethylpyrrole with hydrogen peroxide in presence of pyridine we have obtained a product which was identical with Plieninger and Decker's 3,4-dimethyl-3-pyrrolin-2-one[10] (II; R = H, R′ = Me) although contaminated with about 10% of dimethylmaleimide. The latter was conveniently removed by taking advantage of

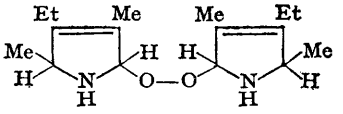
[3] Ref. 1; vol. II, Part I, p. 715.
[4] R. Lemberg and J. W. Legge, "Haematin Compounds and Bile Pigments," Interscience Publ., Inc., New York, 1949, p. 108 *et seq.*; C. H. Gray, "The Bile Pigments," Methuen, London, 1953; A. J. Birch, *Chem. and Ind.*, 1955, 652; C. H. Gray, D. C. Nicholson, *et al.*, *J.*, 1958, 3085; 1961, 2265, 2268, 3085.
[5] E. Berthele, H. Boos, J. D. Dunitz, F. Elsinger, A. Eschenmoser, I. Felner, H. P. Gribi, H. Gschwend, E. J. Meyer, M. Pesaro, and R. Scheffold, *Angew. Chem.*, 1964, **76**, 393.
[6] A. W. Johnson and I. T. Kay, *Proc. Chem. Soc.*, 1964, 89.
[7] H. Fischer *et al.*, *Z. physiol. Chem.*, 1932, **212**, 146; 1942, **274**, 231; *Annalen*, 1937, **528**, 265.
[8] W. Siedel, *Annalen*, 1943, **554**, 144.
[9] A. Hüni and F. Frank, *Z. physiol. Chem.*, 1947, **282**, 96.
[10] H. Plieninger and M. Decker, *Annalen*, 1956, **598**, 198.
[11] H. Plieninger, H. Bauer, and A. R. Katritzky, *Annalen*, 1962, **654**, 165.

its solubility in alkali. Oxidation of 2,3,4-trimethyl- and 3-ethyl-2,4-dimethylpyrrole (cryptopyrrole) gave products showing similar ultraviolet absorption spectra to that of (II; R = H, R′ = Me). This oxidation product of cryptopyrrole was referred to by Fischer[7] as "cryptopyrrolone." The n.m.r. spectra of the trialkyl oxidation products (cf. ref. 11) were consistent with their formulation as 3,4,5-trialkyl-3-pyrrolin-2-ones (II; R = R′ = Me; R = Me, R′ = Et) although the spectra were complicated by second-order splittings. The spectrum of (II; R = H, R′ = Me) shows a broad peak for the methylene protons at C-5 and the absorptions due to the protons of one of the methyl groups are definitely split. This splitting, which was not mentioned by Plieninger *et al.*,[11] is probably caused by five-bond interaction between the protons of the 3-methyl and the 5-methylene groups (see below).

In the preparation of 3,4,5-trimethyl-3-pyrrolin-2-one, a by-product, $C_{14}H_{20}N_2O_2$, was formed which proved to be identical with the "2,3,4-trimethylpyrrole peroxide," obtained by Metzger and Fischer[12] by aerial oxidation of the pyrrole. The structure (VI) originally assigned to this compound and the analogous peroxide from cryptopyrrole, has been recently criticised by Seebach[13] on the grounds that no peroxides of the type ArO·OAr (Ar = aryl) are known. However, in spite of his assertion to the contrary, the alternative structure (VII), $C_{16}H_{28}N_2O_2$, advanced by Seebach without any further experimental evidence, does not agree with the analytical evidence.



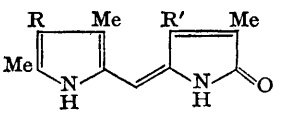
(VI)



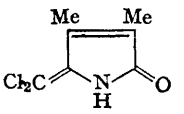
(VII)

The chemical properties of 3,4,5-trimethyl-3-pyrrolin-2-one (II; R = R′ = Me) were, as expected, similar to those of Fischer's "cryptopyrrolone" (II; R = Me, R′ = Et).[14] Thus, bromination and subsequent condensation with cryptopyrrole gave (VIII; R = Et, R′ = Me). Chlorination of (II; R = R′ = Me) gave a crystalline derivative formulated as (IX) on the basis of ultraviolet absorption[15] and analysis. The analogous compound from (II; R = Me, R′ = Et) had been prepared by Fischer,[7] but the product had been formulated incorrectly.

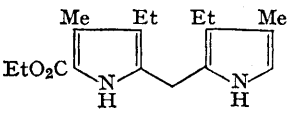
An attempted condensation of cryptopyrrolone (II; R = Me, R′ = Et) with pyrrole under the conditions of the Vilsmeier–Haack reaction[16] gave a small yield of (VIII; R = R′ = Et) the structure of which was proved by n.m.r. measurements. The pyrrole evidently takes no part in the reaction. Several other reactions of the 3,4-dialkyl-3-pyrrolin-2-ones, largely involving the reactive 5-methylene group, were described by Plieninger *et al.*[11]



(VIII)



(IX)



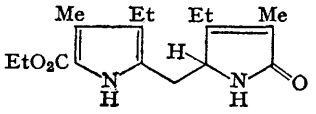
(X)

Just as the 3,4-dialkyl- and 3,4,5-trialkyl-pyrroles can be oxidised to the corresponding 3-pyrrolin-2-ones (II), we have found that ethyl 3,3′-diethyl-4,4′-dimethyldipyrromethane-5-carboxylate (X),[17] an α-free dipyrromethane, can be oxidised with hydrogen peroxide in presence of pyridine to (XI), contaminated with a small amount of the methene (XII) which can be conveniently hydrogenated back to (XI). Further hydrogenation of (XI) in presence

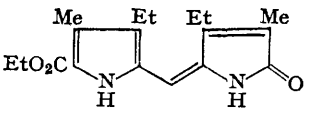
[12] W. Metzger and H. Fischer, *Annalen*, 1936, **527**, 1.
[13] D. Seebach, *Chem. Ber.*, 1963, **96**, 2723.
[14] H. Fischer and P. Hartmann, *Z. physiol. Chem.*, 1934, **226**, 116.
[15] Cf. A. Roedig and G. Märkl, *Annalen*, 1960, **636**, 1.
[16] Cf. H. Rapoport and N. Castagnoli, *J. Amer. Chem. Soc.*, 1962, **84**, 2178; J. H. Atkinson, R. Grigg, and A. W. Johnson, *J.*, 1964, 893.
[17] A. H. Corwin and E. C. Coolidge, *J. Amer. Chem. Soc.*, 1952, **74**, 5196.

of Raney nickel gave the pyrrolidone (XIII) as a mixture of stereoisomers, and further applications of intermediates of this type will be described in later papers.

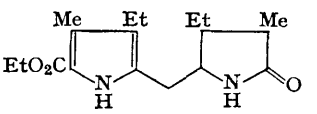
The second group of pyrrolin-2-ones which we have examined, (XIV), contain a 4-ester substituent and are prepared by the action of ammonia on the α-acetylsuccinic esters, following Emery.[18] From an examination of these pyrrolin-2-ones, as well as the corresponding acetoxypyrroles, Grob and Ankli[19] concluded that the parent compounds were cyclic amides and not derivatives of 2-hydroxypyrrole, and these conclusions have been accepted by later workers.[20] It appeared to us however that the interpretation of



(XI)

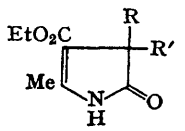


(XII)

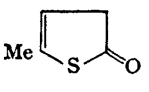


(XIII)

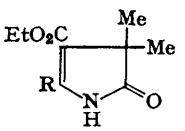
ultraviolet absorption spectra for ethanolic solutions used by the Swiss workers in assigning these structures, and in particular the position of the double bond, was arguable and accordingly we have re-examined the problem by use of n.m.r. spectra. The results we have obtained confirm the conclusions of Grob and Ankli,[19] in that (XIV; R = R′ = H)[10] exists as the 4-pyrrolin-2-one tautomer, at least in chloroform solution and the ultraviolet spectra of the compounds (XIV; R = H, Me, R′ = H, Me) are similar. The n.m.r. spectrum of (XIV; R = R′ = H) is complicated by long-range coupling between the 5-methyl and the 3-methylene protons; a similar coupling has been reported for 2,3-dihydro-5-methylthiophen-2-one (XV).[21] Theoretical considerations[22] require that for maximum long-range coupling in the system $CH_3{\cdot}C{=}C{\cdot}C{\cdot}H$, the plane of the $C{\cdot}C{=}C{\cdot}C$ grouping should be perpendicular to the $={\cdot}C{\cdot}C{\cdot}H$ plane, which can occur only by some stereochemical restraint, or in this case, through the constraining action of the ring. A similar coupling was observed in the n.m.r. spectrum of (XIV; R = Me, R′ = H), as well as in that of the corresponding methyl ester.



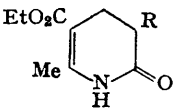
(XIV)



(XV)



(XVI)

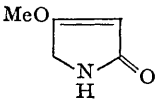


(XVII)

The analogous pyrrolinone (XVI; R = Me) has now been prepared by an initial condensation of ethyl α-bromoisobutyrate with the potassium derivative of acetoacetic ester. This gave a mixture containing some ethyl methacrylate impurity (formed by dehydrobromination of ethyl α-bromoisobutyrate) and when the mixture was treated with ammonia, two products were obtained. One was the expected compound (XVI; R = Me) and the other, having a similar absorption spectrum, was identified as ethyl 1,4,5,6-tetrahydro-2,5-dimethyl-6-oxopyridine-3-carboxylate (XVII; R = Me) by comparison of its spectra with those of ethyl 1,4,5,6-tetrahydro-2-methyl-6-oxopyridine-3-carboxylate (XVII; R = H).[23] The by-product (XVII; R = Me) was formed by a Michael addition of ethyl acetoacetate to ethyl methacrylate followed by condensation with ammonia. The ultraviolet absorption spectrum of (XVI; R = Me) which must be a derivative of 4-pyrrolin-2-one, was similar to

[18] W. O. Emery, *Annalen*, 1890, **260**, 137.
[19] C. A. Grob and P. Ankli, *Helv. Chim. Acta*, 1949, **32**, 2010, 2023.
[20] *E.g.* F. Korte and K. Trautner, *Chem. Ber.*, 1962, **95**, 281.
[21] R. A. Hoffman and S. Gronowitz, *Arkiv Khemi*, 1960, **16**, 471, 499. The tautomerism of the 5-substituted thiolen-2-ones, which resembles that of the pyrrolin-2-ones, is discussed in detail by Hörnfeldt and Gronowitz, *ibid.*, 1963, **21**, 239; 1964, **22**, 211; *Acta Chem. Scand.*, 1962, **16**, 789.
[22] M. Karplus, *J. Chem. Phys.*, 1960, **33**, 1842.
[23] N. F. Albertson, *J. Amer. Chem. Soc.*, 1952, **74**, 3816.

those of (XIV; R = R′ = H and R = Me, R′ = H) but, as expected, in the n.m.r. spectrum of (XVI; R = Me), the 5-bond interaction was not observed. It is established therefore, that the alkylpyrrolin-2-ones normally exist as the Δ^3-isomers but, when the ring carries a 4-ester substituent, the double bond migrates to the Δ^4-position, presumably to permit interaction between the ester carbonyl group and the amide nitrogen atom. Grob and Ankli[19] obtained pyrrolin-2-one itself (amide tautomer of I) from the corresponding 4-ethoxycarbonyl derivative by hydrolysis and decarboxylation and they assumed, probably incorrectly, that the double bond remained in the Δ^4-position. In a later paper, Langenbeck and Boser[24] prepared the parent compound by another route and formulated it as the Δ^3-compound without reference to the earlier Swiss work. Examples of 3-pyrrolin-2-ones where the position of the double bond has been established by spectral methods include (XVIII),[25] (XIX),[26] (XX)[27] and (XXI)[28] and a variety of pyrrolin-2-ones, including the antibiotic holomycin (XXII),[29] which contain an exocyclic Δ^5-double bond.



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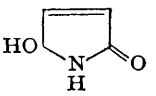

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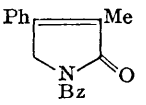
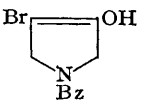
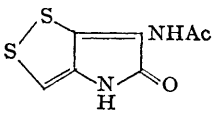


(XX)



(XXI)



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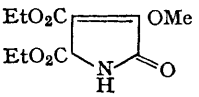

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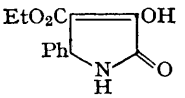
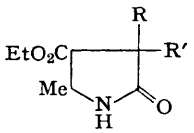


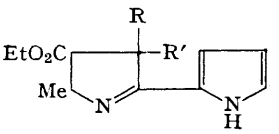
(XXIV)

Pyrrolin-2-ones, containing electron-attracting substituents in the 4-position, and which have been claimed to contain Δ^3-double bonds (*e.g.* XXIII[30] and XXIV[31]) without supporting spectral evidence, would seem worthy of reinvestigation.

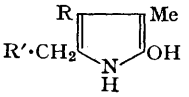
The 4-pyrrolin-2-ones (XIV) could not be hydrogenated at room temperature and pressure in ethanolic solution in presence of platinum. However, when acetic acid containing a few drops of perchloric acid was used as solvent, hydrogenation occurred and gave the saturated pyrrolidones (XXV; R = Me, R′ = H; R = R′ = Me). The products did not melt sharply, however, and were probably mixtures of stereoisomers. The reduction products (XXV; R = Me, R′ = H; R = R′ = Me) were successfully employed in Vilsmeier-type condensations with pyrrole[16] to give the 2-pyrrolylpyrrolines (XXVI; R = Me, R′ = H; R = R′ = Me).



(XXV)



(XXVI)

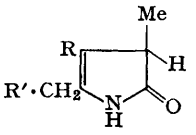


(XXVII)

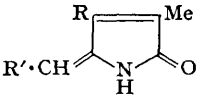
Bromination of the three 5-oxo-3-pyrroline-3-carboxylic esters (XIV; R = H, Me, R′ = H and XVI; R = Me) gave a different type of product in each case. With (XVI; R = Me) either the monobromo- (XVI; R = CH_2Br) or dibromo-derivative (XVI; R = $CHBr_2$) could

[24] W. Langenbeck and H. Boser, *Chem. Ber.*, 1957, **84**, 526.
[25] D. J. Cram, O. Theander, H. Jager, and M. K. Stanfield, *J. Amer. Chem. Soc.*, 1963, **85**, 1430.
[26] P. de Mayo and S. T. Reid, *Chem. and Ind.*, 1962, 1576.
[27] J. A. Moore *et al.*, *J. Amer. Chem. Soc.*, 1959, **81**, 6029; 1962, **84**, 3022.
[28] P. L. Southwick and J. A. Vida, *J. Org. Chem.*, 1962, **27**, 3075.
[29] L. Ettlinger, E. Gäumann, R. Hütter, W. Keller-Schierlein, F. Kradolfer, L. Neipp, V. Prelog, and H. Zähner, *Helv. Chim. Acta*, 1959, **42**, 563.
[30] R. Adams, S. Miyano, and M. D. Nair, *J. Amer. Chem. Soc.*, 1961, **83**, 3323.
[31] W. R. Vaughn and R. C. Tripp, *J. Amer. Chem. Soc.*, 1960, **82**, 4370.

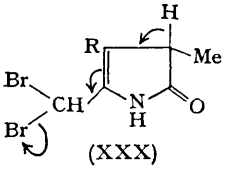
be isolated according to the amount of bromine used. In the case of (XIV; R = R′ = H) an intensely blue solution was obtained on bromination, but no crystalline product was isolated from the reaction. Bromination of (XIV; R = Me, R′ = H) has been reported[32] to give (XXVII; R = CO_2Et, R′ = Br) which we expected would be more correctly formulated as (XXVIII; R = CO_2Et, R′ = Br). However, examination of ultraviolet and n.m.r. spectra showed that the product was the 5-bromomethylene derivative (XXIX; R = CO_2Et, R′ = Br) formed by 1,4-elimination of hydrogen bromide from the 5-dibromomethyl compound (XXX). This 5-bromomethylene compound (XXIX; R = CO_2Et, R′ = Br) has been prepared previously[33] by bromination of 4-ethoxycarbonyl-3,5-dimethylpyrrole-2-sulphonic acid, and was correctly formulated. As expected, the spectral properties of (XXIX; R = CO_2Et, R′ = Br) differed appreciably from those of (XVI; R = CH_2Br).



(XXVIII)



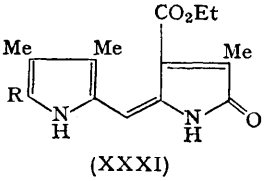
(XXIX)



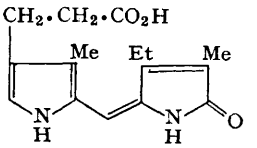
(XXX)

Related compounds previously formulated by Fischer[32] as 2-hydroxypyrroles (XXVII; R = Ac, R′ = H, Br; R = CO_2Et, R′ = Cl) probably should be re-formulated as (XXVIII; R = Ac, R′ = H) and (XXIX; R = Ac, R′ = Br; R = CO_2Et, R′ = Cl) respectively. In fact, an examination of the chlorination product obtained from (XIV; R = Me, R′ = H) with sulphuryl chloride confirmed that it had the structure (XXIX; R = CO_2Et, R′ = Cl).

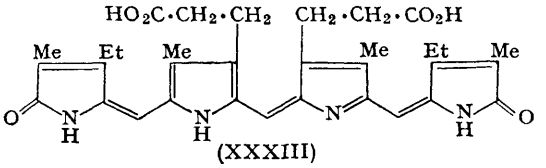
Hydrogenation of (XXIX; R = CO_2Et, R′ = Br) in presence of platinum gave the original pyrrolinone (XIV; R = Me, R′ = H) after absorption of two equivalents of hydrogen. Condensation of the 5-bromomethylenepyrrolinone (XXIX; R = CO_2Et, R′ = Br) with 3,4-dimethylpyrrole gave the condensation product (XXXI; R = H); a green crystalline by-product formed in this reaction was not investigated further. The general class of compounds (XXXI; R = H) includes xanthobilirubinic acid (XXXII), a key intermediate in the



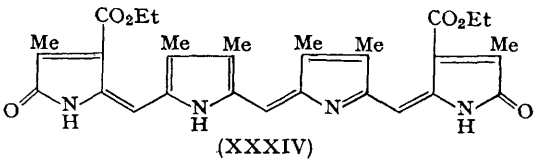
(XXXI)



(XXXII)



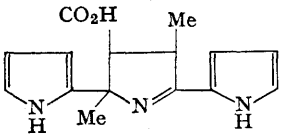
(XXXIII)



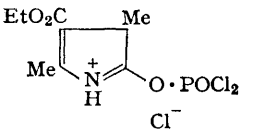
(XXXIV)

[32] H. Fischer and E. Adler, *Z. physiol. Chem.*, 1931, **197**, 237.
[33] A. Treibs and H. Bader, *Annalen*, 1959, **627**, 182.

synthesis[34] of glaucobilin (XXXIII). Xanthobilirubinic acid was formylated by the Gattermann method and then condensed with a second mol. of xanthobilirubinic acid. We have found that formylation of (XXXI; R = H) is more conveniently effected under Vilsmeier–Haack conditions and that condensation of the resulting (XXXI; R = CHO) with (XXXI; R = H) gives the green bilatriene-*abc* (XXXIV), the visible spectrum of which closely resembled that of natural glaucobilin. It is of interest to note that dipyrromethenes are not normally subject to electrophilic attack at the 5- and 5′-positions; the ease of formylation of (XXXI; R = H) is therefore a further indication that these compounds are cyclic amides rather than derivatives of 2-hydroxypyrrole.



(XXXV)



(XXXVI)

An attempt to utilise the 4-pyrrolin-2-one (XIV; R = R′ = Me) as the amide component in a Vilsmeier reaction with pyrrole gave no useful product but (XIV; R = Me, R′ = H), when condensed with a fivefold excess of pyrrole by using tetrahydrofuran as solvent, gave a product which had the spectral characteristics of a 2-pyrrylpyrroline and was formulated as (XXXV) on the grounds of analysis and spectral data. The second mol. of pyrrole evidently undergoes a Michael-type addition to the intermediate complex (XXXVI).

Experimental

Ultraviolet and visible absorption spectra were determined for ethanolic solutions except where otherwise stated. Nuclear magnetic resonance spectra were determined for chloroform solutions with an AEI RS2 instrument operating at 60 Mc./sec. and using tetramethylsilane as internal reference.

3,4-*Dimethyl*-3-*pyrrolin*-2-*one* (II; R = H, R′ = Me).—To 3,4-dimethylpyrrole (7·4 g.) in dry pyridine (14 ml.) was added hydrogen peroxide (8 ml. of a 30% w/v solution) at once. The mixture was stirred and gentle heating of the solution was carried out until an exothermic reaction was initiated. The heating was discontinued, and the pyridine solution, refluxing with the heat of the reaction, was allowed to cool slowly to room temperature, the stirring being continued throughout, and evaporated to dryness *in vacuo*. The crystalline residue was taken up with chloroform (20 ml.) and extracted rapidly with sodium hydroxide solution (50 ml. of 2N). The chloroform layer was dried and evaporated and the product sublimed from the residue as colourless needles (4 g., 46%), identical in all respects with an authentic sample of 3,4-dimethyl-3-pyrrolin-2-one, prepared according to the method of Plieninger and Decker.[10] Dimethylmaleimide (10 mg.) was obtained by chromatography on alumina (Spence type H) of a small fraction of the product (100 mg.), before base extraction, as colourless needles, m. p. 116—118° (lit.,[35] 118°).

3,4,5-*Trimethyl*-3-*pyrrolin*-2-*one* (II; R = R′ = Me).—This was prepared from 2,3,4-trimethylpyrrole (8·5 g.), pyridine (17 ml.), and hydrogen peroxide (12·75 ml. of 30% w/v solution), as described above. After evaporation of solvent, the residue was dissolved in ethyl alcohol (20 ml.) and hydrogenated over Adams' platinum catalyst for 6 hr, in order to reduce any unchanged pyridine *N*-oxide. Distillation of the residue, after removal of alcohol, gave the product (6·9 g.; 71%), b. p. 142—145°/9 mm., as a viscous pale yellow oil, which crystallised slowly. It was sublimed as colourless cubes, m. p. 74—75° (Found: C, 67·0; H, 8·8; N, 11·4. $C_7H_{11}NO$ requires C, 67·15; H, 8·85; N, 11·2%); light absorption: $\lambda_{max.}$ 211 mμ (ε, 14,980), $\nu_{max.}$ 1698 cm.$^{-1}$. The n.m.r. spectrum showed bands at (τ values): 8·21 (3-methyl group, quartet, J = 1·14 c./sec.); 8·02 (4-methyl, singlet); 8·68 (5-methyl, doublet, J = 10·45 c./sec.); 5·94 (5-H, multiplet).

2,3,4-*Trimethyl*-2-*pyrrolyl Peroxide* (VI).—2,3,4-Trimethylpyrrole was oxidised with hydrogen peroxide exactly as in the previous experiment but the hydrogenation was omitted. A solid residue was obtained after the 3,4,5-trimethyl-3-pyrrolin-2-one had been distilled, and this was

[34] W. Seidel, *Z. physiol. Chem.*, 1935, **237**, 18.
[35] H. Fischer and B. Walach, *Annalen*, 1926, **450**, 164.

washed with cold ethanol and then crystallised from ethanol as colourless prisms, m. p. 256—258° (decomp.) (Found: C, 67·9; H, 7·95; N, 11·4. Calc. for $C_{14}H_{20}N_2O_2$: C, 67·7; H, 8·1; N, 11·25%). The product was identical with the product obtained by the method of Metzger and Fischer.[12]

4-Ethyl-3,5-dimethyl-3-pyrrolin-2-one (II; R = Me, R′ = Et).—Prepared by the method of Fischer *et al.*,[7] it had m. p. 78—80° (lit.,[7] 83°) [Found: C, 68·7; H, 9·35; N, 9·95%; *M* (thermistor drop), 143. Calc. for $C_8H_{13}NO$: C, 69·05; H, 9·4; N, 10·05%; *M*, 139]; light absorption: $\lambda_{max.}$ 211·5 mμ (ε, 13,950), $\nu_{max.}$ 1693 cm.$^{-1}$. The n.m.r. spectrum contained the following bands (τ values): 8·04 (3-methyl group; doublet; J = 0·9 c./sec.), 7·54 (4-CH_2 of ethyl; multiplet); 8·78 (CH_3 of ethyl; triplet, J = 8·60 c./sec.); 5·8 (5-H; multiplet); 8·6 (5-methyl; doublet, J = 6·7 c./sec.).

4-Ethyl-5-(4-ethyl-3,5-dimethyl-2-pyrrolylmethylene)-3-methyl-3-pyrrolin-2-one (VIII; R = R′ = Et).—(i) Prepared, following Fischer and Hartmann,[14] from 4-ethyl-3,5-dimethyl-3-pyrrolin-2-one (above) by bromination and condensation with cryptopyrrole, the product formed yellow needles (chloroform–methanol), m. p. 249—251° (lit.,[14] 244—245°); light absorption ($CHCl_3$): $\lambda_{max.}$ 235, 270, and 416 mμ (ε, 9670, 4800, and 37,200); $\nu_{max.}$ 1663 cm.$^{-1}$ (amide carbonyl). The n.m.r. spectrum showed bands at (τ values) 8·83 (CH_3 of 4- and 4′-ethyl groups; triplet, J = 7·5 c./sec.), 7·52 (CH_2 of ethyl; quartet, J = 7·5 c./sec.), 7·45 (CH_2 of ethyl; quartet; J = 7·5 c./sec.), 8·00 (3-methyl; singlet), 7·56 (5′-methyl; singlet) and 3·89 (*meso*-hydrogen; singlet).

(ii) 4-Ethyl-3,5-dimethyl-3-pyrrolin-2-one (3·0 g.) and pyrrole (1·45 g.) were dissolved in dry ether (50 ml.), and to the stirred solution was added phosphorus oxychloride (3·32 g.) in dry ether (20 ml.). The mixture was stirred for a further 15 min. before it was poured into water (50 ml.). The two layers were separated and the organic layer was basified and dried. Most of the solvent was removed and the residue kept at 0° overnight. The product (31 mg.), which separated as yellow needles, was identical with the previous condensation product. No other useful compound could be isolated from the reaction mixture.

5-(4-Ethyl-3,5-dimethyl-2-pyrrolylmethylene)-3,4-dimethyl-3-pyrrolin-2-one (VIII; R = Et, R′ = Me).—Prepared from 3,4,5-trimethyl-3-pyrrolin-2-one (above) by bromination and subsequent condensation with cryptopyrrole by using the method of Fischer and Hartmann,[14] the product formed yellow prisms (chloroform), m. p. 287—290° (Found: C, 73·7; H, 8·05; N, 11·4. $C_{15}H_{20}N_2O$ requires C, 73·75; H, 8·25; N, 11·45%).

4-Ethyl-3-methyl-5-(3,4,5-trimethyl-2-pyrrolylmethylene) 3-pyrrolin-2-one (VIII; R = Me, R′ = Et).—Prepared from 4-ethyl-3,5-dimethyl-3-pyrrolin-2-one (1·25 g.; above) and 2,3,4-trimethylpyrrole (1·0 g.) by Fischer's method.[14] Crystallisation of the product (500 mg.) from chloroform gave mustard-yellow prisms, m. p. > 300° (Found: C, 73·4; H, 7·95; N, 11·7. $C_{15}N_{20}N_2O$ requires C, 73·75; H, 8·25; N, 11·5%); $\lambda_{max.}$ 233, 272 and 418 mμ (ε, 8890, 3895 and 33,850); $\nu_{max.}$ 1661 cm.$^{-1}$.

5-(5-Ethoxycarbonyl-3-ethyl-4-methylpyrrolyl-2-methyl)-4-ethyl-3-methyl-3-pyrrolin-2-one (XI).—Ethyl 3,3′-diethyl-4,4′-dimethyldipyrromethane-5-carboxylate (X; 2·0 g.) was dissolved in pyridine (10 ml.), the solution warmed to 45—50° and treated dropwise with hydrogen peroxide (8 ml.; 30% w/v), with stirring. The clear solution was heated to 98° for 5 min., cooled, and diluted with ethanol (10 ml.). The product was filtered off, washed with cold ethanol, and dried to give a pale yellow crystalline solid (1·22 g.), m. p. 208—212°. The yellow colour was not removed by repeated crystallisation or fractional sublimation; $\lambda_{max.}$ 208, 281·5, 369, 383 and 404·5 mμ (ε, 16,530, 18,400, 682, 756 and 617, respectively). Hydrogenation in ethanol by using Adams' catalyst gave, after crystallisation from ethanol, an almost quantitative yield of the pure product as colourless needles, m. p. 210—212° (Found: C, 68·3; H, 7·95; N, 9·1%; *M*, 380. $C_{18}H_{20}N_2O_3$ requires C, 67·9; H, 8·25; N, 8·8%; *M*, 318); $\lambda_{max.}$ 209 and 282·5 mμ (ε, 17,700 and 19,450).

5-Dichloromethylene-3,4-dimethyl-3-pyrrolin-2-one (IX).—To 3,4,5-trimethyl-3-pyrrolin-2-one (1·85 g.) in ether (20 ml.) was added sulphuryl chloride (3·75 ml.), with stirring. The solution was evaporated slowly at room temperature and pressure, and then on a water-pump to give a thick red oil. After being kept overnight, the crystalline product which had formed was triturated with methanol and then separated. A further quantity of product was obtained by leaving the methanol mother liquors for a few days. Crystallisation of the product from methanol gave colourless needles, m. p. 217—218° (Found: C, 44·1; H, 3·55; N, 7·3. $C_7H_7Cl_2NO$ requires C, 43·75; H, 3·7; N, 7·3%); light absorption: $\lambda_{max.}$ 286·5 mμ (ε, 19,630), $\nu_{max.}$ 1699 cm.$^{-1}$ (amide carbonyl).

Ethyl 2-Methyl-5-oxo-2-pyrroline-3-carboxylate (XIV; R = R′ = H).—Prepared by the method of Fischer and Herrmann[36] from diethyl α-acetylsuccinate, the product had m. p. 134—135°; $\lambda_{max.}$

[36] H. Fischer and M. Herrmann, *Z. physiol. Chem.*, 1922, **122**, 1.

218 and 280 mμ (ε, 3240 and 11,180); $\nu_{max.}$ 1759, 1724, and 1695 cm.$^{-1}$. The n.m.r. spectrum showed bands at (τ values) 6·71 (3-H; quartet, J = 2·29 c./sec.); 7·63 (5-methyl; triplet, J = 2·29 c./sec.); 5,68 (CH_2 of ester; quartet, J = 7·16 c./sec.); 8·69 (CH_3 of ester; triplet, J = 7·16 c./sec.).

Ethyl 2,4-Dimethyl-5-oxo-2-pyrroline-3-carboxylate (XIV; R = Me; R′ = H).—Prepared from diethyl α-acetyl-α′-methylsuccinate by the method of Emery,[18] the product had m. p. 126—127° (lit.[18] 127°); $\lambda_{max.}$ 218 and 280 mμ (ε, 4250 and 12,000), $\nu_{max.}$ 1730 and 1693 cm.$^{-1}$. The n.m.r. spectrum showed bands at (τ values): 8·57 (3-methyl; doublet, J = 7·56 c./sec.); 6·68 (3-H; multiplet); 7·58 (5-methyl; doublet, J = 1·92 c./sec.); 5·72 (CH_2 of ester; quartet, J = 7·20 c./sec.); 8·67 (CH_3 of ester; triplet, J = 7·20 c./sec.).

The corresponding *methyl ester* was prepared similarly from dimethyl α-acetyl-α′-methylsuccinate. The product was crystallised from chloroform–light petroleum (b. p. 60—80°) and sublimed to give colourless needles, m. p. 110—112·5° (Found: C, 56·6; H, 6·2; N, 7·95. $C_8H_{11}NO_3$ requires C, 56·8; H, 6·55; N, 8·3%); $\lambda_{max.}$ 219 and 280 mμ (ε, 3890 and 10,630), $\nu_{max.}$ 1730 and 1696 cm.$^{-1}$.

Ethyl 2,4,4-Trimethyl-5-oxo-2-pyrroline-3-carboxylate (XVI; R = Me).—Potassium (42·35 g.) was dissolved in dry t-butyl alcohol (1 l.) and, after cooling, ethyl acetoacetate (150·6 ml.) was added dropwise, with stirring, during 1 hr. Solid sodium iodide (0·5 g.) was added, followed by ethyl α-bromoisobutyrate (211·7 g.), dropwise, over 24 hr. The mixture was then heated under reflux for 4 days and, after cooling, was neutralised (litmus) with concentrated hydrochloric acid and treated directly with a stream of dry ammonia gas for 12 hr. t-Butyl alcohol was then removed by distillation through a short column and the potassium bromide separated. The residue was heated under reflux in xylene (100 ml.) for 1 hr. and then distilled, the fraction, b. p. 180—200°/10 mm., being collected. This yellow oil solidified after cooling and was purified by crystallisation from ethanol, to give white rhombs (27 g., 13% overall), m. p. 165—166·5° (Found: C, 61·0; H, 7·4; N, 7·6. $C_{10}H_{15}NO_3$ requires C, 60·9; H, 7·65; N, 7·1%); $\lambda_{max.}$ 216 and 279 mμ (ε, 3945 and 12,750), $\nu_{max.}$ 1734 and 1692 cm.$^{-1}$. Evaporation of the alcoholic mother liquors from the crystallisation of the product and chromatography of the residue on alumina (Spence type H), gave a product. (XVII; R = Me), after elution with ether, as colourless needles (from ethanol–water), m. p, 157—157·5° (Found: C, 60·9; H, 7·6; N, 7·35. $C_{10}H_{15}NO_3$ requires C, 60·9; H, 7·65; N, 7·1%); $\lambda_{max.}$ 214 and 279 mμ (ε, 2915 and 12,270), $\nu_{max.}$ 3404, 1701, 1692 (infl.) and 1642 cm.$^{-1}$.

For ethyl 1,4,5,6-tetrahydro-2-methyl-6-oxopyridine-3-carboxylate (XVII; R = H, $\lambda_{max.}$ 212 and 279 mμ (ε, 2435 and 11,740), $\nu_{max.}$ 3409, 1700, 1692 (infl.) and 1643 cm.$^{-1}$.

Ethyl 2-Bromomethylene-4-methyl-5-oxo-3-pyrroline-3-carboxylate (XXIX; R = CO_2Et, R′ = Br).—On using the quantities given by Fischer,[31] an oily product was obtained which crystallised slowly. In the present method, bromine (3·15 ml.) in chloroform (10 ml.) was added slowly to a stirred solution of ethyl 2,4-dimethyl-5-oxo-2-pyrroline-3-carboxylate (5 g.) in chloroform (20 ml.). Chloroform (*ca.* 20 ml.) was then distilled off, together with the hydrogen bromide formed, and then ethanol (30 ml.) was added, after cooling. An immediate precipitation of the product occurred. Separation and crystallisation (from ethanol) gave buff needles (3 g., 42%); $\lambda_{max.}$ 276 and 326 mμ (ε, 8870 and 14,180), $\nu_{max.}$ 1724 and 1720 cm.$^{-1}$. The n.m.r. spectrum showed only one proton (τ 3·07) besides ester and 3-methyl (τ 7·77) protons. The compound decomposed slowly on heating without melting.

Ethyl 2-Bromomethyl-4,4-dimethyl-5-oxo-2-pyrroline-3-carboxylate (XVI; R = CH_2Br).—Bromine (0·14 ml.) in chloroform (20 ml.) was added to a well stirred solution of ethyl 2,4,4-trimethyl-5-oxo-2-pyrroline-3-carboxylate (490 mg.) in chloroform (20 ml.), during 15 min. The bromine was instantly decolourised. The solution was evaporated, *in vacuo*, to yield an oil which slowly crystallised. Recrystallisation (from aqueous ethanol) gave colourless plates (480 mg., 66%), m. p. 101—103° (Found: C, 43·7; H, 4·75; N, 5·25; Br, 28·7. $C_{10}H_{14}BrNO_3$ requires C, 43·5; H, 5·1; N, 5·1; Br, 28·95%); $\lambda_{max.}$ 291 mμ (ε, 10,170), $\nu_{max.}$ 1734 and 1695 cm.$^{-1}$. The n.m.r. spectrum showed bands at (τ values): 8·58 (3-methyl groups; singlet, 6 protons); 5·28 (CH_2Br protons; singlet); 8·62 (CH_3 of ester; triplet, J = 7·08 c./sec.); 5·68 (CH_2 of ester; quartet, J = 7·08 c./sec.).

Ethyl 2-Dibromomethyl-4,4-dimethyl-5-oxo-2-pyrroline-3-carboxylate (XVI; R = $CHBr_2$).—Bromine (1% solution in chloroform) was added dropwise to a gently boiling solution of ethyl 2,4,4-trimethyl-5-oxo-2-pyrroline-3-carboxylate (500 mg.) in chloroform (10 ml.) until the bromine colour persisted after boiling for a further 30 sec. The solution was evaporated to dryness (water pump) and the residue crystallised from chloroform–light petroleum (b. p. 60—80°) as colourless needles (650 mg.; 72%), m. p. 170—171° (Found: C, 33·6; H, 3·55; N, 4·25; Br, 44·4. $C_{10}H_{13}Br_2NO_3$ requires C, 33·8; H, 3·7; N, 3·95; Br, 45·0%); $\lambda_{max.}$ 294 mμ (ε, 7700), $\nu_{max.}$ 1742 and 1695 cm.$^{-1}$.

Ethyl 2-Chloromethylene-4-methyl-5-oxo-3-pyrroline-3-carboxylate (XXIX; R = CO_2Et; R′ = Cl).—By using the method of Fischer,[7] a dark oil was obtained which failed to crystallise. In a modified procedure, ethyl 2,4-dimethyl-5-oxo-2-pyrroline-3-carboxylate (1 g.) in ether (10 ml.) was treated with sulphuryl chloride (0·9 ml.) in one portion. When kept, yellow crystals separated from the solution and were sublimed, forming small colourless blades, m. p. 186—186·5° (lit.[7] 186°) (Found: C, 50·5; H, 4·75; Cl, 16·45. Calc. for $C_9H_{10}ClNO_3$: C, 50·1; H, 4·65; Cl, 16·45%), $\lambda_{max.}$ 273·5 and 336 mμ (ε, 7150 and 9220), $\nu_{max.}$ 1722 and 1716 cm.$^{-1}$.

Ethyl 2-(3,4-Dimethyl-2-pyrrolylmethylene)-4-methyl-5-oxo-3-pyrroline-3-carboxylate (XXXI; R = H).—A mixture of ethyl 2-bromomethylene-4-methyl-5-oxo-3-pyrroline-3-carboxylate (1·0 g.) and 3,4-dimethylpyrrole (365 mg.) was heated under reflux in methanol (50 ml.) for 15 min. The hot solution was filtered to remove a green crystalline by-product and the filtrate evaporated to dryness under reduced pressure. The residue was dissolved in chloroform and chromatographed on a magnesium oxide column. Elution of the first yellow band with chloroform and crystallisation of the resulting solid from chloroform–light petroleum gave deep red prisms (826 mg., 76%), m. p. 220° (decomp.) (Found: C, 65·4; H, 6·55; N, 10·3. $C_{15}H_{18}N_2O_3$ requires: C, 65·65; H, 6·6 N, 10·2%); $\lambda_{max.}$ 282, 434 and 450 mμ (ε, 12,630, 25,350 and 21,650, respectively).

Ethyl 2-(5-formyl-3,4-dimethyl-2-pyrrolylmethylene)-4-methyl-5-oxo-3-pyrrolin-3-carboxylate (XXXI; R = CHO).—A solution of phosphorus oxychloride (0·9 ml.) in *NN*-dimethylformamide (5 ml.) was added at 100° with stirring to a solution of ethyl 2-(3,4-dimethyl-2-pyrrolylmethylene)-4-methyl-5-oxo-3-pyrrolin-3-carboxylate (250 mg.) in *NN*-dimethylformamide (5·0 ml.), and the solution kept at 100° for a further 2 hr. The mixture was poured into cold water (50 ml.), and the solution just basified with aqueous sodium hydroxide and kept for 15 min. After acidifying with dilute hydrochloric acid, the product was separated, washed with methanol, dissolved in chloroform and chromatographed on an alumina column. Elution of the first yellow band with chloroform and crystallisation of the product from chloroform–light petroleum afforded golden-yellow micro-needles (130 mg.; 47%), m. p. 274—275° (Found: C, 63·3; H, 5·8; N, 9·35. $C_{16}H_{18}N_2O_4$ requires: C, 63·55; H, 6·0; N, 9·25%); $\lambda_{max.}$ 282, 434 and 450 mμ (ε, 12,630, 25,350 and 21,650, respectively).

Diethyl 1,3,4,5,6,8-Hexamethylbilatriene-abc-2,7-dicarboxylate (XXXIV).—A chloroform–ethanol solution (1:5; 30 ml.) containing ethyl 2-(3,4-dimethyl-2-pyrrolylmethylene)-4-methyl-5-oxo-3-pyrroline-4-carboxylate (65 mg.) and the corresponding 5-formyl compound (75 mg.), together with a solution of hydrogen bromide (5·0 ml.; 48% w/v in acetic acid), was heated under reflux for 40 min. The deep green solution was poured into excess of chloroform (50 ml.), and the chloroform solution washed with ammonium hydroxide solution followed by water, then dried, and, after being concentrated (to *ca.* 20 ml.), chromatographed on an alumina column. Elution of the deep green band with chloroform and crystallisation of the resulting product from chloroform–ethyl acetate gave green micro-needles (114 mg.), m. p. > 300°; $\lambda_{max.}$ 271, 323·5, 403, and 700 mμ ε, 22,600, 23,900, 35,300, and 12,500, respectively.

Ethyl 2,4-Dimethyl-5-oxopyrrolidine-3-carboxylate (XXV; R = Me, R′ = H).—Ethyl 2,4-dimethyl-5-oxo-3-pyrroline-3-carboxylate (5 g.) was hydrogenated using Adams' catalyst in glacial acetic acid (25 ml.) to which perchloric acid (5 drops) had been added. The uptake of hydrogen was very slow and required 3 days, renewal of the catalyst being necessary. After the perchloric acid had been neutralised with the equivalent of aqueous sodium hydrogen carbonate, the bulk of the acetic acid was removed under reduced pressure and the remainder neutralised by addition of aqueous sodium hydrogen carbonate. After extraction with chloroform (3 × 15 ml.) and removal of the dried solvent, colourless needles (1·65 g., 33%), m. p. 126—129·5°, were obtained by crystallisation of the residue from chloroform–light petroleum (b. p. 60–80°) (Found: C, 58·2; H, 8·4; N, 7·9. $C_9H_{15}NO_3$ requires C, 58·35; H, 8·15; N, 7·55%).

Ethyl 2,4,4-Trimethyl-5-oxopyrrolidine-3-carboxylate (XXV; R = R′ = Me).—Prepared by a similar method from ethyl 2,4,4-trimethyl-5-oxo-3-pyrroline-3-carboxylate, the *product* formed colourless needles, m. p. 52—63° (Found: C, 59·9; H, 8·75; N, 6·7. $C_{10}H_{17}NO_3$ requires C, 60·3; H, 8·6; N, 7·05%).

The ester (0·7 g.) was heated under reflux for 2 hr. with an aqueous solution (20 ml.) of sodium hydroxide (308 mg.). After cooling, N-hydrochloric acid (7·7 ml.) was added and the solution evaporated to dryness *in vacuo*. The residue was heated at 150° for 30 min. and then crystallised from water; the corresponding acid was then obtained as small colourless cubes, m. p. 229—233° (Found: C, 56·1; H, 7·45; N, 8·4. $C_8H_{13}NO_3$ requires C, 56·1; H, 7·65; N, 8·2%).

5-(5-*Ethoxycarbonyl*-3-*ethyl*-4-*methylpyrrolyl*-2-*methyl*)-4-*ethyl*-3-*methyl*-2-*pyrrolidone* (XIII).—

5-(5-Ethoxycarbonyl-3-ethyl-4-methyl-2-pyrrolylmethyl)-4-ethyl-3-methyl-3-pyrrolin-2-one (XI; 1·0 g.) was dissolved in ethanol and hydrogenated over Raney nickel at 120 atm./80° for 3 hr. After removal of catalyst and evaporation under reduced pressure, a colourless solid (950 mg.) was obtained which gave colourless prisms [from light petroleum (b. p. 60—80°)–ether], m. p. 139—142° (Found: C, 67·1; H, 8·7; N, 8·55. $C_{18}H_{28}N_2O_3$ requires C, 67·45; H, 8·8; N, 8·75%), $\lambda_{max.}$ 281 mμ (ε, 18,550), $\lambda_{infl.}$ 241 mμ (ε, 4780).

Ethyl 3,5-*Dimethyl*-2-2-*pyrrolyl*-1-*pyrroline*-4-*carboxylate* (XXVI; R = Me, R′ = H).—Prepared from ethyl 2,4-dimethyl-5-oxopyrrolidine-3-carboxylate (1·16 g.) and pyrrole (2·22 ml.; 5-fold excess) in dry tetrahydrofuran (15 ml.) by the dropwise addition of phosphorus oxychloride (0·57 ml.). The mixture was then boiled under reflux for 15 min. and evaporated to dryness at a water pump. The oily residue was triturated with light petroleum (b. p. 60—80°) to remove unchanged pyrrole and the liquid decanted. After dissolving the oily residue in chloroform (20 ml.), washing successively with dilute ammonium hydroxide and water, and drying (sodium sulphate), evaporation gave the impure product, which was converted directly into its picrate. The picrate (1·48 g., 51%) formed yellow needles (from chloroform–methanol), m. p. 185—192° (Found: C, 49·5; H, 4·7; N, 15·3. $C_{19}H_{21}N_5O_9$ requires C, 49·25; H, 4·55; N, 15·1%).

Ethyl 3,3,5-*Trimethyl*-2-2-*pyrrolyl*-1-*pyrroline*-4-*carboxylate* (XXVI; R = R′ = Me).—Prepared from ethyl 2,4,4-trimethyl-5-oxopyrrolidine-3-carboxylate (360 mg.) but using pyrrole (123 mg., 1 mol.) in dry ether (20 ml.) by a method similar to that described above, after addition of phosphorus oxychloride (0·16 ml.) in ether (5 ml.), the mixture being stirred for 24 hr. at room temperature and then worked up as described above. The picrate (500 mg.) gave deep yellow needles (from methanol), m. p. 128—132° (Found: C, 50·0; H, 5·1; N, 14·6. $C_{20}H_{23}N_5O_9$ requires C, 50·3; H, 4·85; N, 14·65%). Regeneration of the base and bulb-tube distillation afforded a colourless oil (30 mg.), b. p. (bath temp.) 120—124°/0·5 mm.; $\lambda_{max.}$ 246 and 286 mμ (ε, 3590 and 15,960); (in ethanol–0·01N-hydrochloric acid) 272·5 and 328 mμ (ε, 3195 and 25,300); $\nu_{max.}$ 1755 (C=O) and 1598 cm.$^{-1}$ (C=N).

Ethyl 3,5-*Dimethyl*-2,5-*di*-2′-*pyrrolyl*-1-*pyrroline*-4-*carboxylate* (XXXV).—Phosphorus oxychloride (1·72 ml.) was added to a stirred mixture of pyrrole (6·64 ml.) and ethyl 2,4-dimethyl-5-oxo-2-pyrroline-3-carboxylate (XIV; R = Me, R′ = H; 3·44 g.) in tetrahydrofuran (30 ml.). The stirred mixture was heated on a water-bath for 30 min. during which time the solution became dark red. The bulk of the solvent was removed under reduced pressure and dry ether (30 ml.) added to the residual oil. After trituration, the ether was removed by decantation and the oil again washed with ether (10 ml.). The residue was dissolved in chloroform, washed successively with dilute ammonium hydroxide and water and then, after removal of the solvent, the product was isolated as the *picrate* (400 mg.), which formed yellow needles, m. p. 173—175·5° (from aqueous ethanol) (Found: C, 52·4; H, 4·7; N, 15·65. $C_{23}H_{24}N_6O_9$ requires C, 52·25; H, 4·6; N, 15·9%).

From the above ethereal extract, the corresponding *hydrochloride* (700 mg.) crystallised slowly. It was separated and converted directly into the free base by washing a solution in chloroform with dilute ammonium hydroxide. After removal of solvent the free base was sublimed, and formed colourless prisms, m. p. 140—147° (diastereoisomers) (Found: C, 67·8; H, 7·3; N, 13·65. $C_{17}H_{21}N_3O_2$ requires C, 68·2; H, 7·05; N, 14·05%); $\lambda_{max.}$ 207·5 and 286 mμ (ε, 9770 and 16,920); in ethanolic hydrochloric acid $\lambda_{max.}$ 209 and 325·5 mμ (ε, 11,370 and 23,750) with an inflection at 273·5 mμ (ε, 3580). The infrared spectrum (chloroform solution) contained a strong band at 1616 cm.$^{-1}$ (C=N). The n.m.r. spectrum contained peaks at (τ values): 8·90 (CH_3 of ester; triplet, J = 7·02 c./sec.); 8·50 (3-methyl; doublet, J = 7·02 c./sec.); 8·08 (5-methyl; singlet); 7·06 (4-H; doublet, J = 6·10 c./sec.); 6·10 (CH_2 of ester; quartet, J = 7·02 c./sec., superimposed on a multiplet from 3-H); complex splitting between 4·03 and 3·39 from pyrrolic protons.

We thank the D.S.I.R. for a Maintenance Grant to one of us (J. H. A.).

THE UNIVERSITY, NOTTINGHAM. [*Received, August, 25th* 1964.]