257. *Bipyrroles. Part IV.* Some Further Reactions.*

By D. Dolphin, R. Grigg, A. W. Johnson, and J. Leng.

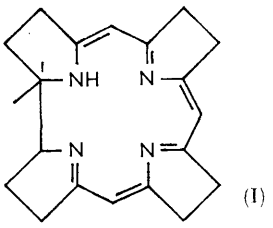
Ultraviolet irradiation of chloroform solutions of certain 2,2′-bipyrroles has given dichlorocarbene adducts. The new dichloromethyl group is shown to occupy the 5-, and not the 2-, position in all the cases examined. Alkaline hydrolysis converts the adducts into 5-formyl-2,2′-bipyrroles which have been condensed with α-free 2,2′-bipyrroles to yield the 5,5′-di(pyrrol-2-yl)dipyrromethenes (VI). Other new tetrapyrrolic systems based on 2,2′-bipyrrole which have been synthesised are the 1′,8′-dideoxy-b-norbilenes-a (XIII) and the 1′,8′-dideoxy-a-norbilenes-b (XIV).

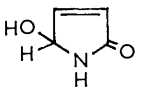
A feature of all the naturally occurring corrins of the vitamin B_{12} group is the presence of an angular methyl group at C_1 (as in I) and in order to assess the possibility of introducing such a group at a late stage in a synthesis we have examined some model reactions in the 2,2′-bipyrrole series. The reaction which has been examined in most detail is the ultraviolet irradiation of chloroform solutions of the bipyrroles in a Pyrex apparatus surrounding a water-cooled Hanovia 400w medium pressure lamp. Oxygen was carefully excluded from the system during the irradiation in order to avoid side reactions; for example de Mayo and Reid [1] have shown that pyrrole in dilute aqueous solution containing a

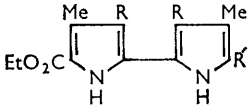
* Part III, R. Grigg and A. W. Johnson, *J.*, 1964, 3315.

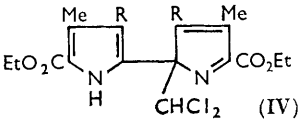
[1] P. de Mayo and S. T. Reid, *Chem. and Ind.*, 1962, 1576.

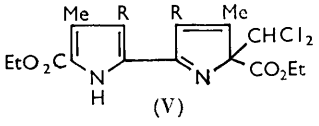
trace of eosin rapidly absorbed one mole of oxygen, on irradiation with a 100w lamp, to give 2-hydroxy-3-pyrrolin-5-one (II). Irradiation of the bipyrroles (III; R = Me, CO_2Et; R′ = CO_2Et) [2] in ethanolic solution caused no spectral change, but when a dilute solution of (III; R = Me; R′ = CO_2Et) in chloroform was irradiated, a marked change in the ultraviolet spectrum occurred, the band at 323 mμ in the spectrum of the starting material rapidly disappeared. After irradiation for 14 hours, the product was isolated as an oil which slowly solidified. It contained chlorine and the infrared spectrum indicated


(I)


(II)


(III)


(IV)


(V)

an NH band of approximately one half the intensity of the original as well as two non-equivalent esters. Analysis indicated that the elements of dichlorocarbene had been added to the original bipyrrole, and the nuclear magnetic resonance spectrum of the product showed the presence of a new proton (τ, 3·42) together with the absence of aliphatic methyl groups. All of this evidence was consistent with the structures (IV) or (V) for the irradiation product.

As will be shown below, the product is correctly formulated as (V) and the reactive intermediate is probably dichlorocarbene which is known to react with pyrroles [3] and indoles.[4] The same product (V; R = Me) has also been obtained from the bipyrrole (III; R = Me; R′ = CO_2Et) by reaction with sodium trichloroacetate in hot 1,2-dimethoxyethane, conditions which are known [5] to involve dichlorocarbene. On the other hand, very little of the adduct (V; R = Me) was formed by reaction of (III; R = Me; R′ = CO_2Et) with chloroform and potassium t-butoxide [6] and none from chloroform and benzoyl peroxide [7] which produces trichloromethyl free radicals. The production of dichlorocarbene by photolysis of chloroform solutions has not been reported previously to our knowledge, but the free-radical addition of carbon tetrachloride or bromotrichloromethane to olefins has been studied by Kharasch and his co-workers [7] who obtained the free radicals in several ways including photolysis. Free radicals have also been produced from chloroform by reaction with diacyl peroxides [7] and have reacted with olefins:

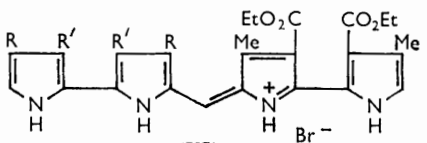
$$R{\cdot}CH{:}CH_2 + CHCl_3 \longrightarrow RCH_2{\cdot}CH_2{\cdot}CCl_3.$$

A similar product (V; R = Et) was obtained from the bipyrrole (III; R = Et; R′ = CO_2Et) by irradiation of a chloroform solution; in this case the reaction appeared to be complete in about five hours. On the other hand the reaction with the bipyrroletetracarboxylic ester (III; R = R′ = CO_2Et) was very slow and no pure product was isolated.

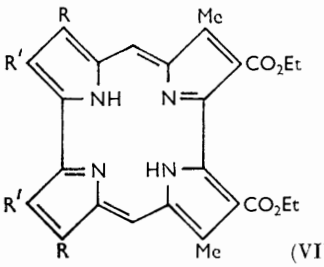
The distinction between structures (IV) and (V) for the adduct from diethyl 3,3′,4,4′-tetramethyl-2,2′-bipyrrole-5,5′-dicarboxylate (III; R = Me; R′ = CO_2Et) was made on the basis of chemical reactions; treatment with three moles of aqueous sodium hydroxide gave ethyl 5′-formyl-3,3′-4,4′-tetramethyl-2,2′-bipyrrole-5-carboxylate (III; R = Me;

[2] R. Grigg, A. W. Johnson, and J. W. F. Wasley, *J.*, 1963, 359.
[3] H. Wynberg, *Chem. Rev.*, 1960, **60**, 169.
[4] B. Robinson, *Tetrahedron Letters*, 1962, 139; C. W. Rees and C. E. Smithen, *J.*, 1964, 928.
[5] N. M. Wagner, *Proc. Chem. Soc.*, 1959, 229.
[6] W. von E. Doering and A. K. Hoffmann, *J. Amer. Chem. Soc.*, 1954, **76**, 6162.
[7] M. S. Kharasch, W. H. Urry *et al.*, *J. Amer. Chem. Soc.*, 1947, **69**, 1100, 1105.

R′ = CHO). 5-Formyl-2,2′-bipyrroles have been obtained previously [8] by direct formylation of 2,2′-bipyrroles using the Vilsmeier *NN*-dimethylformamide–phosphorous oxychloride procedure. In a parallel hydrolysis, 3,3′-diethyl-5′-formyl-4,4′-dimethyl-2,2′-bipyrrole-5-carboxylic acid was obtained from (V; R = Et). When the alkaline fission of the adduct (V; R = Me) was effected with a larger excess of sodium hydroxide the ester group was lost by hydrolysis and decarboxylation. The resulting product was treated,



(VI)

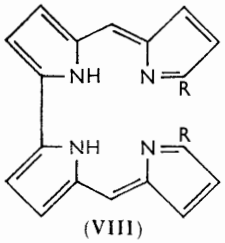


(VII)

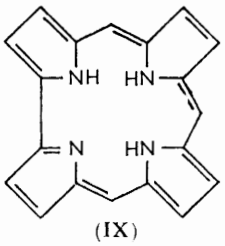
without isolation, with diethyl 4,4′-dimethyl-2,2′-bipyrrole-3,3′-dicarboxylate in presence of hydrobromic acid, and the purple product identified as (VI; R = R′ = Me), a member of the 5,5′-di(pyrrol-2-yl)dipyrromethenes. Such compounds have been prepared previously [9] by condensation of 5-formyl-2,2′-bipyrroles with unsubstituted 2,2′-bipyrroles.

The product (VI; R = R′ = Me) as well as the related compounds (VI; R = Me,Et; R′ = H) [9] failed to react with either formaldehyde or formic acid in presence of hydrobromic acid to yield macrocycles of the bi-norporphyrin type (VII).

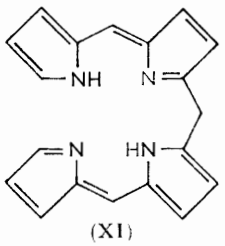
In our earlier Paper,[8] we described the condensation of 2,2′-bipyrroles with 2-formylpyrroles in an attempt to obtain the tetrapyrrolic compounds (VIII; R = H) which were potential intermediates for the synthesis of the corrole ring system (IX). It was found however that although the condensation of the first mole of the formylpyrrole with the 2,2′-bipyrrole in presence of hydrogen bromide occurred readily to give 5,5′-(pyrrol-2-yl)dipyrromethenes (X), as the hydrobromides, the terminal pyrrole ring was now so deactivated towards electrophilic attack that the condensation with the second mole of the



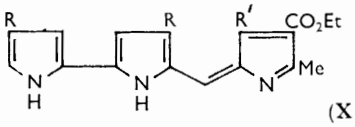
(VIII)



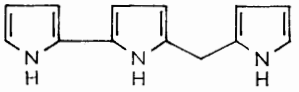
(IX)



(XI)



(X)



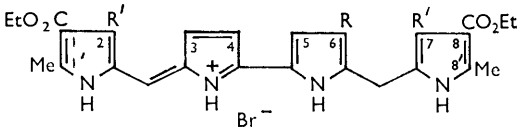
(XII)

formylpyrrole did not occur. Although the synthesis of corroles has recently been achieved in our laboratory [10] by the photocyclisation of 1′,8′-dideoxybiladienes-ac (XI), we have continued our investigations of the linear tetrapyrrolic systems based on 2,2′-bipyrrole.

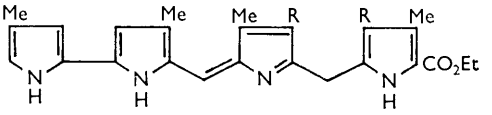
[8] E. Bullock, R. Grigg, A. W. Johnson, and J. W. F. Wasley, *J.*, 1963, 2326.
[9] R. Grigg and A. W. Johnson, *J.*, 1964, 3315.
[10] A. W. Johnson and I. T. Kay, *Proc. Chem. Soc.*, 1964, 89.

It has now been found that when the pyrrolyldipyrromethene-free bases (X) are subjected to hydrogenation, the corresponding pyrrolyldipyrromethanes (XII) can be obtained although these are unstable and were usually not isolated in the solid state. However when solutions of the pyrrolyldipyrromethanes (XII) were treated with 2-formylpyrroles in the presence of hydrogen bromide, the crystalline condensation products (XIII; R = Me,Et; R′ = Me,Et), 5″-(dipyrromethen-5-yl)dipyrromethane monohydrobromides were obtained. As expected, the visible spectra of these products resembled those of the hydrobromides of the pyrrolyldipyrromethenes (X). Experiments designed to bring about cyclisations of the condensation products (XIII), *e.g.*, by the cupric acetate technique,[11] and to dehydrogenate the salts to bi-5,5″(dipyrromethenyls) (VIII; R = Me) are in hand.

In a parallel investigation, members of the related series (XIV) have been prepared by condensation of 5′-formyldipyromethane-5-carboxylic esters with 2,2′-bipyrroles. The intermediate 5′-formyldipyrromethane-5-carboxylic esters were prepared from the corresponding 5′-carboxylic acids by decarboxylation and formylation.[12] The products (XIV) again showed spectra similar to those of the pyrrolyldipyrromethenes (X) and further transformations of these compounds are under investigation. In order to avoid cumbersome nomenclature we suggest that compounds of the types (XIII) and (XIV) might



(XIII)



(XIV)

be regarded as 1′,8′-dideoxynorbilenes, *e.g.*, (XIII) would be a 1′,8′-dideoxy-b-norbilene-a, (XIV) a 1′,8′-dideoxy-a-norbilene-b, (VI) a 1′,8′-dideoxy-ac-bisnorbilene-b, and (VIII) a 1′,8′-dideoxy-b-norbiladiene-ac, with the numbering of the rings as advocated earlier [11] and illustrated in (XIII).

Experimental

Melting points were determined on a Kofler hot-stage apparatus; ultraviolet and visible absorption spectra were determined for chloroform solutions except where otherwise stated. N.m.r. spectra were determined on an AEI RS2 instrument operating at 60 Mc./sec. tetramethyl silane being used as internal reference.

Reaction of Diethyl 3,3′,4,4′-*Tetramethyl*-2,2′-*bipyrrole*-5,5′-*dicarboxylate with Chloroform.*—(i) The 2,2′-bipyrrole ester [2] (3 g.) was dissolved in chloroform (1·8 l.) and heated under reflux for 30 min. while oxygen-free nitrogen was bubbled through the solution. The solution was cooled in an atmosphere of nitrogen and then irradiated with a water-cooled Hanovia 400w medium-pressure mercury lamp in a Pyrex apparatus while maintaining the nitrogen atmosphere. The reaction was followed spectroscopically by the disappearance of the 323 mμ band. After 14 hr., the dichroic solution (red-green) was evaporated to dryness under reduced pressure and the residual viscous oil dissolved in ether (50 ml.), filtered and then chromatographed on a column of Spence alumina, ether being used as the eluant. The first fraction, after removal of the solvent, was a gum (1·89 g.) which solidified after 4 days. The product, *ethyl* 5-*dichloromethyl*-2-(5′-*ethoxycarbonyl*-3′,4′-*dimethylpyrrol*-2′-*yl*)-3′,4′-*dimethylpyrrolenine*-5-*carboxylate* (V;

[11] A. W. Johnson and I. T. Kay, *J.*, 1961, 2418.
[12] J. H. Atkinson, University of Nottingham, unpublished observations.

R = Me) was triturated with light petroleum, filtered, washed with light petroleum, and dried in air; it (1·24 g.) then had m. p. 130—132°, raised to 134·5—136° after crystallisation from ethanol (Found, on a sample dried at 56°: C, 54·65; H, 5·95; N, 6·8; Cl, 17·6. $C_{19}H_{24}Cl_2N_2O_4$ requires C, 54·95; H, 5·85; N, 6·75; Cl, 17·1%). Light absorption (i) $\lambda_{max.}$ 258 and 319·5 mμ (ε 18,680 and 14,850, respectively) and (ii) in ethanol–0·01N-hydrochloric acid: $\lambda_{max.}$ 248, 254, 309·5, and 384·5 mμ (ε 11,630, 11,430, 4960, and 21,050, respectively). The infra-red spectrum (CCl_4 solution) contained bands at 3470 (NH), 3306 (bonded NH), 1743, 1726, 1691 (non-pyrrolic and pyrrolic esters), 1649, 1309, 1252, and 1237 $cm.^{-1}$.

(ii) The 2,2′-bipyrrole ester (3 g.) in dry chloroform (75 ml.) was stirred at room temperature in an atmosphere of nitrogen, and potassium t-butoxide (6·5 g.) was added in small portions during 2 hr. The resulting deep purple solution, which still contained most of the original bipyrrole, was stirred with 5N-hydrochloric acid (50 ml.), and the separated chloroform layer then washed with water and dried. Most of the chloroform was removed, and the unchanged bipyrrole ester (1·5 g.) crystallised from the concentrate (4 ml.). The filtrate was chromatographed on alumina (Spence type H; 4 × 40 cm.) with chloroform as eluant. More of the bipyrrole ester (0·8 g.) was obtained as the first fraction and a blue pigment (<5 mg.) having spectral properties similar to those of (VI; R = R′ = Me; see below) was obtained.

Reaction of Diethyl 3,3′4,4′-Tetramethyl-2,2′-bipyrrole-5,5′-dicarboxylate with Sodium Trichloroacetate.—The 2,2′-bipyrrole ester (3 g.) in 1,2-dimethoxyethane (100 ml.; distilled from sodium) was heated under reflux in an atmosphere of nitrogen. Sodium trichloroacetate (1·68 g.; 1 mole) was added and the mixture heated under reflux for 1½ hr. Although some sodium chloride had precipitated, determination of the ultraviolet absorption of a sample of the solution showed that most of the bipyrrole still remained. More (3·1 g.) sodium trichloroacetate was therefore added in one portion to the hot solution and a rapid reaction set in. After heating under reflux for 15 min., the solvent was removed from the cooled solution at room temperature under reduced pressure. Ether (50 ml.) and water (25 ml.) were added to the residue and, after shaking, the ethereal layer was separated, dried ($MgSO_4$), and chromatographed on a column of alumina (Spence type H; 4 × 40 cm.), ether being used as eluant. The progress of the separation was followed by ultraviolet absorption and the fraction having an absorption similar to the product (V; R = Me) of the previous experiment ($\lambda_{max.}$ 258 and 319 mμ) was collected. Removal of the solvent gave an oil which slowly solidified. When the solid (300 mg.) was crystallised from methanol it had m. p. 134·5—136° and ultraviolet and infrared spectra identical with the product of the previous experiment.

Ethyl 5′-Formyl-3,3′,4,4′-tetramethyl-2,2′-bipyrrole-5-carboxylate (III; R = Me; R′ = CHO).—The foregoing dichlorocarbene adduct (570 mg.) in methanol (50 ml.) was heated under reflux while an aqueous solution of sodium hydroxide (171 mg. in 5 ml. water) was added during 30 min. The mixture was heated under reflux for a further 15 min., and then poured into water. The *product* was separated, washed, dried, and crystallised from methanol; it then formed elliptical plates (301 mg.), m. p. 217—218° (Found: C, 66·8; H, 7·1; N, 9·85. $C_{16}H_{20}N_2O_3$ requires C, 66·65; H, 6·95; N, 9·7%); $\lambda_{max.}$ 221, 264, and 344 mμ (ε 11,530, 14,250, and 24,050, respectively); $\nu_{max.}$ 1411, 1464, 1633 (CHO), 1686 (ester carbonyl), 2862, 2930, 3034, 3277, and 3450 $cm.^{-1}$. The n.m.r. spectrum contained bands at (i) τ 7·74 (6 H of 2 nuclear methyl groups; s) and 7·93 (6 H of 2 nuclear methyl groups; s) in deuterochloroform and (ii) τ −1·86 (NH; s), −1·62 (NH; s), 0·05 (CHO; s), 5·50 (CH_2 of ester ethyl group; q) and 8·60 (CH_3 of ester ethyl group; t) in dimethyl sulphoxide.

Diethyl 1′,8′-dideoxy-1,2,3,4,5,8-hexamethyl-ac-bisnorbilene-b-6,7-dicarboxylate (VI; R = R′ = Me).—The dichlorocarbene adduct (V; R = Me; 1·43 g.) and sodium hydroxide (0·70 g.) in methanol (50 ml.) and water (10 ml.) was heated under reflux for 1 hr. The solution was cooled and diethyl 4,4′-dimethyl-2,2′-bipyrrole-3,3′-dicarboxylate [2] (1·5 g.) was added. The resulting mixture was acidified with hydrobromide acid and then heated at 60° for ½ hr. The product was poured into water (500 ml.) and then extracted with chloroform (50 ml.). The chloroform extract was washed with dilute ammonium hydroxide and then water and dried. The volume of the extract was reduced to 20 ml. and then chromatographed on alumina (Spence type " H "; 4 × 40 cm.), chloroform being used as the eluant. The purple band was collected, and the eluate washed with aqueous hydrobromic acid and dried. The solvent was removed and the residue crystallised from chloroform–methanol when it formed green needles (420 mg.) (Found: C, 59·8; H, 6·05; N, 9·7. $C_{29}H_{35}BrN_4O_4$ requires C, 59·7; H, 6·05; N, 9·6%); $\lambda_{max.}$ (in EtOH containing one drop hydrobromic acid) 238, 292, 338, 422, and 621 mμ (ε 18,850,

19,230, 23,150, 7500, and 53,700, respectively). The free base showed $\lambda_{max.}$ 237, 328, and 544 mμ (ε 19,500, 33,700, and 27,100, respectively). The infrared spectrum showed $\nu_{max.}$ 1549, 1580, 1593, 1616, and 1703 cm.$^{-1}$ in the carbonyl region. The n.m.r. spectrum, determined on a trifluoroacetic acid solution, contained bands at τ −1·17 (NH, s), −0·95 (NH, s), −0·13 (NH, s), 2·40 (dipyrromethene CH, s), 2·98 (2″,2‴-hydrogens, s), 5·14 (ester CH_2, q), 5·45 (ester CH_2, q), 7·35 (methyl, s), 7·45 (2 methyls, s), 7·64 (methyl, s), 7·78 (methyl, s), 7·83 (methyl, s), 8·37 (ester methyl, t), and 8·49 (ester methyl, t).

Reaction of Diethyl 3,3′-Diethyl-4,4′-dimethyl-2,2′-bipyrrole-5,5′-dicarboxylate with Chloroform.—The 2,2′-bipyrrole ester [2] (3·2 g.) was dissolved in chloroform (1·8 l.) and purged with nitrogen as described above for the tetramethyl-2,2′-bipyrrole ester. The solution was irradiated as before and the reaction followed spectroscopically by the disappearance of the band at 315 mμ. After 5½ hr. the solution was evaporated to dryness under reduced pressure. The residual viscous oil was dissolved in ether (50 ml.), the solution filtered and chromatographed on Spence alumina (type " H ") ether being used as eluant. The first fraction, after removal of solvent, was a gum (1·89 g.) which solidified when kept for 4 days. The solid was triturated with light petroleum, separated, washed with light petroleum and dried in air; the product (917 mg.), m. p. 102·5—104°, crystallised from ethanol as needles (Found, on a sample dried at 56° *in vacuo*: C, 56·8; H, 6·05; N, 6·55; Cl, 15·4. $C_{21}H_{28}Cl_2N_2O_4$ requires C, 56·9; H, 6·35; N, 6·3; Cl, 16·0%); $\lambda_{max.}$ (i) 259 and 317 mμ (ε 17,750 and 11,540, respectively), (ii) in ethanol–0·01N-hydrochloric acid $\lambda_{max.}$ 249, 301, and 390 mμ (ε 8650, 3150, and 16,910, respectively), $\lambda_{infl.}$ 215 and 254 mμ (ε 5520 and 8270, respectively). The infrared spectrum (CCl_4 solution) contained bands at 3476, 3467 (NH), 3302 (bonded NH), 1745, 1729, 1693 (non-pyrrolic and pyrrolic esters), 1646, 1305, 1262, and 1233 cm.$^{-1}$. The n.m.r. spectrum ($CHCl_3$ solution) contained the following absorptions: 4 overlapping triplets at τ 9·02, 8·91, 8·73, and 8·61 (methyls of of nuclear ethyl groups and ethyl esters), singlets at 7·9 and 7·64 (nuclear methyl groups), 2 overlapping quartets at 7·51 and 7·37 (methylenes of nuclear ethyl groups), a distorted quartet at 5·72 (methylenes of ethyl esters), a singlet at 3·51 (proton of the dichloromethyl group), and a broad singlet at 0·65 (NH).

3,3′-Diethyl-5′-formyl-4,4′-dimethyl-2,2′-bipyrrole-5-carboxylic Acid.—The foregoing dichloromethyl derivative (V, R = Et; 1·0 g.) and sodium hydroxide (507 mg.) in methanol (25 ml.) and water (10 ml.) were heated under reflux for 30 min. The methanol was then removed by distillation, water being added to keep the volume of the solution at *ca.* 30 ml. The solution was then acidified (Congo Red) with dilute hydrochloric acid, and the product (411 mg.) separated, washed, and dried. It crystallised from methanol as plates, m. p. 241—243° (decomp.) (Found: C, 66·3; H, 7·0; N, 10·05. $C_{16}H_{20}N_2O_3$ requires C, 66·7; H, 6·95; N, 9·75%); $\lambda_{max.}$ 221, 267, and 331 mμ (ε 10,270, 15,200, and 19,620 respectively); $\nu_{max.}$ (KBr disc) 1428, 1463, 1476, 1588, 1615 (CHO), 1665 (carboxyl), 2470, 2526, 2580, 2750, 2930, 2968, 3065, 3140, and 3250 cm.$^{-1}$.

Diethyl 1′,8′-Dideoxy-1′,2,3,6,7,8′-hexamethyl-b-norbilene-a-1,8-dicarboxylate Hydrobromide (XIII; R = R′ = Me).—Ethyl 3,3′,5′-trimethyl-5-(4-methylpyrrol-2-yl)dipyrromethene-4′-carboxylate (X; R = R′ = Me; 100 mg.; prepared by basification of the hydrobromide [8] with dilute ammonium hydroxide), was suspended in ethanol (75 ml.) and hydrogenated at room temperature and atmospheric pressure over a platinum (Adams) catalyst. At the end of the reaction, oxygen-free nitrogen was bubbled through the colourless solution for 1 min. A solution of ethyl 2-formyl-3,5-dimethylpyrrole-4-carboxylate [12] (112 mg.; 2 mole) in ethanol (10 ml.) was added followed immediately by a 50% (w/v) solution (0·25 ml.) of hydrogen bromide in acetic acid; the solution immediately changed from almost colourless to deep violet. The flask was stoppered and kept at 0° for 30 min. The dark green amorphous *hydrobromide* (105 mg.; 59%) was separated and crystallised from chloroform–light petroleum, forming green micro-prisms (82 mg.), m. p. 243—245° (decomp.) (Found: C, 60·1; H, 6·0; N, 9·75. $C_{30}H_{37}BrN_4O_4$ requires C, 60·3; H, 6·2; N, 9·35%); $\lambda_{max.}$ 270, 305, 388, 400, and 585 mμ (ε 9520, 16,600, 6350, 6030, and 83,500, respectively), $\lambda_{infl.}$ 555 mμ (ε 53,300).

Diethyl 1′,8′-Dideoxy-3,6-diethyl-1′,2,7,8′-tetramethyl-b-norbilene-a-1,8-dicarboxylate Hydrobromide (XIII; R = Et, R′ = Me).—This was prepared by a similar method from ethyl 3-ethyl-3′,5′-dimethyl-5-(4-ethylpyrrol-2-yl)dipyrromethene-4-carboxylate [8] (X; R = Et, R′ = Me; 100 mg.) and ethyl 2-formyl-3,5-dimethylpyrrole-4-carboxylate [13] (105 mg.; 2

[13] H. Fischer and W. Zerweck, *Ber.*, 1922, **55**, 1942.

mole) giving the *salt* as a green amorphous solid (119 mg.; 70%) which crystallised from chloroform–light petroleum as greenish violet microcrystals, m. p. 234—236° (decomp.) (Found: C, 61·3; H, 6·5; N, 9·15. $C_{32}H_{41}BrN_4O_4$ requires C, 61·4; H, 6·55; N, 8·95%); $\lambda_{max.}$ 272, 305, 390, 400, and 585 mμ (ε 10,400, 16,640, 6240, 6240, and 77,100, respectively), shoulder at 555 mμ (ε 50,400).

4-Ethoxycarbonyl-3-ethyl-5-methylpyrrole-2-carboxylic Acid.—Diethyl 3-ethyl-5-methylpyrrole-2,4-dicarboxylate [14] (10 g.) in ethanol (150 ml.) was heated under reflux for 4 hr. with a solution of sodium hydroxide (1·58 g.) in water (60 ml.). The ethanol was slowly removed by distillation and water (100 ml.) added to the residue. A small amount of unchanged diester which precipitated was separated, and the filtrate then acidified with dilute hydrochloric acid. The *product* was separated, washed, and dried at 75° for 4 hr. The white solid (8·2 g.; 92%) crystallised from ethanol as needles, m. p. 190—191° (Found: C, 58·3; H, 6·5; N, 6·2. $C_{11}H_{15}NO_4$ requires C, 58·65; H, 6·7; N, 6·2%).

Ethyl 4-Ethyl-2-methylpyrrole-3-carboxylate.—The foregoing acid (2·68 g.) was dissolved in ethanolamine (1 ml.) and the solution heated under reflux for 3 hr. On pouring the solution into cold water (25 ml.), the *product* separated as an oil which quickly solidified. The solid was separated, washed, and dried, and then crystallised from light petroleum when it was obtained as small needles (1·5 g.; 70%), m. p. 75—77° (Found: C, 66·0; H, 8·3; N, 7·8. $C_{10}H_{15}NO_2$ requires C, 66·25; H, 8·35; N, 7·75%). The infrared spectrum contained max. at 1695 (ester carbonyl) and 3480 (NH) $cm.^{-1}$.

Ethyl 3-Ethyl-2-formyl-5-methylpyrrole-4-carboxylate.—The above pyrrole ester (5·6 g.) was dissolved in dry ether (30 ml.) and *NN*-dimethylformamide (2·25 ml.) added with stirring. A solution of redistilled phosphorus oxychloride (2·9 ml.) in dry ether was added during 10 min., a red oil separating. The mixture was stirred at room temperature for a further 30 min., and the ether was then decanted from the oil which was dissolved in water (50 ml.). 10% Aqueous sodium hydroxide was added to the solution until the precipitation of the product was complete. The *formyl* derivative was separated, washed with water, and crystallised from ethanol, forming long colourless needles (4·1 g.; 63%), m. p. 126—127° (Found: C, 62·8; H, 7·5; N, 6·55. $C_{11}H_{15}NO_3$ requires C, 63·15; H, 7·2; N, 6·7%). The infrared spectrum contained bands at 1635 (formyl carbonyl), 1695 (ester carbonyl), 3250 (bonded NH) and 3420 (NH) $cm.^{-1}$.

Ethyl 3-Ethyl-3',5-dimethyl-5'-(4-methylpyrrol-2-yl)dipyrromethene-4-carboxylate Hydrobromide (X; R = Me, R' = Et).—Ethyl 3-ethyl-2-formyl-5-pyrrole-4-carboxylate (1·57 g.) was dissolved in ethanol (50 ml.) and a stream of nitrogen passed through the solution for 5 min. 4,4'-Dimethyl-2,2'-bipyrrole [2] (0·6 g.) was added and after this had dissolved, a solution of hydrogen bromide (50%, w/v) in acetic acid (4 ml.). The flask was stoppered and kept overnight at 0°; the *product* was then obtained as blue-green needles (1·52 g.; 94%), which were crystallised from chloroform–light petroleum. The salt was thus obtained as violet needles which did not melt <300° (Found: C, 58·6; H, 6·25; N, 9·75. $C_{21}H_{26}BrN_3O_2$ requires C, 58·4; H, 6·0; N, 9·7%); $\lambda_{max.}$ 270, 299, 378, 393, and 566 mμ (ε 7280, 13,790, 5750, 5600, and 105,300, respectively), $\lambda_{infl.}$ at 535 mμ (ε 57,400).

Diethyl 1',8'-Dideoxy-2,7-diethyl-1',3,6,8'-tetramethyl-b-norbilene-a-1,8-dicarboxylate Hydrobromide (XIII; R = Me, R' = Et).—Prepared by the method described above from the product of hydrogenation of the foregoing 5-pyrrolyldipyrromethene free base (100 mg.) and ethyl 3-ethyl-2-formyl-5-methylpyrrole-4-carboxylate (128 mg.; 2 mole) giving the crude *product* (60 mg.; 34%) which was crystallised from chloroform–light petroleum to give glistening green prisms (46 mg.), m. p. 235—237° (decomp.) (Found: C, 61·5; H, 7·0; N, 8·75. $C_{32}H_{41}BrN_4O_4$ requires C, 61·4; H, 6·55; N, 8·95%); $\lambda_{max.}$ 273, 306, 376, 400, and 586 mμ (ε 10,340, 16,030, 5170, 4910, and 86,200, respectively), $\lambda_{infl.}$ 555 mμ (ε 53,000).

Ethyl 3,3',4,4'-Tetramethyldipyrromethane-5-carboxylate.—Diethyl 3,3',4,4'-tetramethyldipyrromethane-5,5'-dicarboxylate [15] (11 g.) was dissolved in a mixture of ethanol (500 ml.) and dioxan (40 ml.), and the solution heated under reflux. A solution of sodium hydroxide (1·27 g.; 1 mole) in water (10 ml.) was added to the refluxing solution during 5 hr., and the mixture heated under reflux for a further 3 hr. The ethanol was removed by distillation under reduced pressure and the residue extracted with boiling water (300 ml.). The hot solution was filtered and sodium chloride (50 g.) added to the filtrate, whereby the sodium salt of the monocarboxylic acid was precipitated after storage overnight. The sodium salt was separated,

[14] H. Fischer and G. Stangler, *Annalen*, 1927, **459**, 53.
[15] H. Fischer and B. Walach, *Annalen*, 1926, **450**, 109.

dissolved in water at 80°, and the solution acidified with glacial acetic acid. The acid was separated, dried *in vacuo* (P_2O_5) for 5 hr. The acid was then sublimed at 180—190°/0·2 mm. decarboxylation occurring to give the *monocarboxylic ester* as small colourless needles (1·24 g.; 14%), m. p. 114—119°, which was purified by sublimation at 160°/0·2 mm. The ester formed colourless needles, m. p. 117·5—118° (Found: C, 70·0; H, 8·0; N, 9·9. $C_{16}H_{22}N_2O_2$ requires C, 70·05; H, 8·1; N, 10·2%). The product gave a strong red-violet Ehrlich reaction in the cold.

Ethyl 5'-Formyl-3,3',4,4'-tetramethyldipyrromethane-5-carboxylate.—The foregoing ester (510 mg.) was dissolved in *NN*-dimethylformamide (10 ml.) and a solution of redistilled phosphorus oxychloride (0·17 ml.) in *NN*-dimethylformamide was added during 5—10 min. The mixture was stirred for 4 hr., during which some of the intermediate salt crystallised. The suspension was poured into ice–water (200 ml.) and 10% aqueous sodium hydroxide solution was added until precipitation of the product was complete. The *product* was separated, dried, and crystallised from ethanol; it was then obtained as colourless needles (338 mg.; 60%), m. p. 190—191° (Found: C, 67·3; H, 7·55; N, 9·4. $C_{17}H_{22}N_2O_3$ requires C, 67·5; H, 7·3; N, 9·25%).

Ethyl 1',8'-Dideoxy-1,4,5,6,7,8-hexamethyl-a-norbilene-b-8'-carboxylate (XIV; R = Me).—Ethyl 5'-formyl-3,3',4,4'-tetramethyldipyrromethane-5-carboxylate (253 mg.) was suspended in methanol (30 ml.) and a current of oxygen-free nitrogen passed through the solution for 5 min. 4,4'-Dimethyl-2,2'-bipyrrole [2] (135 mg.; 1 mole) was added while maintaining the nitrogen stream, and after 5 min., a 50% (w/v) solution (1·3 ml.) of hydrogen bromide in acetic acid was added and thoroughly mixed. The solution immediately turned violet and the product crystallised from the reaction mixture as small violet needles (359 mg.; 82%) and crystallised from chloroform–light petroleum as violet needles which did not melt below 350° (Found: C, 61·6; H, 6·65; N, 10·5. $C_{27}H_{33}BrN_4O_2$ requires C, 61·5; H, 6·25; N, 10·6%); $\lambda_{max.}$ 282, 400, and 582 mμ (ε 21,100, 7300, and 103,500, respectively); $\lambda_{infl.}$ 294, 303, 380, and 550 mμ (ε 19,080, 17,850, 6900, and 44,700, respectively).

Ethyl 1',8'-Dideoxy-6,7-diethyl-1,4,5,8-tetramethyl-a-norbilene-b-8'-carboxylate (XIV; R = Et).—This was prepared similarly from ethyl 3,3'-diethyl-5'-formyl-4,4'-dimethyldipyrromethane-5-carboxylate [12] (1·68 g.), m. p. 171·5—172·5°, and 4,4'-dimethyl-2,2'-bipyrrole [2] (814 mg.; 1 mole). The green prisms (2·09 g.; 78%) which separated from the reaction mixture were separated, washed with a little methanol, and crystallised from chloroform–light petroleum, they then had m. p. 238—240° (decomp.) (Found: C, 62·5; H, 7·05; N, 10·2. $C_{29}H_{37}BrN_4O_2$ requires C, 62·9; H, 6·7; N, 10·1%); $\lambda_{max.}$ 282, 400, and 582 mμ (ε 23,100, 7095, and 101,900, respectively); $\lambda_{infl.}$ 303, 380, and 555 mμ (ε 17,720, 6075, and 44,300, respectively).

Triethyl 1,4,5,8-Tetramethyl-a-norbilene-b-6,7,8'-tricarboxylate (XIV; R = CO_2Et).—Prepared by a similar method from triethyl 5-formyl-4,4'-dimethyldipyrromethane-3,3',5-tricarboxylate [12] (1·5 g.), m. p. 157·5—159°, and 4,4'-dimethyl-2,2'-bipyrrole [2] (0·58 g.; 1 mole), the *product* separated as small red-violet needles which were crystallised from chloroform–light petroleum; they then had m. p. 210—212° (decomp.) (Found: C, 58·3; H, 5·95; N, 8·7. $C_{31}H_{37}BrN_4O_6$ requires C, 58·05; H, 5·75; N, 8·75%); $\lambda_{max.}$ 272, 299, 382, 396, and 564 mμ (ε 20,300, 14,200, 6080, 6280, and 66,300, respectively); $\lambda_{infl.}$ 536 mμ (ε 43,400).

Ethyl 1,4,6,7-Tetraethyl-5,8-dimethyl-a-norbilene-b-8'-carboxylate.—Prepared similarly from ethyl 3,3'-diethyl-5-formyl-4,4'-dimethyldipyrromethane-5-carboxylate [12] (196·5 mg.) and and 4,4'-diethyl-2,2'-bipyrrole [2] (111·5 mg.; 1 mole), the *product* separated as green prismatic needles (153 mg.; 44%), m. p. 224—227° (decomp.) (from chloroform–light petroleum) (Found: C, 64·2; H, 6·95; N, 9·65. $C_{31}H_{41}BrN_4O_2$ requires C, 64·1; H, 7·05; N, 9·65%); $\lambda_{max.}$ 282, 400, and 583 mμ (ε 20,500, 7690, and 98,600, respectively); $\lambda_{infl.}$ 302, 383, and 550 mμ (ε 17,420, 7180, and 43,600, respectively).

We thank the D.S.I.R. for Maintenance Grants (to D. D. and J. L.) and the Glaxo Triangle Trust for a grant (to R. G.).

DEPARTMENT OF CHEMISTRY, THE UNIVERSITY, NOTTINGHAM. [*Received, July 29th,* 1964.]