Porphyrinogens and Porphodimethenes, Intermediates in the Synthesis of *meso*-Tetraphenylporphins from Pyrroles and Benzaldehyde.

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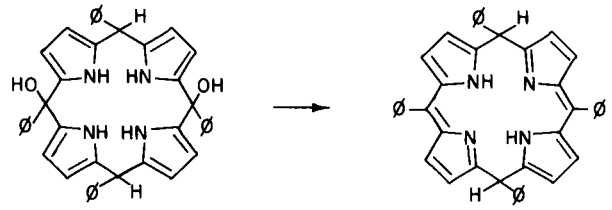
The reaction between pyrroles and benzaldehyde in refluxing acetic acid gives *meso*-tetraphenylporphins and chlorins. The initial condensations give a porphyrinogen which undergoes an acid catalyzed autoxidation to porphyrin *via* a porphodimethene. The chlorin is shown to be derived from the reduction of porphyrin.

INTRODUCTION

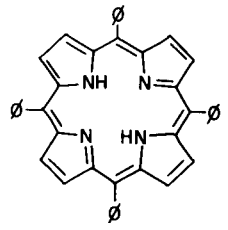
The reaction between pyrrole and aldehydes represents one of the first syntheses of *meso*-substituted porphyrins (1), and at the present time affords the most convenient route to the large scale preparation of synthetic porphyrins. In 1939, Rothemund (2) isolated *meso*-tetraphenylporphin (TPP) (**1**) from a sealed tube reaction of pyrrole and benzaldehyde in pyridine at 150°. It was later found (3) that the addition of zinc acetate to the reaction improved the yield of porphyrin, and these conditions have been widely used in the preparation of a variety of *meso*-substituted porphyrins (4). Under these reaction conditions yields rarely exceed 10%, and the porphyrin is invariably contaminated with the corresponding chlorin **2**. The occurrence of chlorin, coupled with the isolation of a zinc dipyrromethene led Badger (5) to postulate that the mechanism of the Rothemund reaction could be visualized as proceeding through the macrocycle **3**. This macrocycle is capable of eliminating two molecules of water to give the dihydroporphyrin **4**. Rearrangement would then give a chlorin, or oxidation a porphyrin, thereby accounting for the experimentally observed products.



(3) (4)

An examination of the stoichiometry of the reaction shows that the formation of a mole of TPP, from four moles of pyrrole and four of benzaldehyde, requires six oxidizing equivalents. Accordingly the yield of porphyrin increased from 10 to 40% when the Rothemund reaction was carried out in refluxing acetic acid, rather than under the anaerobic conditions of the sealed tube (6).

These more amenable conditions, and higher yields of porphyrin, resulted in a series of detailed mechanistic studies (6,7) which showed that during the acid catalyzed reaction, water rapidly appeared as a reaction product, an oxidant was required for porphyrin formation, and *meso*-tetraphenylchlorin (TPC) (**2**) appeared concomitantly with TPP. While these studies led to no definitive mechanism, the intermediacy of a phlorin **5**, which might rearrange to chlorin or to be oxidized to a porphyrin, was suggested.



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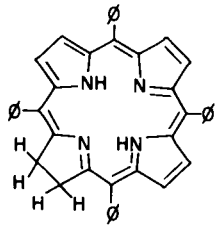

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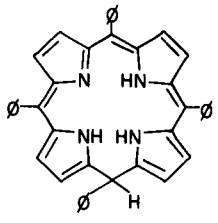

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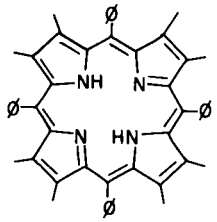


(6)

Inspection of space filling models of 2,3,7,8,12,13,17,18-octamethyl-5,10,15,20-tetraphenylporphyrin (OMTPP) (**6**) (8) indicated that even when the four phenyl groups were placed perpendicular to the plane of the porphyrin nucleus considerable steric interaction between the phenyl and methyl groups was still to be expected. The diffuse ill-defined absorption spectrum of OMTPP compared to that of TPP (Figure 1) is an indication of these interactions.

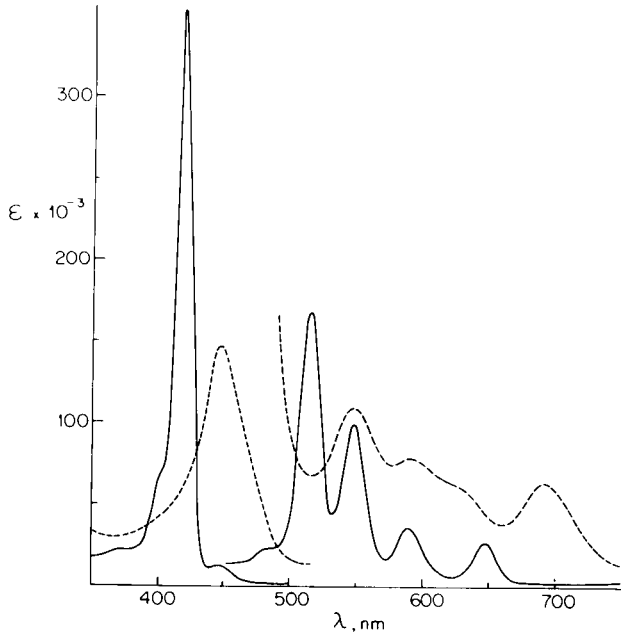


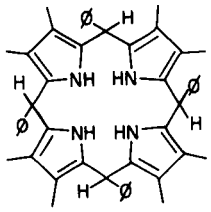
Figure 1. Visible absorption spectra (CH_2Cl_2) of *meso*-tetraphenylporphin (1) (———), and *meso*-tetraphenyl-octamethylporphin (6) (– – – –).

Further, it was noted that alkyl-substituted pyrroles are more susceptible to electrophilic attack than pyrrole itself. These observations suggested that during the reaction between 3,4-dimethylpyrrole and benzaldehyde the initial condensation steps should be fast, while the subsequent oxidations, leading to "planar intermediates" should be slow. These conditions favor the accumulation, and thereby isolation, of reaction intermediates.

RESULTS

When followed spectrophotometrically the reactions of benzaldehyde with pyrrole, or 3,4-dimethylpyrrole, in refluxing acetic acid showed the same general pattern. With dimethylpyrrole an initial increase in absorption at 518 nm decreased as a band at 426 nm (the Soret band of protonated OMTPP) increased in intensity. During the reaction with pyrrole an initial increase in absorption at 482 nm was replaced by a band at 438 nm (the Soret band of protonated TPP. The similarity in these spectroscopic changes and the isolation of comparable amounts of *meso*-substituted porphyrins (42% OMTPP; 38% TPP) suggested that the same mechanism for the formation of porphyrin was operative.

Equimolar amounts of 3,4-dimethylpyrrole and benzaldehyde were added to acetic acid at 50°; after five minutes the solvent was removed leaving a deep-purple viscous oil. Trituration of this oil with deoxygenated benzene gave a white crystalline product. Analytical and spectroscopic data (Table I) suggested that this material was the porphyrinogen **7**. This assignment was confirmed when **7** was oxidized by six equivalents of iodine to OMTPP. Only starting materials were recovered from a similar reaction of pyrrole with benzaldehyde. However, on refluxing this mixture for 45 minutes, the porphyrinogen **8**, identical to the porphyrinogen prepared from the Zn/acetic acid reduction of TPP, was isolated in low yield.



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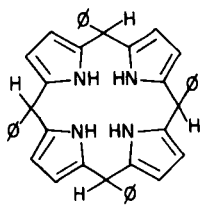


(8)

The slower overall rate of oxidation of **7** relative to **8** (Figure 2) presented an opportunity to study the oxidation levels between the porphyrinogen **7** and OMTPP. The

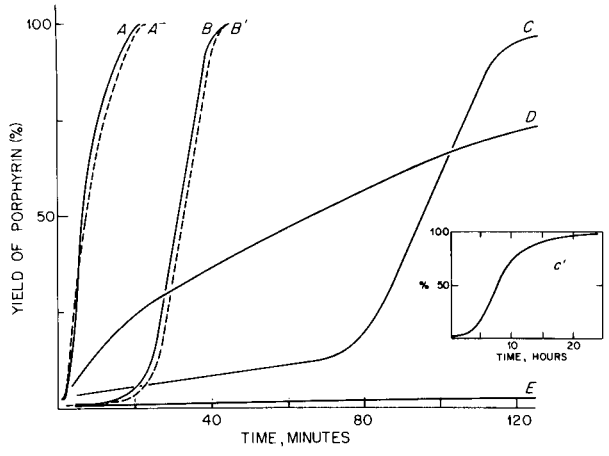
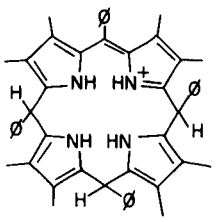


Figure 2. (**A**) Photolysis of tetraphenylporphyrinogen (**8**) in glacial acetic acid; (**A'**) Photolysis of **8** in 0.1 *M* HCl/CH_2Cl_2; (**B**) Photolysis of octamethyl tetraphenyl-porphyrinogen (**7**) in glacial acetic acid; (**B'**) Photolysis

of 7 in 0.1 *M* HCl/CH_2Cl_2; (**C**) Oxidation of **8** in acetic acid in the absence of light; (**C'**) Oxidation of **7** in acetic acid in the absence of light; (**D**) Photolysis of **8** in methylene dichloride; (**E**) Oxidation of **7** in methylene dichloride. All reactions were carried out on 2.4×10^{-4} *M* solutions open to the air. Solutions were photolyzed in a 1 cm quartz cell surrounded by water at 30° and placed 50 cm from a 150 w tungsten bulb. During the prolonged photolyses fresh solvent was added, when needed, to maintain a constant volume.

autoxidation of the colorless porphyrinogen **7** in acetic acid showed the same spectral changes as the uninterrupted reaction between benzaldehyde and dimethylpyrrole. A transient absorption appeared at 518 nm which then decayed as the spectrum of protonated OMTPP appeared. Both the porphomethene **9** and the porphodimethene **10** would be expected to show similar absorption in the visible region, but attempts to isolate the species absorbing at 518 nm were unsuccessful. When, however, the oxidation of **7** was stopped at the point of highest absorbance



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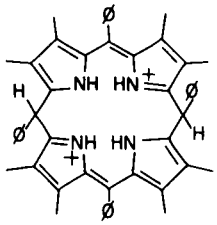


(10)

at 518 nm and zinc acetate added to the reaction mixture, a product **11**, identified as the zinc complex of the porphodimethene **10**, was isolated along with unoxidized porphyrinogen and ZnOMTPP.

To a close approximation the chromophore of the porphodimethene **11** can be considered as consisting of two isolated dipyrromethene units. Dipyrromethenes substituted at the *meso* position by a phenyl group have not previously been reported. The reaction between cryptopyrrole and benzaldehyde was reported (9) to lead to dark intractable products. However, the reaction between 2,3,4-trimethylpyrrole and benzaldehyde, in ethanolic hydrogen chloride, gave a high yield of white crystalline

TABLE I

NMR Spectra

Compound	Chemical Shifts (δ)				
	meso-H	*meso*-Phenyl	β-H	β-Methyl	N-H
1 (a)		8.42 (m, 8) 7.69 (m, 12)	8.68 (s, 8)		−2.02 (bs, 4)
6 (a)		[8.32 (m), 7.90 (m), 7.50 (m), 20]		1.84 (s, 24)	−0.76 (bs, 4)
7 (b)	5.34 (s, 4)	7.0 (m), 20)		1.77 (s, 24)	6.41 (bs, 4)
8 (b)	5.38 (s, 4)	7.24 (s, 20)	5.68 (d, J=6Hz, 4) 5.78 (d, J=6Hz, 4)		8.2 (bm, 4)
11 (b)	5.52 (s, 2)	[7.40 (m), 7.21 (m), 7.01 (m), 20]		1.90 (s, 12); 1.77 (s, 12)	
12 (b)	5.41 (s, 1)	7.24 (s, 5)		2.07 (s, 6), 1.92 (s, 6), 1.77 (s, 6)	7.07 (bs, 2)
13 (b)		7.16 (m, 5)		2.04 (s, 6), 1.90 (s, 6), 1.80 (s, 6)	
14 (b)	7.37 (m, 3) 7.20 (m, 2)		2.05 (s, 6), 1.90 (s, 6), 1.77 (s, 6)		

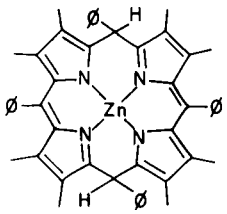
(a) 10% Trifluoroacetic acid in deuteriochloroform. (b) Deuteriochloroform.

meso-phenyl-3,3',4,4',5,5'-hexamethyl-2,2'-dipyrromethane (**12**), which upon oxidation was quantitatively converted to the corresponding dipyrromethene **13**. In agreement with our proposed structure, the visible absorption spectrum of the zinc complex **11** was similar, both in intensity and position, to that of the complex **14** (Table II). Moreover the chemical shifts of the *meso*-protons and β-methyl groups of **11** were compatible to those of the dipyrromethane **12** and to the zinc dipyrromethene **14** (Table I).

TABLE II

Visible Absorption Spectra

Compound	λ max nm (ethanol)	(ϵ x 10^{-3})
10	518	(301.5)
11	519	(317.2)
13	516	(159.4)
14	507	(307.6)



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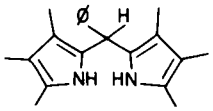

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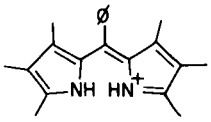

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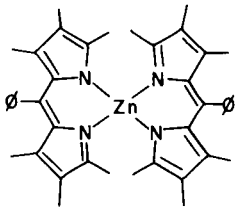
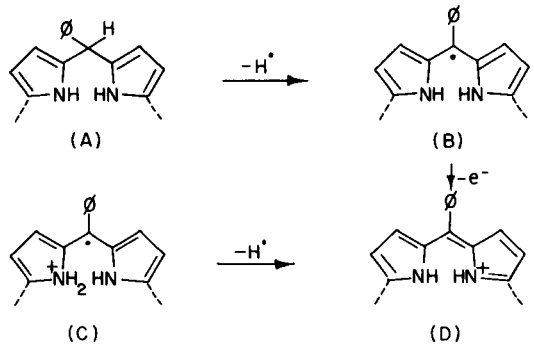


(14)

Acid Catalysis of Porphyrinogen Oxidation.

The autoxidation of the porphyrinogens **7** and **8** was found to be autocatalytic and catalyzed by light. The addition of porphyrin to the reaction mixture before photoxidation eliminated the induction period shown in Figure 2 (curves **A**, **A'**; **B**, **B'**). Porphyrins have been used to photosensitize the formation of singlet oxygen (10), but the higher energy of the photosensitized system, rather than a specific role for singlet oxygen, can account for faster rates of the irradiated systems.

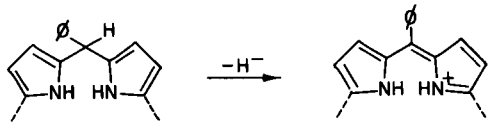
The acid catalysis shown during the oxidation of the porphyrinogens was also exhibited by the dipyrromethane **12**. On the other hand oxidation of the zinc porphodimethene (**11**) was catalyzed by light, but not acid. This suggested that the catalysis was associated with a protonation on nitrogen. No specific mechanism has been elucidated for this acid catalysis, but protonation could influence the radical oxidation in the following manner. The oxidation of a methane unit **A** to the resonance stabilized radical **B** involves the removal of a hydrogen atom.



(A) (B) (C) (D)

The loss of an electron from **B** gives the protonated methene **D**. It is possible, however, that the loss of a further hydrogen atom is more facile than electron transfer. In order to generate **D** from **B** by loss of a hydrogen atom, an initial protonation to give **C** is required.

We have so far assumed that the acid catalyzed autoxidation is free radical in nature, and that the catalysis is a function of protonation on a pyrrolic nitrogen. However, the oxidation of xanthene by oxygen to the xanthyl cation is acid catalyzed and it has been suggested (11) that the hydroperoxy (HO_2^+) cation may play the role of a hydride acceptor in this reaction. A similar acid catalyzed autoxidation of triphenylmethane to triphenylmethyl cation has been observed (12). The similarity in structure between triphenylmethane and *meso*-phenyldipyrromethanes (**A**) coupled with the hydride donating ability of triphenylmethane suggest that the oxidation of **A** might be envisaged as a hydride transfer to the hydroperoxy cation to give directly the protonated methene **D**.

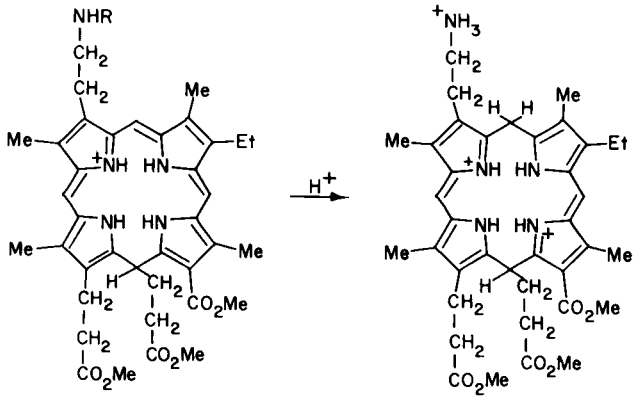


(A) (D)

Porphodimethenes.

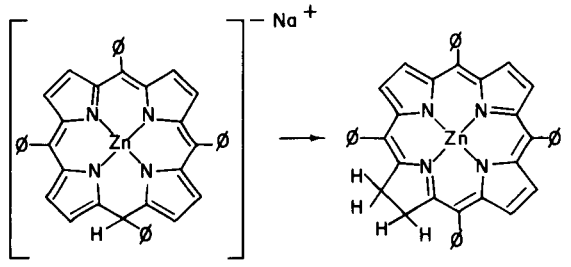
The central role of uroporphyrinogen (**21**) in the biosynthesis of naturally occurring tetrapyrrolic macrocycles has resulted in a number of studies on its oxidation to uroporphyrin (13-15). During the oxidation an absorption at 500 nm increased in intensity and then decayed as the spectrum of uroporphyrin appeared. On the basis of these spectroscopic changes Mauzerall (16) suggested that both a porphomethene and a porphodimethene were intermediates in the formation of uroporphyrin. The spectroscopic changes observed during the oxidation of the porphyrinogen **7** parallel those of uroporphyrinogen oxidation, and the mediation of a porphodimethene in the natural system is supported by the isolation of the zinc porphodimethene **11**.

The visible absorption spectrum of the zinc porphodimethene **11** in methylene dichloride did not change over a period of several days even upon the addition of either acetic acid or triethylamine. Photolysis of these solutions in the presence of oxygen brought about the smooth oxidation of **11** to ZnOMTPP. The appearance of isosbestic points when the reaction was followed spectrophotometrically showed that no other products were formed. When **11** was treated with trifluoroacetic acid the metal was removed regenerating the porphodimethene **10** which absorbed at 518 nm. The visible absorption spectra of **10** under these acidic conditions did not change over a period of several days, while in the presence of oxygen diprotonated OMTPP, *but none of the corresponding chlorin*, was produced. These reactions of the protonated porphodimethene **10** are in accord with the observations of Woodward (17) who showed that the phlorin salt **15** was protonated, under strongly acidic conditions, to give the porphodimethene **16**. Once again oxidation of this system gave porphyrin *but no chlorin* (18).



(15) (16)

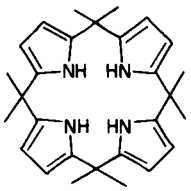
In contrast Closs (19) has shown that zinc *meso*-tetraphenylphlorin **17** (prepared by the protonation of the π-dianion of TPP) slowly rearranged, in the presence of excess methanol, to zinc tetraphenylchlorin (**18**).



(17) (18)

The Mechanism of the Rothemund Reaction.

The rapid formation of the porphyrinogen **7**, its isolation in yields comparable to those of OMTPP isolated from the uninterrupted reaction (31% porphyrinogen, 43% porphyrin), and its quantitative oxidation to OMTPP show this porphyrinogen to be the principal intermediate in the synthesis of OMTPP from 3,4-dimethylpyrrole and benzaldehyde. This facile cyclization of a monopyrrole to a porphyrinogen has a number of analogies. The reaction between pyrrole and acetone (20) gives, in high yield, the non-oxidizable acetonepyrrole (**19**). Porphobilinogen (**20**) is cyclized under both acidic (21) and enzymic (16) conditions to uroporphyrinogen III (**21**) which serves as a common intermediate for the biosynthesis of porphyrins and chlorins.



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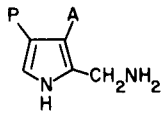
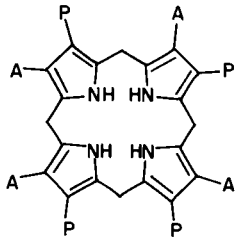


(20)

A = $-CH_2CO_2H$

P = $-CH_2CH_2CO_2H$



(21)

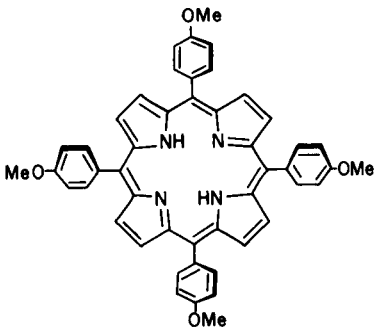
Although the reactions between benzaldehyde and pyrrole or 3,4-dimethylpyrrole showed similar spectroscopic changes, only a 7% yield of porphyrinogen **8** was isolated compared to 31% of **7**. This low yield of **8** does not exclude it from being the principal precursor of TPP, since the lower concentration of **8** relative to that of **7** is consistent with the rapid oxidation of **8** to TPP, and the low susceptibility of pyrrole towards electrophilic attack. Isolation of the porphodimethene (**11**) determines the pathway of porphyrin formation, since the porphomethene (**9**) must be the intermediate between the porphyrinogen **7** and the porphodimethene **10**.

Briefly the formation of *meso*-substituted porphyrins from pyrroles and benzaldehyde can be summarized as follows:

4 Pyrrole + 4 Benzaldehyde → Porphyrinogen + 4 H_2O
↓
Porphomethene
↓
Porphodimethene
↓
Porphyrin.

The Origin of Chlorin in the Rothemund Reaction.

The occurrence of chlorin in both the acid catalyzed and sealed tube preparations of *meso*-substituted porphyrins has been the major influence on the mechanisms postulated for the Rothemund reaction (5-7). Either a common intermediate capable of rearrangement to chlorin and oxidation to porphyrin, or the direct formation of chlorin followed by partial oxidation to porphyrin has been suggested. Oxidation, under the conditions employed in the acid catalyzed reaction, of either porphyrinogen **7** or **8** leads only to the corresponding porphyrin, even though any chlorin formed would be stable (7). This implies that an alternate pathway may exist for the formation of chlorin (and perhaps porphyrin). However, the reaction between pyrrole and benzaldehyde gives rise to a number of reducing agents, including porphyrinogen and porphodimethene. Therefore, the possibility that chlorin could occur through porphyrin reduction was tested. Pyrrol, benzaldehyde and *meso*-tetra-(*p*-methoxyphenyl)porphyrin (**22**) were refluxed in acetic acid under conditions previously found (6) to give high yields of TPP and the usual TPC contaminant. At the end of the reaction *meso*-tetra-(*p*-methoxyphenyl)chlorin (**23**) was obtained. Only starting material was recovered when either (**22**) or (**23**) was refluxed in acetic acid under the same conditions.



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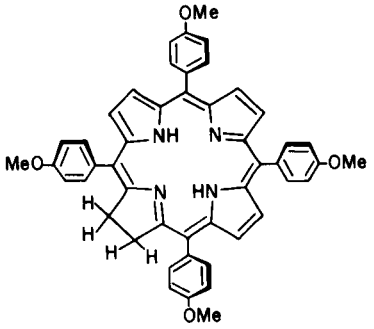

(23)

This indicates that the chlorin produced in the Rothemund reaction can simply be derived from the reduction of porphyrin.

EXPERIMENTAL

Melting points were measured on a Kofler micro hot stage and are uncorrected. Visible spectra were recorded on a Cary Model 14 Spectrometer. High resolution mass spectra were recorded on an AE1 MS-9 mass spectrometer operating at 70 ev with an emission current of 300 to 400 μA and a resolution of 7,000 to 10,000. The internal standard in the high resolution mass spectra was heptacosafluorotributylamine. Nuclear magnetic resonance spectra were run on a Varian Associates Model HA-100 (100 MHz) spectrometer, with tetramethylsilane as internal standard.

Many of the compounds, whose preparation is given below, are susceptible to aerial oxidation. In these experiments all solvents were degassed by refluxing, cooling, and storing under argon. The alumina for anaerobic chromatography was deoxygenated by passing a stream of argon through a suspension of neutral alumina (Woelm, grade II) in refluxing methylene dichloride for 24 hours. The methylene dichloride was then removed under vacuum, the alumina dried for 24 hours at 100° in a vacuum oven, and finally stored under argon.

Reaction Between 3,4-Dimethylpyrrole and Benzaldehyde in Acetic Acid.

To refluxing acetic acid (125 ml.) was added 0.25 g. (2.63 mmoles) of freshly distilled 3,4-dimethylpyrrole (22) and 0.128 g. (2.63 mmoles) of freshly distilled benzaldehyde. The reaction was followed spectroscopically by measuring the increase in intensity of the Soret band of protonated OMTPP at 462 nm.

Time, Minutes	% Yield of OMTPP
1	2
10	33
30	41
60	44
90	47
120	47
150	48
180	46
240	46
300	46
540	47

The reaction was repeated, and after 2 hours the solvent was removed under vacuum. The residue was dissolved in 50 ml. of methylene dichloride, washed with saturated sodium bicarbonate until the washings were basic, and dried over sodium sulfate (magnesium sulfate could not be used to dry solutions of OMTPP, since it was sufficiently acidic to protonate the porphyrin). The solution was filtered, the filtrate reduced in volume and chromotographed on neutral alumina (Woelm grade II). Methylene dichloride removed a number of small colored bands, then elution with chloroform gave a large green band of OMTPP (6). The porphyrin (23) crystallized from methylene dichloride-methanol as glistening purple plates, 0.20 g. (43%), m.p. $> 300°$; λ max (methylene dichloride), nm (ϵ x 10^{-3}), 447 (140.5), 456 (11.08), 568 (8.00), 635 sh (6.15), 691 (6.15), see Figure 1; λ max (trifluoroacetic acid), nm (ϵ x 10^{-3}), 466 (243.6), 635 (8.23), 692 (32.3); nmr Table I.

Anal. Calcd. for $C_{52}H_{46}N_4$: C, 85.91; H, 6.38; N, 7.71. Found: C, 85.72; H, 6.21; N, 7.70. m/e 726.3731, $C_{52}H_{46}N_4$ requires m/e 726.3722.

ZnOMTPP.

Prepared by the method used for ZnTPP (24). Crystallized from methylene dichloride-methanol as red plates with a purple lustre; λ max (methylene dichloride), nm (ϵ x 10^{-3}), 442 (175.5), 573 (15.90), 625 sh (5.63); m/e 788.2862, $C_{52}H_{44}N_4Zn$ requires m/e 788.2857 (for Zn = 63.9291).

CuOMTPP.

Prepared using the method for CuTPP (24). Crystallized from methylene dichloride-methanol as red needles; λ max (methylene dichloride), nm (ϵ x 10^{-3}), 426 (193.4), 563 (15.05), 605 sh (3.95); m/e 787.2851, $C_{52}H_{44}N_4Cu$ requires m/e 787.2864 (for Cu = 62.9298).

Reaction Between Pyrrole and Benzaldehyde in Acetic Acid (6).

To refluxing acetic acid (125 ml.) was added 0.18 ml. (2.63 mmoles) of freshly distilled pyrrole and 0.28 g. (2.63 mmoles) of freshly distilled benzaldehyde. The reaction was followed spectroscopically by measuring the increase in intensity of the Soret band of protonated TPP at 426 nm.

Time, Minutes	% Yield of TPP
8	½
20	1
35	3
55	6
75	22
105	26
165	34
225	38
285	42
375	43
480	44
720	44

The reaction was repeated, and after 8 hours the solvent was removed under vacuum. Chromatography on neutral alumina (Woelm, grade II) using chloroform as eluent gave TPP (**1**) (38% yield).

2,3,7,8,12,13,17,18-Octamethyl-5,10,15,20-tetraphenylprophyrinogen (**7**) (8).

Method A. (Anaerobic Conditions Throughout).

To 20 ml. of acetic acid at 50° was added 0.5 g. (5.26 mmoles) of freshly distilled 3,4-dimethylpyrrole (22) and 0.56 g. (5.26 mmoles) of freshly distilled benzaldehyde. After 5 minutes the acetic acid was removed at 0° under vacuum. The resulting purple viscous oil was triturated with 10 ml. of benzene and the mixture was allowed to stand at 0° for 2 hours. The product was collected by filtration under argon and the residue washed with cold benzene to give **7**, 0.3 g. (31%). Recrystallized (in the absence of light) from methylene dichloride-methanol, m.p. 290-292° dec.; λ max (ethanol), end absorption only; nmr Table I.

Anal. Calcd. for $C_{52}H_{52}N_4$: C, 85.20; H, 7.15; N, 7.64. Found: C, 85.00; H, 7.20; N, 7.61. m/e 732.4190, $C_{52}H_{52}N_4$ requires m/e 732.4192.

Method B. (Anaerobic Conditions Throughout.).

The porphyrinogen **7** was more conveniently prepared as follows: To 10 ml. of deoxygenated benzene were added 0.5 g. of freshly distilled 3,4-dimethylpyrrole and 0.56 g. of freshly distilled benzaldehyde. Trifluoroacetic acid (0.5 ml.) was added to the solution which was allowed to stand, in the absence of light, at 0° overnight. The product was collected by filtration, recrystallized as above to give 0.41 g. (43%) of material identical to that prepared by method A.

meso-Tetraphenylporphyrinogen (**8**).

Method A. (Anaerobic Conditions Throughout).

To 20 ml. of refluxing acetic acid were added 0.36 g. of freshly distilled pyrrole and 0.56 g. of freshly distilled benzaldehyde. After refluxing for 45 minutes the mixture was cooled to 0° and the solvent removed under vacuum. The black residue was triturated with 10 ml. of methylene dichloride, and filtered under an atmosphere of argon. The filtrate was transferred to a column of deoxygenated alumina. Elution with methylene dichloride gave, as the first fraction, the porphyrinogen **8**, 0.012 g. (7%), recrystallized in the absence of light from deoxygenated methylene dichloride-methanol, m.p. 237-238° dec.; λ max (ethanol), nm (ϵ x 10^{-3}), 230 sh (5.88).

Anal. Calcd. for $C_{44}H_{36}N_4$: C, 85.13; H, 5.85; N, 9.03. Found: C, 85.01; H, 5.79; N, 9.20. m/e 620.2921, $C_{44}H_{36}N_4$ requires m/e 620.2940.

Method B (Anaerobic Conditions Throughout).

The porphyrinogen (**8**) was more conveniently prepared by the reduction of TPP (**1**). Trifluoroacetic acid (5 ml.) and TPP (1 g.) were mixed together and diluted to 100 ml. with acetic acid. This solution was refluxed and cooled under argon. Zinc dust (5 g.) was added to the stirred solution and the mixture was kept in the absence of light for 1 hour. The zinc was removed by filtration under argon, and the filtrate diluted with 1 l. of water. Sodium

carbonate (50 g.) was added to bring about the precipitation of the porphyrinogen **8**, which was collected by filtration under argon, washed with water, and recrystallized, in the absence of light, from methylene chloride-methanol to give 0.42 g. (43%) of porphyrinogen identical to the material prepared by method A.

Zinc 2,3,7,8,12,13,17,18-Octamethyl-5,10,15,20-tetraphenylporphodimethene (**11**) (8).

The porphyrinogen **7** (1 g.) was dissolved in 5 ml. of methylene dichloride and diluted to 25 ml. with acetic acid. Oxygen was then slowly bubbled through the solution until the absorption at 518 nm reached a maximum value. At this time the solution was flushed with argon, and 0.5 g. of zinc acetate and 5 g. of sodium acetate were added. The mixture was stirred under argon for 2 hours and then the solvent removed under vacuum. The residue was shaken with 50 ml. of chloroform, filtered, and the filtrate chromatographed on deoxygenated alumina. Elution with chloroform gave 0.82 g. (82%) of the starting porphyrinogen, 0.074 g. (7%) of the zinc porphodimethene **11**, and finally 0.10 g. (9%) of ZnTPP. Attempts to recrystallize **11** resulted in contamination due to oxidation, and purification was therefore carried out by rechromatography on deoxygenated alumina followed by removal of the solvent under vacuum to give an orange-red powder, m.p. $> 300°$; λ max (methylene dichloride), nm (ϵ x 10^{-3}) 519 (317.2); nmr Table I; m/e 790.3002, $C_{52}H_{46}N_4Zn$ requires m/e 790.3013.

meso-Phenyl-3,3′,4,4′,5,5′-hexamethyl-2,2′-dipyrromethane (**12**). (Anaerobic Conditions Throughout).

2,3,4-Trimethylpyrrole (2 g.) (25) and benzaldehyde (1 g.) were dissolved in 25 ml. of ethanol. Two drops of concentrated hydrochloric acid were added and the solution allowed to stand, in the absence of light, at room temperature for 30 minutes and then overnight at 0°. The product was filtered under argon, and recrystallized from methylene dichloride-methanol to give 1.91 g. (66%) of **12**, m.p. 143-144°; λ max (ethanol), end absorption only; nmr, Table I.

Anal. Calcd. for $C_{21}H_{26}N_2$: C, 82.30; H, 8.55; N, 9.14. Found: C, 82.37; H, 8.71; N, 9.26.

meso-Phenyl-3,3′,4,4′,5,5′-hexamethyl-2,2′-dipyrromethene Hydrobromide **13**.

To a solution of 1 g. of dipyrromethane **12** in 200 ml. of methylene dichloride was added 20 ml. of 48% aqueous hydrobromic acid. This mixture was stirred, open to the air, and in direct sun light, for 12 hours. The organic layer was separated, dried over sodium sulfate, filtered, and the filtrate taken down to dryness. The residue was crystallized from methylene dichloride-petroleum ether (b.p. 20-40°) as red-brown prisms with an orange reflux; 1.06 g. (84%), m.p. slowly decomposed above 250°; λ max (ethanolic hydrogen bromide), nm (ϵ x 10^{-3}) 516 (159.4); nmr, Table I.

Anal. Calcd. for $C_{21}H_{25}BrN_2$: C, 65.45; H, 6.53; N, 7.26. Found: C, 65.32:65.67; H, 7.03:6.39; N, 7.26:7.52.

Zinc *meso*-Phenyl-3,3′,4,4′,5,5′-hexamethyl-2,2′-dipyrromethene **14**.

To a solution of 0.2 g. of the dipyrromethene hydrobromide **13** in 100 ml. of ethanol was added 0.5 g. zinc acetate and 2 g. of sodium acetate. The solution was refluxed for 20 minutes and the solvent removed under vacuum. The residue was triturated with 20 ml. of methylene dichloride, filtered, and the filtrate taken down to dryness. The zinc complex was crystallized from methylene dichloride-petroleum ether (b.p. 20-40°) as orange-brown needles with a green metallic sheen, 0.15 g. (88%), m.p. $> 300°$; λ max (ethanol), nm (ϵ x 10^{-3}), 507 (307.6); nmr Table I.

Anal. Calcd. for $C_{42}H_{46}N_4Zn$: C, 75.04; H, 6.89; N, 8.33. Found: C, 74.43:73.99; H, 6.63:7.61; N, 8.37:8.63 (26). m/e 670.3033, $C_{42}H_{46}N_4Zn$ requires 670.3103 (for Zn = 63.9291). Treatment of this zinc complex with hydrogen bromide gave a quantitative yield of the dipyrromethene hydrobromide **13**.

The Reaction Between Pyrrole, Benzaldehyde, and *meso*-Tetra(*p*-methoxyphenyl)porphyrin (**22**).

To 250 ml. of acetic acid were added 0.36 g. of freshly distilled pyrrole, 0.56 g. of freshly distilled benzaldehyde and 0.2 g. of the porphyrin **22**. The mixture was refluxed for 8 hours and then the solvent removed under vacuum. The residue was dissolved in 200 ml. of chloroform, washed with saturated sodium bicarbonate, until the washings were basic, dried over sodium sulfate, and filtered. The filtrate was put onto a column of dry neutral alumina (Woelm grade II) and the column eluted with chloroform. When the eluent was colorless the chlorins, which remained at the top of the column were removed from the alumina by boiling in pyridine (27) and rechromatographed on an alumina preparative layer plate using methanol as eluent. Two green bands were separated, TPC (17 mg.) identical to an authentic sample and, the chlorin **23** (27 mg.); λ max (methylene dichloride), nm (ϵ x 10^{-3}), 421 (180.0), 515 (16.3), 547 (12.0), 598 (5.1), 654 (41.7).

Anal. Calcd. for $C_{48}H_{40}N_4O_4$: C, 78.23; H, 5.47; N, 7.60. Found: C, 78.14; H, 5.52; N, 7.46. m/e 736.3017, $C_{48}H_{40}N_4O_4$ requires m/e 736.3049.

Prolonged heating on the probe gives the corresponding porphyrin **22** m/e 734.2881, $C_{48}H_{38}N_4O_4$ requires m/e 734.2893.

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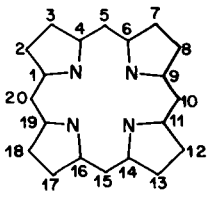

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