# Long Wavelength Photosensitizers Related to Chlorins and Bacteriochlorins for use in Photodynamic Therapy†

**Ravindra K. Pandey,[a,b] Fuu-Yau Shiau,[a] Kishore Ramachandran,[a] Thomas J. Dougherty[b] and Kevin M. Smith[a,*]**

[a] *Department of Chemistry, University of California, Davis, CA 95616, USA*

[b] *Division of Radiation Biology, Department of Radiation Medicine, Roswell Park Cancer Institute, Buffalo, NY 14263, USA*

A series of long wavelength photosensitizers related to chlorins and bacteriochlorins has been synthesized from the Diels–Alder reaction of protoporphyrin III dimethyl ester **6**, or protoporphyrin II dimethyl ester **29**. These porphyrins were prepared either by copper(II)-promoted cyclization of the corresponding *a,c*-biladienes or by following the modified MacDonald dipyrromethane approach. To eliminate the possibility of isomer formation in synthesis of so-called 'benzoporphyrin derivatives' and also to understand structure–activity relationships among various photosensitizers, Diels–Alder reactions were also performed on 13,17-bis(2-methoxycarbonylethyl)-2,3,8,12,18-pentamethyl-7-vinylporphyrin **21** and 3-(1-hydroxyethyl)-13,17-bis(2-methoxycarbonylethyl)-2,7,12,18-tetramethyl-8-vinylporphyrin **22**.

Photodynamic therapy (PDT) involves the combination of non-ionizing radiation and photosensitizing drugs to treat malignant cancer[1] or benign diseases.[2] The present treatment schedules which are in clinical trials are based on the retention of a photosensitizer such as Photofrin II[3] in tumour tissue in concentrations which are higher than in surrounding non-malignant tissues. Subsequent photoactivation of the sensitizer evokes tumour destruction. The exact mechanisms of action for effective PDT in cancer treatment are not known. While studies *in vitro* have indicated that generation of singlet oxygen is the main mechanism for PDT cytotoxicity,[4,5] studies *in vivo* with animal models have suggested that photodynamic damage to the blood vessels of the tumour may be the major cause of tumour destruction.[6–9]

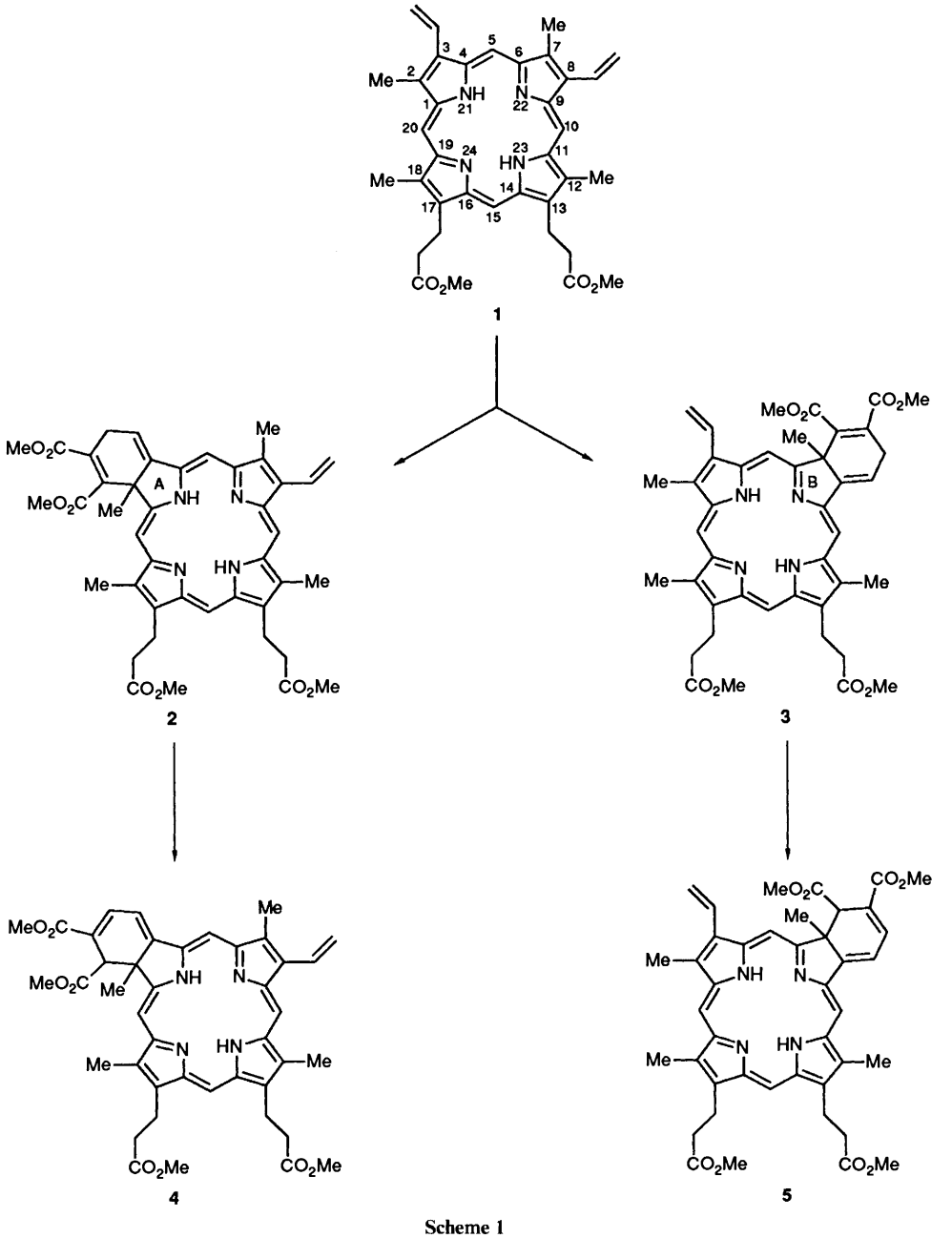
Despite the utility of Photofrin II, it has several disadvantages. Firstly, it is a complex mixture of porphyrin oligomers[10–13] linked with ether,[14–16] ester[12,17] or carbon–carbon linkages,[16,18] which makes it difficult to study; secondly, it is phototoxic and patients must remain in subdued light for 4–6 weeks after drug administration to avoid cutaneous phototoxicity.[19] Finally, lack of penetration of the light through the tissue severely limits the size of tumour which can be treated using PDT. Porphyrins in general, including Photofrin II, have weak absorption at 630 nm, the wavelength usually used for treatment. It is, therefore, desirable to develop photosensitizers with strong absorption at wavelengths near or above 700 nm in order to take full advantage of greater tissue penetration by low energy light. In recent years, a number of photosensitizers related to chlorins, methyl pheophorbide, purpurins, benzoporphyrin derivatives (BPD), phthalocyanines, texaphyrins, and naphthalocyanines have been described in the literature.[20]

A number of years ago Johnson and co-workers[21] reported a facile synthesis of compounds possessing the chlorin chromophore by using the Diels–Alder reaction on vinylporphyrins. Dolphin *et al.*[22a] extended this methodology and showed that the vinyl groups of protoporphyrin IX react with tetracyanoethylene (TCNE) in [4 + 2] and [2 + 2]cycloaddition reactions, giving rise to a mixture of cycloaddition products. Reaction of protoporphyrin IX dimethyl ester **1** with dimethyl acetylenedicarboxylate (DMAD) gave initially the Diels–Alder adduct **2** or **3** which could be rearranged in base to give isomers **4** and **5** possessing the conjugated 'benzoporphyrin' system (Scheme 1); the ring A and ring B adducts were separated by chromatography.[22b] In *in vitro* studies, both the isomers, as their mono- or di-carboxylic acids were found to be active in PDT.[23] However, the *in vivo* studies have shown that only the monomethyl ester/monocarboxylic acid of the ring A and B derivative of protoporphyrin IX dimethyl ester is effective as a PDT sensitizer if the mice were treated 3 h after injection of the drug.[24] At the same dose, no tumour cures were observed if the drug was administered 24 h prior to light treatment. These results suggest that this drug does not remain in the system for a long time and is less phototoxic than Photofrin II. Benzoporphyrin derivative (BPD) has some advantages over Photofrin II, but it is still synthesized as a mixture of isomers, and the biologically active isomer is separable only by preparative thin layer chromatography (TLC) or by HPLC.

*Syntheses of Porphyrins.*—To eliminate the problem of isomer formation in the Diels–Alder reaction of protoporphyrin IX dimethyl ester **1** due to its asymmetry, we sought to start with symmetrically substituted divinylporphyrins. Thus, significant simplification in the regioselectivity of the Diels–Alder reaction of divinylporphyrins with dienophiles could be achieved by use of, for example, protoporphyrin III dimethyl ester **6**.[25] Protoporphyrin III dimethyl ester was prepared by the *a,c*-biladiene approach. The known acetoxymethylpyrrole **7**[26] was self-condensed using a Montmorillonite clay catalyst[27] to give a high yield of the symmetrical dipyrromethane **8**. Catalytic debenzylation, to give **9**, followed by acid catalysed condensation with 2 mol equiv. of the formylpyrrole **10**[28] afforded the *a,c*-biladiene **11** in 80% yield. This was cyclized with copper(II) acetate in dimethylformamide (DMF) (140 °C) to give the 3,7-bis(2-chloroethyl)porphyrin **12** in good yield after removal of the chelated copper with strong acid. It was converted into the corresponding divinyl analogue **6** after treatment first with aqueous sodium hydroxide in boiling pyridine and then by stirring with methanol–sulfuric acid to re-esterify the propionic acid functions.

To our surprise, when *a,c*-biladiene **13** was cyclized under similar reaction conditions, the expected porphyrin **12** was obtained only in 15% yield, along with the 3-(2-chloroethyl)-7-

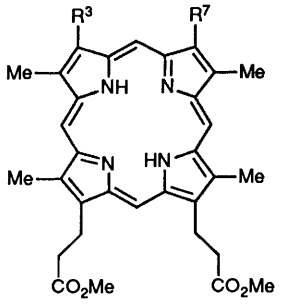
† Reported in part at the SPIE International Symposium, 'Biomedical Optics '91', Los Angeles, CA, USA, January, 1991.



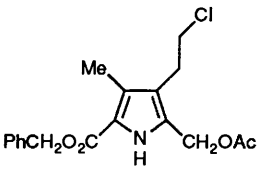
Scheme 1

(2-hydroxyethyl)porphyrin **14** and the 3,7-bis(2-hydroxyethyl)-porphyrin **15** in 12 and 5% yield, respectively. Dehydrohalogenation of porphyrin **14** with aqueous sodium hydroxide produced the monohydroxyethylmonovinylporphyrin **16**, which confirmed the presence of only one 2-chloroethyl group in porphyrin **14**. Reaction of porphyrin **16** and **15** with acetic anhydride–pyridine gave the corresponding mono- and di-(2-acetoxyethyl)porphyrins **17** and **18**, respectively. At the present time it is not at all clear how or why the two procedures for synthesis of porphyrin **12** afford such widely different results. The *a,c*-biladiene **13**, in turn, was obtained by treating the dipyrromethanedicarboxylic acid **19**[29] with 2 equiv. of chloroethylformylpyrrole **20**[28] and the product was isolated in 82% yield.

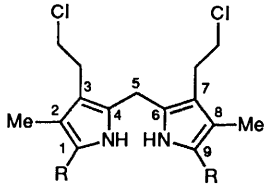
Our previous experience involving porphyrin dimers with ether and carbon–carbon linkages suggested that changing the substituents at peripheral positions of the porphyrin nucleus makes a remarkable difference in PDT activity. For example divinyl analogues of these dimers were found to be much more effective as PDT agents than their monovinyl counterparts which, in turn, showed better photosensitizing ability than those having 1-hydroxyethyl substituents.[16,20,30,31] To explore the structure–activity relationships in the benzoporphyrin derivative series, and also to compare the biological results with other photosensitizers as well as to find an alternate and efficient procedure for eliminating the possibility of isomer formation, porphyrin **21**[32] and **22**[30] were used as starting materials in the Diels–Alder reaction. Porphyrin **21** was prepared by *a,c*-biladiene approach; the *a,c*-biladiene **23** was obtained in 85% yield by condensing the dipyrromethane **24** with 2 equiv. of the formylpyrrole **10**, and was then cyclized to the corresponding porphyrin **25** (after removal of copper) as reported in the literature[32] in 36% yield. Vinylation with base then gave porphyrin **21**. For the synthesis of 3-(1-hydroxyethyl)-8-vinyldeuteroporphyrin IX dimethyl ester **22**, hematoporphyrin IX dimethyl ester **26** was first partially oxidized with 4-methylmorpholine *N*-oxide and tetrapropylammonium perruthenate (TPAP) to give 3-acetyl-8-(1-hydroxyethyl)- and 8-acetyl-3-(1-hydroxyethyl)-porphyrins.[33] These isomers were easily separable by chromatography. 8-Acetyl-3-(1-hydroxy-



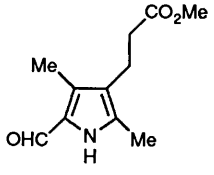
**6** $R^3 = R^7 = CH{=}CH_2$
**12** $R^3 = R^7 = CH_2CH_2Cl$



**7**



**8** $R = CO_2CH_2Ph$
**9** $R = CO_2H$



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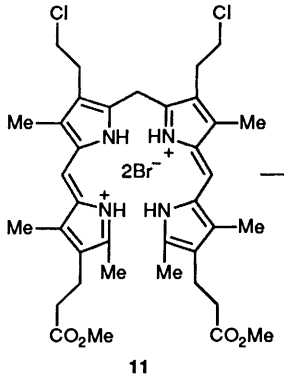
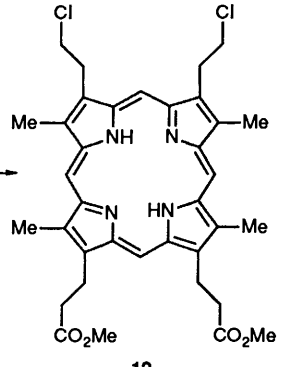
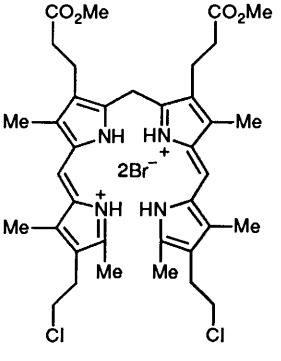


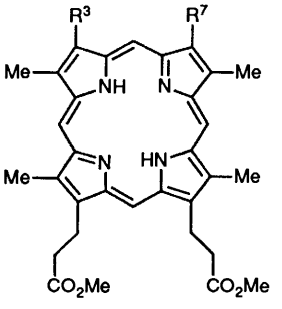
**11**



**12**

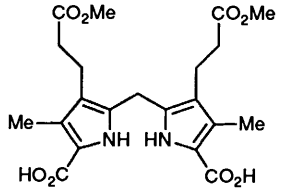


**13**

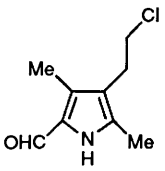


**14** $R^3 = CH_2CH_2Cl$, $R^7 = CH_2CH_2OH$
**15** $R^3 = R^7 = CH_2CH_2OH$
**16** $R^3 = CH{=}CH_2$, $R^7 = CH_2CH_2OH$
**17** $R^3 = CH{=}CH_2$, $R^7 = CH_2CH_2OAc$
**18** $R^3 = R^7 = CH_2CH_2OAc$

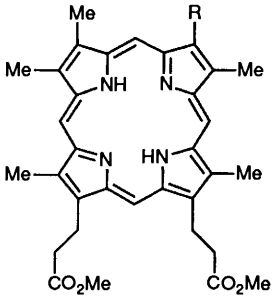
**Scheme 2** *Reagents and conditions:* i, $Cu(OAc)_2$, DMF, 140 °C



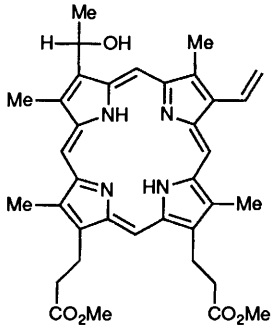
**19**



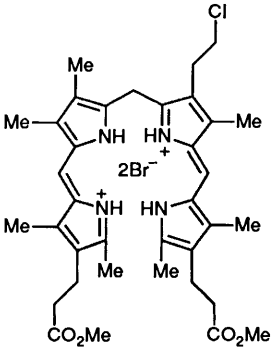
**20**



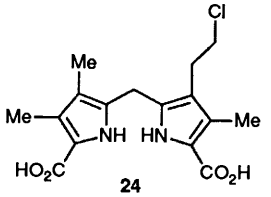
**21** $R = CH{=}CH_2$
**25** $R = CH_2CH_2Cl$



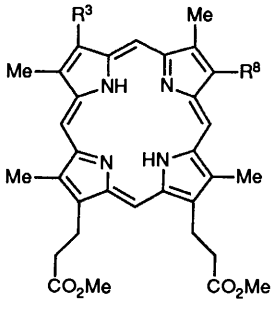
**22**



**23**



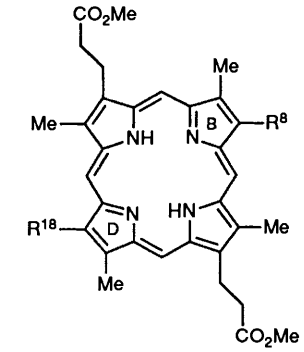
**24**



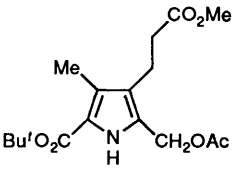
**26** $R^3 = R^8 = CH(OH)Me$
**27** $R^3 = CH{=}CH_2$, $R^8 = COMe$
**28** $R^3 = CH{=}CH_2$, $R^8 = CH(OH)Me$

ethyl)deuteroporphyrin IX dimethyl ester, upon treatment with toluene-*p*-sulfonic acid, was dehydrated to the corresponding vinyl derivative **27**, which upon subsequent reaction with sodium borohydride, afforded the porphyrin **28**. Likewise, the 3-(1-hydroxyethyl)-8-vinylporphyrin **22** was obtained from the 3-acetyl-8-(1-hydroxyethyl)porphyrin analogue.[30]

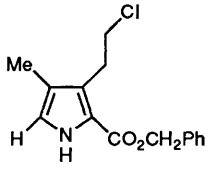
In order to synthesize a photosensitizer with long wavelength absorbance by using the Diels–Alder approach, a symmetrical porphyrin **29** having vinyl groups on rings B and D was synthesized by following the MacDonald dipyrromethane approach.[34] The acetoxymethylpyrrole **30**[35] was treated with 2-unsubstituted pyrrole **31**[36] in the presence of either Montmorillonite clay or toluene-*p*-sulfonic acid to give the unsymmetrical dipyrromethane **32** in 80% yield. Treatment with trifluoroacetic acid, followed by addition of trimethyl orthoformate,[37] gave the formyldipyrromethane benzyl ester



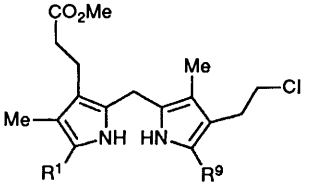
**29** $R^8 = R^{18} = CH{=}CH_2$
**35** $R^8 = R^{18} = CH_2CH_2C$



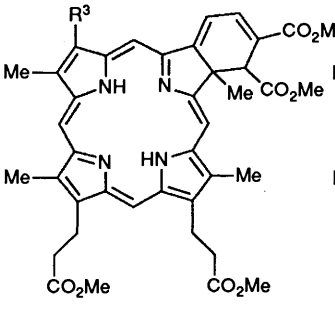
**30**



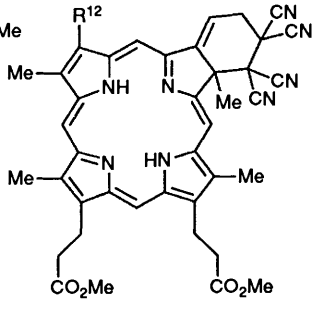
**31**



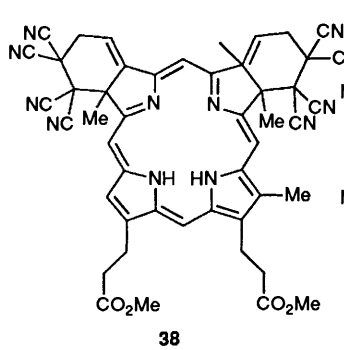
**32** $R^1 = CO_2Bu^t$, $R^9 = CO_2CH_2Ph$
**33** $R^1 = CHO$, $R^9 = CO_2CH_2Ph$
**34** $R^1 = CHO$, $R^9 = CO_2H$



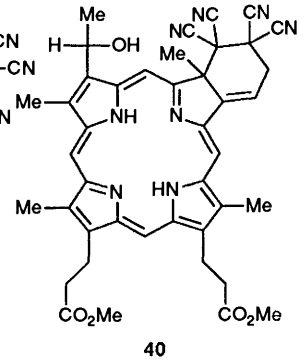
**36** $R^3 = CH{=}CH_2$
**41** $R^3 = Me$



**37** $R^{12} = CH{=}CH_2$
**39** $R^{12} = Me$



**38**



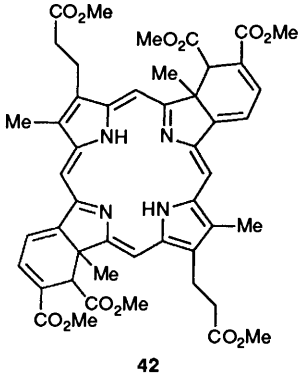
**40**

**33**; this was catalytically debenzylated to give the dipyrromethanecarboxylic acid **34** in almost quantitative yield, and self-condensation of this dipyrromethane under typical modified MacDonald conditions[34] afforded the 8,18-bis(2-chloroethyl)porphyrin **35** in 38% yield. It was dehydrohalogenated with aqueous sodium hydroxide–pyridine to produce the desired 8,18-divinylporphyrin **29** in 75% yield.

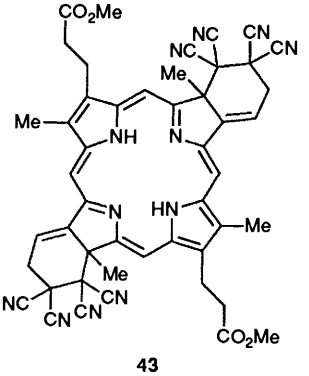
*Diels–Alder Reactions on Vinylporphyrins.*—The Diels–Alder reaction of protoporphyrin III dimethyl ester **6** with DMAD afforded the 'benzoporphyrin-type' analogue **36**; no evidence of further reaction at the second vinyl group was evident, and Fig. 1(*a*) shows the optical spectrum of this compound. However, when TCNE was the dienophile, the reaction to give the mono Diels–Alder adduct **37** was faster, and with an excess of TCNE and long reaction time, mainly isobacteriochlorin **38** was obtained. Monovinylporphyrins **21** and **22**, on reaction with TCNE gave the corresponding Diels–Alder adducts **39** and **40** in excellent yield. Reaction of DMAD with porphyrin **21** gave the expected benzoporphyrin derivative **41** in 40% yield after double bond migration promoted by triethylamine or DBU.* However, (1-hydroxyethyl)vinylporphyrin **22** gave a mixture including the dehydration product on reaction with DMAD under refluxing conditions in toluene.

The benzoporphyrin derivative **41**, obtained from the Diels–Alder reaction on monovinylporphyrin **21**, had a significant absorption maximum at 672 nm [Fig. 1(*b*)]. However, replacement of the methyl group at position-2 with a vinyl substituent (*i.e.* compound **36**) gave a 10 nm bathchromic shift, these analogues showing a strong absorption peak at 682 nm [Fig. 1(*a*), (*b*)]. The Diels–Alder adduct obtained from protoporphyrin III dimethyl ester **6** with TCNE had its absorption maximum at 660 nm. The blue shift in the absorption maximum is explained by lack of conjugation in this Diels–Alder adduct when compared with the Diels–Alder product **36**.

We have also used the Diels–Alder approach for the syntheses of photosensitizers related to the bacteriochlorin system, which absorbs substantially at longer wavelengths than isobacteriochlorins or chlorins. Thus, when the ring-B,D divinylporphyrin **29** was allowed to react with an excess of DMAD in refluxing toluene for 5 days, followed by treatment with triethylamine or DBU, the desired bacteriochlorin **42** was obtained as the



**42**



**43**

major product along with a small amount of chlorin in which only one of the vinyl groups (either ring B or ring D) was transformed (identified by spectrophotometry). In contrast, treating porphyrin **29** with TCNE gave bacteriochlorin **43** in poor yield, along with a number of other products which were not further characterized; these products are very likely the [2 + 2] and [4 + 2]/[2 + 2] cycloaddition products as reported by Dolphin *et al.*[22] in their studies with protoporphyrin IX. Jackson and co-workers[38] have observed formation of bacteriochlorins from reactions of various protoporphyrin isomers with an excess of *p*-nitrosobenzene, though they were unable to characterize the products. In addition, Yon-Hin *et al.*[39] have very recently published a communication in which they exploited chemistry similar to that which we have described above, and obtained similar bacteriochlorins. Both the bacteriochlorins **42** and **43** have long wavelength absorption maxima [Fig. 1(*c*), (*d*)] at 720 and 782 nm, respectively. All of the new photosensitizers described herein are being evaluated for their photosensitizing

* 1,8-Diazabicyclo[5.4.0]undec-7-ene.

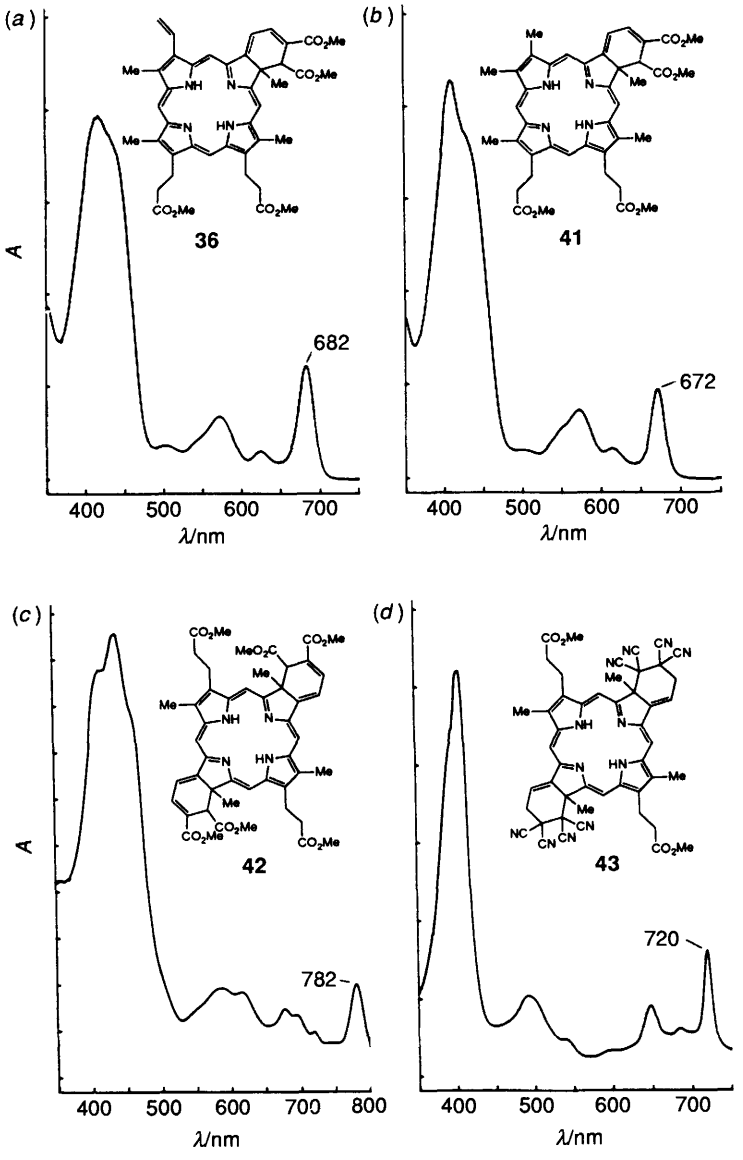



**Fig. 1** Visible absorption spectra ($CH_2Cl_2$) of (a) chlorin **36**; (b) chlorin **41**; (c) bacteriochlorin **42**; (d) bacteriochlorin **43**

ability and these biological results will be reported elsewhere.

## Experimental

M.p.s are uncorrected and were measured on a Thomas Bristoline hot stage apparatus. Electronic absorption spectra were measured on a Hewlett-Packard 8450A spectrophotometer using solutions in dichloromethane. Proton NMR spectra were obtained in $CDCl_3$ either at 90 MHz (Varian EM-390) or at 300 MHz (General Electric QE300) using internal TMS (EM-390) or chloroform (7.258 ppm, 300 MHz) as internal standards. Reactions were usually carried out in the dark (aluminium foil) under nitrogen and were monitored using TLC on commercially available Eastman-Kodak 13181 (100 μm thick) silica gel sheets. Preparative TLC was carried out on 20 × 20 cm glass plates coated with Merck GF 254 silica gel (1 mm thick). Gravity and flash column chromatography employed either Merck neutral alumina (70–230 mesh) or Merck Silica Gel 60. Elemental analyses were performed at the Mid-West Microchemical Analysis Laboratory. Mass spectral analyses were performed at the mass spectrometry facility, School of Pharmacy, University of California, San Francisco.

*Benzyl* 1-tert-*Butoxycarbonyl*-8-(2-*chloroethyl*)-3-(2-*methoxycarbonylethyl*)-2,7-*dimethyldipyrromethane*-9-*carboxylate* **32**.—*tert*-Butyl 5-acetoxymethyl-4-(2-methoxycarbonylethyl)-3-methylpyrrole-2-carboxylate **30** (1.95 g) and benzyl 3-(2-chloroethyl)-4-methylpyrrole-2-carboxylate **31** (1.6 g) and K-10 Montmorillonite clay (5.0 g) in dichloromethane (100 $cm^3$) were stirred overnight. The reaction mixture was filtered, the filtrate was washed with aqueous sodium hydrogencarbonate and then again with water. The organic layer was separated and dried ($Na_2SO_4$). Evaporation of the solvent gave a residue which was purified by column chromatography (silica gel; elution with 1% methanol in dichloromethane). The appropriate eluates were combined and the solvent was evaporated to give a residue which was crystallized from dichloromethane–hexane to give the title compound (2.5 g, 78%) as a white powder, m.p. 180–182 °C (Found: C, 64.8; H, 6.7; N, 5.0. $C_{30}H_{37}ClN_2O_6$ requires C, 64.72; H, 6.70; N, 5.03%); $\delta_H$ 9.58 (1 H, s, NH), 8.78 (1 H, s, NH), 7.30 (5 H, s, Ph), 5.22 (2 H, s $CH_2$Ph), 3.86 (2 H, s, $CH_2$), 3.52 (3 H, s, OMe), 3.50, 3.20, 2.62, 2.40 (each 2 H, t, $CH_2CH_2Cl$ and $CH_2CH_2CO_2Me$), 2.20, 2.0 (each 3 H, s, $CH_3$) and 1.48 [9 H, s, $C(CH_3)_3$].

*Benzyl* 8-(2-*Chloroethyl*)-1-*formyl*-3-(2-*methoxycarbonylethyl*)-2,7-*dimethyldipyrromethane*-9-*carboxylate* **33**.—The

going dipyrromethane **32** (2.4 g) was dissolved in trifluoroacetic acid (5.0 $cm^3$) and the solution stirred under nitrogen for 10 min. It was warmed at 40 °C for 5 min and then cooled to 0 °C (ice bath). Trimethyl orthoformate (5.0 $cm^3$) was added and the reaction mixture was stirred at the same temperature for 10 min and then at room temp. for 30 min. The reaction mixture was then poured into hot water and extracted with dichloromethane; the extract was washed with aqueous sodium hydrogen carbonate, and then again with water. Finally it was dried ($Na_2SO_4$) and evaporated to give a residue which was purified by column chromatography (silica gel, elution with 2% methanol–dichloromethane). Evaporation of the appropriate eluates gave a residue which was crystallized from dichloromethane–light petroleum (b.p. 40–60 °C) to give the title compound (1.56 g, 75%), m.p. >150 °C (decomp.) (Found: C, 64.48; H, 6.0; N, 5.7. $C_{26}H_{29}ClN_2O_5$ requires C, 64.43; H, 6.03; N, 5.78%); $\delta_H$ 10.77 (1 H, s, NH), 10.53 (1 H, s, NH), 9.35 (1 H, s, CHO), 7.21 (5 H, m, Ph), 5.20 (2 H, s, $CH_2PH$), 3.95 (2 H, s, $CH_2$), 3.64 (3 H, s, $OCH_3$), 3.61, 3.16, 2.74 and 2.39 (each 3 H, t, $CH_3$).

8-(2-*Chloroethyl*)-1-*formyl*-3-(2-*methoxycarbonylethyl*)-2,7-*dimethyldipyrromethane*-9-*carboxylic Acid* **34**.—Formyldipyrromethane **33** (1.4 g) was dissolved in freshly distilled tetrahydrofuran (150 $cm^3$) containing a few drops of triethylamine. 10% Palladium/carbon (150 mg) was added and the mixture was hydrogenated overnight at atmospheric pressure and room temp. The reaction mixture was filtered through a bed of Celite and evaporation of the filtrate gave a residue which upon trituration with tetrahydrofuran–light petroleum solidified, to give a white powder (1.10 g, 97%); this was used immediately without further purification; $\delta_H$ 10.80, 10.34 (each 1 H, s, NH), 9.40 (1 H, s, CHO), 4.00 (2 H, s, $CH_2$), 3.70 (3 H, s, $OCH_3$), 3.62, 3.16, 2.78 and 2.42 (each 2 H, t, $CH_2CH_2Cl$ and $CH_2CH_2CO_2$), 2.20 and 2.10 (3 H, s, $CH_3$).

8,12-*Bis*(2-*chloroethyl*)-2,18-*bis*(2-*methoxycarbonylethyl*)-1,-3,7,13,17,19-*hexamethyl*-a,c-*biladiene Dihydrobromide* **11**.—3,7-Bis(2-chloroethyl)-2,8-dimethyldipyrromethane-1,9-dicarboxylic acid[40] (1.5 g) was dissolved in trifluoroacetic acid (10.0 $cm^3$) and the solution stirred until evolution of carbon dioxide ceased. To the resulting dark red solution was added 4-(2-methoxycarbonylethyl)-3,5-dimethylpyrrole-2-carbaldehyde **10**[28] (1.7 g) in methanol (20.0 $cm^3$). The reaction mixture was stirred for 5 min, after which 33% HBr–acetic acid (10.0 $cm^3$) was added and stirring continued for a further 30 min. Diethyl ether was then added dropwise to precipitate the *a,c*-biladiene salt. The reaction mixture was stirred for an additional 1 h and then filtered to give the product (1.5 g, 38%) as a red powder, m.p. >300 °C (Found: C, 52.6; H, 5.7; N, 6.6. $C_{37}H_{48}Br_2Cl_2N_4O_4$ requires C, 52.84; H, 5.75; N, 6.66%); $\lambda_{max}$/nm 373 (ε 11 400), 448 (61 900) and 520 (109 500). $\delta_H$ 13.47, 13.32 (each 2 H, s, NH), 7.14 (2 H, s =CH), 5.24 (2 H, s, $CH_2$), 3.67 (6 H, s, 2 $OCH_3$), 3.10, 2.75, 2.40, 2.30 (3 H, s, 4 $CH_3$), 3.43, 2.92, 2.75 and 2.48 (2 H, t, 2 $CH_2CH_2Cl$, 2 $CH_2CH_2CO_2$).

2,18-*Bis*(2-*chloroethyl*)-8,12-*bis*(2-*methoxycarbonylethyl*)-1,-3,7,13,17,19-*hexamethyl*-a,c-*biladiene Dihydrobromide* **13**.—3,7-Bis(2-methoxycarbonylethyl)-2,8-dimethyldipyrromethane-1,9-dicarboxylic acid[30,38] **19** (1.1 g) was stirred with TFA (10.0 $cm^3$) and then allowed to react with 4-(2-chloroethyl)-3,5-dimethylpyrrole-2-carbaldehyde **20**[28] (925 mg) by following the method described above for the foregoing *a,c*-biladiene. The title compound was isolated as a deep red powder (1.60 g, 75%), m.p. >300 °C (Found: C, 52.6; H, 5.7; N, 6.5. $C_{37}H_{48}Br_2Cl_2N_4O_4$ requires C, 52.8; H, 5.75; N, 6.7%); $\lambda_{max}$/nm 373 (ε 12 600), 452 (54 300) and 522 (135 400); $\delta_H$ 13.46, 13.30 (each 2 H, s, NH), 7.18 (2 H, s, =CH), 5.23 (2 H, s, $CH_2$), 3.41 (6 H, s, $OCH_3$), 3.59, 2.91, 2.79 and 1.90 (each 2 H, t, $CH_2CH_2Cl$ and $CH_2CH_2CO_2$).

3,7-*Bis*(2-*chloroethyl*)-13,17-*bis*(2-*methoxycarbonylethyl*)-2,-8,12,18-*tetramethylporphyrin* **12**.—The *a,c*-biladiene salt **11** (780 mg) was added to a stirred solution of copper(II) acetate (3.0 g) in refluxing DMF (20.0 $cm^3$), and refluxing was continued for 4 min. The solution was poured immediately into water (1 $dm^3$) and then extracted with dichloromethane. The organic phase was washed several times with water, dried ($Na_2SO_4$) and evaporated to give a residue which was dried under high vacuum to remove the last traces of DMF. The red residue was chromatographed on an alumina column (Grade III; elution with dichloromethane), and the red eluates were combined and evaporated to give a residue. The copper(II) complex so obtained was dissolved in 15% sulfuric acid in trifluoroacetic acid (50 $cm^3$) and the solution stirred at room temp. for 30 min. It was then poured into water and extracted with dichloromethane. The extract was washed with aqueous sodium hydrogencarbonate and water, dried ($Na_2SO_4$), and evaporated to give a crude red product. This was dissolved in 5% sulfuric acid in methanol (100 $cm^3$) and the solution set aside overnight. It was then poured into aqueous sodium acetate and extracted with dichloromethane. The extract was washed with aqueous sodium hydrogencarbonate and water, dried ($Na_2SO_4$), and evaporated. The residue was chromatographed on an alumina column (Brockmann Grade III; elution with dichloromethane), and the appropriate eluates were evaporated to give the title porphyrin (250 mg, 40%), m.p. 258–259 °C; $\lambda_{max}$/nm 400 (ε 172 900), 498 (14 300), 532 (9600), 568 (6800) and 620 (4700); $\delta_H$ 10.10 (2 H, s, *meso*-H), 10.09, 9.95 (each 1 H, s, *meso*-H), 4.55, 4.38 (each 2 H, t, $CH_2CH_2Cl$), 4.29, 3.26 (each 2 H, t, $CH_2CH_2CO_2$), 3.66 (6 H, s, $OCH_3$) and 3.64 (12 H, s, $CH_3$) (Found: $M^+$, 662.2436. Calc. for $C_{36}H_{40}Cl_2N_4O_4$: *M*, 662.2426).

3-(2-*Chloroethyl*)-7-(2-*hydroxyethyl*)-13,17-*bis*(2-*methoxycarbonylethyl*)-2,8,12,18-*tetramethylporphyrin* **14** *and* 3,7-*Bis*-(2-*hydroxyethyl*)-13,17-*bis*(2-*methoxycarbonylethyl*)-2,8,12,18-*tetramethylporphyrin* **15**.—The copper(II)-promoted cyclization of *a,c*-biladiene dihydrobromide **13** (1.5 g) following the procedure described above afforded a mixture of three porphyrins which were separated by preparative thick layer chromatography (silica gel; elution with 5% methanol in dichloromethane). The faster moving band (band A) was identified as the desired porphyrin **12** (175 mg, 15%) and was identical with the authentic sample described above. Band B, the second band from the top of the plate, was characterized as the title porphyrin **14** (140 mg, 12%), m.p. >300 °C; $\lambda_{max}$/nm 400 (ε 145 700), 498 (11 800), 532 (7900), 568 (5400) and 620 (3700); $\delta_H$ 10.07 (2 H, s, 2 *meso*-H), 10.05, 9.98 (each 1 H, s, *meso*-H), 4.47 (m, 8 H, 3-$CH_2CH_2Cl$ and $CH_2CH_2OH$), 4.32, 3.27 (4 H, t, 2 $CH_2CH_2CO_2$), 3.65 (6 H, s, 2 $OCH_3$), 3.63 (12 H, s, 4 $CH_3$) and −3.80 (2 H, br, 2 NH). Finally, the most polar band (band C) was characterized as the title porphyrin **15** (58 mg, 5%), m.p. 246–248 °C; $\delta_H$ 10.10, 9.95 (each 1 H, s, 2 *meso*-H), 9.90 (2 H, s, 2 *meso*-H), 4.35 (4 H, m, 2 $CH_2CH_2OH$), 4.18, 3.18 (4 H, t, 2 $CH_2CH_2CO_2$), 3.70 and 3.68 (9 H, s, 4 $CH_3$ and 2 $OCH_3$).

8,18-*Bis*(2-*chloroethyl*)-3,13-*bis*(2-*methoxycarbonylethyl*)-2,-7,12,17-*tetramethylporphyrin* **35**.—The dipyrromethane-9-carboxylic acid **34** (1.3 g) was dissolved in dichloromethane (100 $cm^3$) and toluene-*p*-sulfonic acid hydrate (1.2 g) in methanol (25 $cm^3$) was added to the solution. The mixture was stirred overnight under a nitrogen atmosphere after which a saturated solution of zinc(II) acetate in methanol (20 $cm^3$) was added and the mixture was stirred under an oxygen atmosphere for a

further 24 h. It was then poured into water and extracted with dichloromethane. The organic phase was washed with aqueous sodium hydrogencarbonate and water and then evaporated to dryness. The residue was stirred with 5% sulfuric acid in methanol (100 $cm^3$) for 12 h and the mixture was then worked up by the standard procedure described above. The residue obtained was purified by column chromatography (alumina; Brockmann Grade III, elution with dichloromethane) and the appropriate eluates were collected and combined. Evaporation of the solvent and crystallization from dichloromethane–light petroleum gave the title porphyrin (300 mg, 29%), m.p. 186–187 °C (Found: C, 65.0; H, 6.05; N, 8.2. $C_{36}H_{40}Cl_2N_4O_4$ requires C, 65.23; H, 6.08; N, 8.45%); $\lambda_{max}$/nm 402 (ε 183 600), 498 (9100), 532 (9700), 568 (9400) and 620 (2800); $\delta_H$ 9.98 (2 H, s, 2 *meso*-H), 9.82, 9.80 (1 H, s, 2 *meso*-H), 4.40 (8 H, m, 2 $CH_2CH_2Cl$), 4.32 (4 H, m, 2 $CH_2CH_2CO_2$), 3.75, 3.73 (3 H, s, 2 $OCH_3$), 3.65, 3.63, 3.62, 3.58 (3 H, s, 4 $CH_3$), 3.25 (4 H, m, 2 $CH_2CH_2CO_2$) and −4.12 (2 H, s, 2 NH).

13,17-*Bis*(2-*methoxycarbonylethyl*)-2,8,12,18-*tetramethyl*-3,7-*divinylporphyrin* **6**.—The bis(2-chloroethyl)porphyrin **12** (225 mg) was dissolved in pyridine (90 $cm^3$) and the solution heated under reflux for 5 min; aqueous sodium hydroxide (3%, 20 $cm^3$) was then added to it. The reaction mixture was then refluxed for 2.5 h before being treated with aqueous acetic acid (25%, 20 $cm^3$). The mixture was concentrated to *ca.* 50 $cm^3$ and the precipitate was collected and dried under high vacuum overnight. The next day the residue was dissolved in methanolic sulfuric acid (5%, 50 $cm^3$) and stirred in the dark for 12 h. The mixture was diluted with water and extracted with dichloromethane. The extract was washed with aqueous sodium hydrogencarbonate and water, dried ($Na_2SO_4$) and evaporated to dryness. The residue was chromatographed on alumina (Brockmann Grade III; elution with dichloromethane), and evaporation of the red eluates gave a residue which was crystallized from dichloromethane–hexane to give the title divinylporphyrin (100 mg, 50%), m.p. 263–265 °C; $\lambda_{max}$/nm 406 (ε 158 300), 504 (13 400), 540 (10 700), 574 (6400) and 628 (4600); $\delta_H$ 10.21, 9.86 (each 1 H, s, 2 *meso*-H), 9.88 (2 H, s, 2 *meso*-H), 8.20 (2 H, m, 2 $CH{=}CH_2$), 6.18–6.20 (4 H, m, 2 $CH{=}CH_2$), 4.40, 3.25 (each 4 H, t, 2 $CH_2CH_2CO_2$), 3.70 (6 H, s, 2 $OCH_3$), 3.68, 3.60 (6 H, s, 2 $CH_3$) and −3.90 (2 H, s, 2 NH) (Found: $M^+$, 590.2879. Calc. for $C_{36}H_{38}N_4O_4$: *M*, 590.2893).

3,13-*Bis*(2-*methoxycarbonylethyl*)-2,7,12,17-*tetramethyl*-8,18-*divinylporphyrin* **29**.—This porphyrin was similarly prepared (180 mg, 81%) from the corresponding bis(2-chloroethyl)porphyrin **35** (250 mg) and was crystallized from dichloromethane–light petroleum, m.p. 260–261 °C (Found: C, 72.8; H, 6.5; N, 9.4. $C_{36}H_{38}N_4O_4$ requires C, 73.18; H, 6.48; N, 9.48%); $\lambda_{max}$/nm 404 (ε 152 900), 504 (13 400), 538 (10 500), 574 (6400) and 628 (4600); $\delta_H$ 10.11 and 10.01 (each 2 H, s, 4 *meso*-H), 8.20 (2 H, m, 2 $CH{=}CH_2$), 6.14, 6.31 (2 H, 2 $CH{=}CH_2$), 4.33, 3.25 (4 H, t, 2 $CH_2CH_2CO_2$), 3.70, 3.69 (each 3 H, s, 2 $OCH_3$), 3.68, 3.61 (6 H, s, 2 $CH_3$) and −3.85 (2 H, s, 2 NH).

7-(2-*Acetoxyethyl*)-13,17-*bis*(2-*methoxycarbonylethyl*)-2,8,-12,18-*tetramethyl*-3-*vinylporphyrin* **17**.—Chloroethylporphyrin **14** (50 mg) in pyridine (20 $cm^3$) was treated with aqueous sodium hydroxide (3%; 10 $cm^3$) following the method described for the preparation of porphyrin **6** to give the 7-(2-hydroxyethyl)porphyrin **16** (40 mg, 75%); $\delta_H$ 10.00, 9.98, 9.96, 9.95 (each 1 H, s, 4 *meso*-H), 8.20 (1 H, m, $CH{=}CH_2$), 6.35, 6.18 (each 1 H, d, $CH{=}CH_2$), 4.38 (4 H, m, $CH_2CH_2OH$), 4.20, 3.25 (each 4 H, t, 2 $CH_2CH_2CO_2$), 3.75 (6 H, s, 2 $OCH_3$), 3.60, 3.58 (each 6 H, s, 2 $CH_3$) and −4.00 (2 H, s, 2 NH). It was redissolved in dry pyridine (20 $cm^3$) and acetic anhydride (5 $cm^3$) was added. The reaction mixture was stirred overnight and then poured into water and extracted with dichloromethane. The extract was washed with water several times and evaporated to dryness under high vacuum (to remove the last traces of pyridine). The residue was then passed through a short silica gel column (elution with 2% methanol–dichloromethane). The appropriate eluates were collected and evaporated, crystallization of the residues from dichloromethane–light petroleum gave the title compound (30 mg, 80%), m.p. 235–237 °C; $\lambda_{max}$/nm 402 (ε 172 000), 502 (11 400), 536 (10 500), 570 (8000) and 624 (3500); $\delta_H$ 10.14, 10.05 (each 1 H, s, 2 *meso*-H), 9.99 (2 H, s, 2 *meso*-H), 8.20 (1 H, m, $CH{=}CH_2$), 6.35, 6.18 (1 H, d, $CH{=}CH_2$), 4.86, 4.42 (each 2 H, t, $CH_2CH_2OAc$), 4.32, 3.24 (4 H, t, 2 $CH_2CH_2CO_2$), 3.70, 3.65, 3.62 (6 H, s, 4 $CH_3$ and 2 $OCH_3$), 2.01 (3 H, s, $OCOCH_3$) and −3.93 (2 H, s 2 NH) (Found: $M^+$, 650.3098. Calc. for $C_{38}H_{42}N_4O_6$: *M*, 650.3104).

3,7-*Bis*(2-*acetoxyethyl*)-13,17-*bis*(2-*methoxycarbonylethyl*)-2,8,12,18-*tetramethylporphyrin* **18**.—3,7-Bis(2-hydroxyethyl)-porphyrin **15** (50 mg) in pyridine (20 $cm^3$) was treated with acetic anhydride as described for the preparation of porphyrin **17**, to give the title porphyrin **18** (46 mg, 82%), m.p. 273–274 °C (Found: C, 67.8; H, 6.35; N, 7.8. $C_{40}H_{46}N_4O_8$ requires C, 67.57; H, 6.52; N, 7.88%); $\lambda_{max}$/nm 399 (ε 180 900), 498 (13 000), 530 (9100), 566 (6800) and 620 (4000); $\delta_H$ 10.18 (1 H, s, *meso*-H), 10.08 (3 H, s, 3 *meso*-H), 4.88, 4.41 (each 4 H, t $CH_2CH_2OAc$), 4.39, 3.26 (4 H, t, $CH_2CH_2CO_2$), 3.64 (18 H, s, 4 $CH_3$ and 2 $OCH_3$), 2.07 (6 H, s, 2 $OCOCH_3$) and −3.80 (2 H, s, 2 NH).

*Diels–Alder Reactions of Porphyrins with Tetracyanoethylene (TCNE); General Procedure.—Reaction of* 13,17-*bis*(2-*methoxycarbonylethyl*)-2,3,8,12,18-*pentamethyl*-7-*vinylporphyrin* **21** *to give* $7^1,7^1,7^2,7^2$-*Tetracyano*-2,18-*bis*(2-*methoxycarbonylethyl*)-3,7,12,13,17-*pentamethyl*-$7,7^1,7^2,7^3$-*tetrahydrobenzo*[g]*porphyrin* **39**.TCNE (50 mg) was added to monovinylporphyrin **21** (50 mg) dissolved in dry chloroform (20 $cm^3$) and the reaction mixture was refluxed for 30 min (monitored by spectrophotometry). The solvent was evaporated and the residue was purified on an alumina column (Brockmann Grade III; elution with dichloromethane). The eluates were collected and evaporated to give a residue which was crystallized from dichloromethane–light petroleum to afford the title compound as a green powder (32 mg, 52%), m.p. >300 °C; $\lambda_{max}$/nm 400 (ε 158 600), 498 (13 800), 532 (10 500), 594 (5600), 620 (4400) and 650 (42 100); $\delta_H$ 9.79, 9.69, 9.39, 9.24 (each 1 H, s, 4 *meso*-H), 7.02 (1 H, m, exocyclic ring CH), 4.33 (2 H, m, $CH_2CH_2CO_2$), 4.11–4.01 (2 H, m, $CH_2CH_2CO_2$), 4.15–4.11 (1 H, dd, exocyclic ring $CH_2$), 4.04–3.98 (1 H, dd, exocyclic ring $CH_2$), 3.67, 3.65 (each 3 H, s, 2 $OCH_3$), 3.55, 3.46, 3.43, 3.36 (each 3 H, s, ring $CH_3$), 3.23–3.18 (2 H, t, $CH_2CH_2CO_2$), 3.16–3.11 (2 H, t, $CH_2CH_2CO_2$), 2.37 (3 H, s, 7-$CH_3$), −2.77 and −2.85 (each 1 H, s, NH) (Found: $M^+$, 706.3018. Calc. for $C_{41}H_{38}N_8O_4$: *M*, 706.3008).

*Reduction of Protoporphyrin-III Dimethyl Ester* **6** *to give* $7^1,7^1,7^2,7^2$-*Tetracyano*-2,18-*bis*(2-*methoxycarbonylethyl*)-3,7,-13,17-*tetramethyl*-12-*vinyl*-$7,7^1,7^2,7^3$-*tetrahydrobenzo*[g]*porphyrin* **37** and $7^1,7^1,7^2,7^2,12^3,12^3,12^4,12^4$-*Octacyano*-2,18-*bis*(2-*methoxycarbonylethyl*)-3,7,13,17-*tetramethyl*- $7,7^1,7^2,7^3,12^2,-12^3,12^4$,13-*octahydro*-23-*dehydro*-24H-*dibenzo*[g,l]*porphyrin* **38**.—Protoporphyrin-III dimethyl ester **6** (50 mg) was treated with TCNE as described for the foregoing porphyrin to give the desired product **37** (15 mg, 36%), m.p. >300 °C; $\lambda_{max}$/nm 404 (ε 142 300), 500 (11 700), 536 (3700), 604 (4200) and 660 (30 700); $\delta_H$ 8.87, 9.81, 9.43, 9.37 (each 1 H, s, *meso*-H), 8.11–8.03 (1 H, m, $CH{=}CH_2$), 7.05 (1 H, m, exocyclic double bond CH), 6.33–6.15 (2 H, m, $CH{=}CH_2$), 4.65 (2 H, d, exocyclic ring $CH_2$), 4.33 (2 H, t, $CH_2CH_2CO_2$), 4.15 (2 H, t, $CH_2CH_2CO_2$), 3.67, 3.65 (each 3 H, s, 2 $OCH_3$), 3.61, 3.55, 3.40, 3.47 (each 3

H, s, ring $CH_3$), 3.23 (2 H, t, $CH_2CH_2CO_2$), 3.16 (2 H, t, $CH_2CH_2CO_2$), 2.35 (3 H, s, 7-$CH_3$), −2.58 and −2.72 (1 H, s, NH) (Found: $M^+$, 718.3056. Calc. for $C_{42}H_{38}N_8O_4$: *M*, 718.3008). Use of an excess of TCNE (*e.g.* 100 mg) and with a longer period of stirring (1 h) gave mainly isobacteriochlorin **38** (20 mg, 25%), m.p. 300 °C; $\lambda_{max}$/nm 410 (ε 135 000), 538 (9400), 542 (9350), 578 (8300), 640 (6650) and 662 (14 000); $\delta_H$[diastereoisomeric mixture (1:1)] 9.87, 9.82, 9.81, 9.63, 9.42, 9.34, 9.19, 8.98 (each 1 H, s, *meso*-H), 7.17 (2 H, m, exocyclic ring CH), 4.3–4.22 (4 H, m, exocyclic ring $CH_2$), 4.20–4.05 (8 H, m, $CH_2CH_2CO_2$), 3.75, 3.72, 3.68, 3.66, 3.55, 3.52, 3.42, 3.40 (3 H, s, $CH_3$ and $OCH_3$), 3.22–3.05 (8 H, m, $CH_2CH_2CO_2$), 2.42 (6 H, s, 13-$CH_3$), 2.38 (6 H, s, 7-$CH_3$), −2.55, −2.40 (1 H, s, NH) and −2.42 (2 H, s, 2 HN) (Found: $M^+$, 846.3132. Calc. for $C_{48}H_{38}N_{12}O_4$: *M*, 846.3128.

*Reaction of Divinylporphyrin* **29** *to give* $7^1,7^1,7^2,7^2,17^1,17^1,17^2,17^2$-*Octacyano*-3,13-*bis*(2-*methoxycarbonylethyl*)-2,7,12,17-*tetramethyl*-$7,7^1,7^1,7^3,17,17^1,17^2,17^3$-*octahydrodibenzo*[g,q]-*porphyrin* **43**.—Divinylporphyrin **29** (50 mg) was treated with TCNE, following the method described for the chlorin above, to give the desired bacteriochlorin **43** (18 mg, 30%), m.p. >300 °C; $\lambda_{max}$/nm 406 (107 200), 490 (24 340), 648 (14 750), 684 (14 340) and 720 (53 190), $\delta_H$ 9.36, 9.32, 9.23 and 9.21 (each 1 H, s, *meso*-H), 7.00 (1 H, m, exocyclic double bond CH), 6.91 (1 H, m, exocyclic double bond CH), 4.25 (4 H, m, exocyclic ring $CH_2$), 4.23–4.19 (2 H, m, $CH_2CH_2CO_2$), 4.08–4.00 (2 H, m, $CH_2CH_2CO_2$), 3.63, 3.62 (each 3 H, s, $OCH_3$), 3.45, 3.44 (each 6 H, s, ring $CH_3$), 2.34 (6 H, s, 7- and 17-$CH_3$), −2.65 and 2.70 (1 H, s, NH) (Found: $M^+$, 846.3138. Calc. for $C_{48}H_{38}N_{12}O_4$: *M*, 846.3128).

*Reaction of* 3-(1-*Hydroxyethyl*)-8-*vinyldeuteroporphyrin Dimethyl Ester* **22** *to give* $7^1,7^1,7^2,7^2$-*Tetracyano*-3-(1-*hydroxyethyl*)-13,17-*bis*(2-*methoxycarbonylethyl*)-2,7,13,17-*tetramethyl*-$7,7^1,7^2,7^3$-*tetrahydrobenzo*[g]*porphyrin* **40**.—3-(1-Hydroxyethyl)-8-vinyl deuteroporphyrin dimethyl ester **22** (15 mg) in chloroform (10 $cm^3$) was treated with TCNE (15 mg), following the method described for synthesis of the chlorin **39**. The product, purified on preparative thick layer plates (silica gel) eluted with 2% methanol in dichloromethane, was extracted and then crystallized from dichloromethane–light petroleum; yield 15 mg (85%), m.p. >300 °C; $\lambda_{max}$/nm 400 (ε 177 000), 496 (13 000), 532 (6700), 596 (4400), 622 (3500) and 650 (44 000); $\delta_H$[mixture of diastereoisomers (1:1)] 10.01, 9.96, 9.76, 9.70, 9.22, 9.20, 9.05, 8.63 (each 1 H, s, 8 *meso*-H), 7.09, 7.08 (each 1 H, m, exocyclic ring CH), 6.95–6.57 (2 H, m, $CH(OH)CH_3$), 4.15 (2 H, m, $CH_2CH_2CO_2$), 4.07 (4 H, d, exocyclic ring $CH_2$), 3.95 (4 H, m, $CH_2CH_2CO$), 3.67, 3.65 (each 3 H, s, $OCH_3$), 3.63, 3.62, 3.45, 3.42, 3.29, 3.22 (6 H, s, ring $CH_3$), 3.01 (4 H, m, $CH_2CH_2CO_2$), 2.90 (4 H, m, $CH_2CH_2CO_2$), 2.45, 2.39 (3 H, s, 7-$CH_3$), 2.22–2.25 (3 H, d, $CH(OH)CH_3$), −2.85, −2.95, −3.09 and −3.34 (1 H, s, 4 NH) (Found: $M^+$, 736.3125. Calc. for $C_{42}H_{40}N_8O_5$: *M*, 736.3113).

*Diels–Alder Reaction of Porphyrins with Dimethyl Acetylenedicarboxylate (DMD): General Procedure.—Reaction of vinylporphyrin* **21** *to give* $7^1,7^2$-*bis*(*methoxycarbonyl*)-2,18-*bis*(*methoxycarbonylethyl*)-3,6,7,13,17-*pentamethyl*-$7,7^1$-*dihydrobenzo*-[g]*porphyrin* **41**. DMD (1.0 $cm^3$) was added to monovinylporphyrin **21** (50 mg) dissolved in dry toluene (25 $cm^3$) and the reaction mixture was refluxed under nitrogen for 5 days. The solvent was evaporated and the residue was dried under high vacuum to remove the remaining traces of DMAD. A few drops of DBU were added and the mixture was stirred for 10 min (monitored by spectrophotometry). The reaction mixture was diluted with dichloromethane, washed with water and the dichloromethane layer was separated, dried ($Na_2SO_4$) and evaporated to dryness. The residue was purified by preparative thick layer plates (silica gel, elution with 2% methanol in dichloromethane). The product, extracted from the silica gel, was recrystallized from dichloromethane–light petroleum to give the title compound as a fluffy solid (20 mg, 32%), m.p. 210–212 °C; $\lambda_{max}$/nm 412 (ε 80 500), 572 (14 800), 614 (6400) and 672 (18 000); $\delta_H$ 9.76, 9.69, 9.29, 9.25 (each 1 H, s, *meso*-H), 7.75, 7.30 (1 H, m, exocyclic CH), 4.80 (1 H), 4.35, 4.20 (2 H, t, $CH_2CH_2CO_2$), 4.27, 3.94 (3 H, s exocyclic ring $OCH_3$), 3.67 (6 H, s, $OCH_3$), 3.51, 3.50 (3 H, s, ring $CH_3$), 3.42 (6 H, s, ring $CH_3$), 3.17 (4 H, m, $CH_2CH_2CO_2$), 1.62 (3 H, s, exocyclic ring $CH_3$) and −2.65 and −2.75 (each 1 H, s, NH) (Found: $M^+$, 720.3155. Calc. for $C_{41}H_{44}N_4O_8$ *M*, 720.3159).

*Reaction of Protoporphyrin-III Dimethyl Ester* **6** *to give* $7^1,7^2$-*Bis*(*methoxycarbonyl*)-2,18-*bis*(2-*methoxycarbonylethyl*)-3,7,-13,17-*tetramethyl*-3-*vinyl*-$7,7^1$-*dihydrobenzo*[g]*porphyrin* **36**.—Protoporphyrin-III dimethyl ester **6** (50 mg) was treated with DMAD as described for the foregoing porphyrin to give the desired monovinylchlorin **36** (15.5 mg, 25%), m.p. 230–232 °C; $\lambda_{max}$/nm 418 (ε 70 000), 500 (6500), 572 (12 500), 624 (5600) and 682 (22 200); $\delta_H$ 9.77, 9.67, 9.31, 9.26 (1 H, s, *meso*-H), 8.07–8.17 (1 H, m, $CH{=}CH_2$), 7.69, 7.31 (1 H, m, exocyclic CH), 6.31, 6.14 (1 H, d, $CH{=}CH_2$), 4.30, 4.17 (4 H, t, $CH_2CH_2CO_2$), 4.24, 3.90 (3 H, exocyclic $OCH_3$), 3.64, 3.65 (3 H, s, $OCH_3$), 3.63, 3.46, 3.41 (3 H, s, ring $CH_3$), 3.17 (4 H, m, $CH_2CH_2CO_2$), 1.61 (3 H, s, exocyclic ring $CH_3$) and −2.56 (2 H, s, 2 NH) (Found: $M^+$, 732.3138. Calc. for $C_{42}H_{44}N_4O_8$: *M*, 732.3159).

*Reaction of the Divinylporphyrin* **29** *to give* $7^2,7^2,17^1,17^2$-*tetrakis*(*methoxycarbonyl*)-3,13-*bis*(2-*methoxycarbonylethyl*)-2,7,12,17-*tetramethyl*-$7,7^1,17,17^1$-*tetrahydrodibenzo*[g,q]*porphyrin* **42**.—The divinylporphyrin **29** (50 mg) in toluene (20 $cm^3$) was treated with DMAD (1 $cm^3$), as described for the preparation of porphyrin **41**, to give the desired bacteriochlorin **42** (15 mg, 20%), m.p. >300 °C; $\lambda_{max}$/nm 440 (ε 45 500), 592 (8800), 614 (8300), 654 (3650), 696 (6400) and 782 (10 900); $\delta_H$ 9.17, 8.70 (2 H, s, *meso*-H), 7.50–7.83 (4 H, dd merged, exocyclic CH), 4.87 (2 H, s), 3.90, 3.95 (2 H, t, $CH_2CH_2CO$), 3.65–3.87 (24 H, s merged, 4 exocyclic $OCH_3$, 2 $CH_2CH_2CO_2CH_3$, 2 ring $CH_3$), 1.80, 1.82 (3 H, s, angular $CH_3$), −1.82 (2 H, br s, 2 NH) (Found: $M^+$, 872.3252. Calc. for $C_{48}H_{48}N_4O_{12}$: *M*, 872.3262).

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