JOC Article

tert-Butyl-Substituted Tripyrranes: Insights into the Steric and Conformational Factors that Influence Porphyrinoid Ring Formation in the "3 + 1" Methodology†

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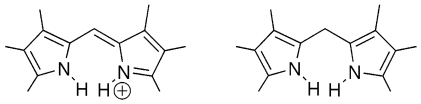
Received December 24, 2002

The MacDonald "3 + 1" route for porphyrinoid synthesis involves the acid-catalyzed condensation of tripyrranes with monocyclic dialdehydes, followed by an oxidation step. In the present study, yields were found to be greatly diminished when *tert*-butyl substituents were introduced on to the tripyrrane unit. Analysis of the proton NMR spectra for the tripyrranes indicates that the preferred conformation in solution has been radically altered by the presence of these *tert*-butyl moieties. This appears to be the first time that the NMR properties of an intermediate in porphyrin or porphyrin analogue synthesis have been correlated to its effectiveness in macrocycle formation.

Introduction

Numerous routes have been developed for the synthesis of porphyrins and related conjugated systems.[1−3] In early studies, Hans Fischer and co-workers made use of pyrromethene intermediates **1** (Chart 1),[2] but most modern approaches to porphyrinoid structures utilize precursors at the dipyrrylmethane oxidation level **2**.[3] However, small changes in the substituents often produce considerable variations in the yields.[1,3] In most syntheses of macrocyclic ring systems, high dilution techniques may be used to improve the yields but this approach, while successful in some cases,[4] must be applied with caution in porphyrin syntheses.[5−9] The pyrrolic intermediates are prone to protonation−fragmentation processes (acidolysis) and the resulting subcomponents may in turn recombine to form mixtures of products.[5−9] Hence, dilution may produce mixtures of porphyrinoids and does not necessarily improve the yield. Therefore, considerable caution must be applied in the synthesis of asymmetrical porphyrinoid macrocycles.[10] However, so long as appropriate conditions are utilized, isomerically pure porphyrinoids can be prepared from dipyrrylmethanes and higher oligomers.[1,3,10]

CHART 1



1 Pyrromethene **2** Dipyrrylmethane (Dipyrromethane)

A valuable route for the synthesis of porphyrins and their analogues is the "3 + 1" variant on the MacDonald condensation.[11] Although this approach was first applied by Johnson and co-workers to the synthesis of oxa- and thiaporphyrins over thirty years ago,[12] it was not until the mid-1990s that this methodology became widely used.[11,13,14] We have applied this chemistry to the synthesis of diverse porphyrin analogues,[15] including carba-

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† Part 25 in the series Conjugated Macrocycles Related to the Porphyrins. for Part 25, see: Liu, D.; Lash, T. D. *J. Org. Chem.* **2003**, *68*, 1755−1761.

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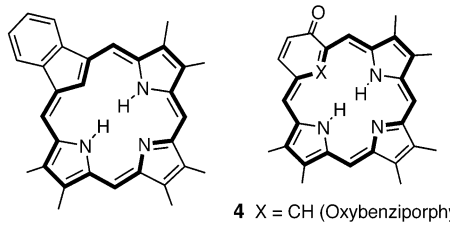
10.1021/jo0207628 CCC: $25.00
Published on Web 04/23/2003

CHART 2



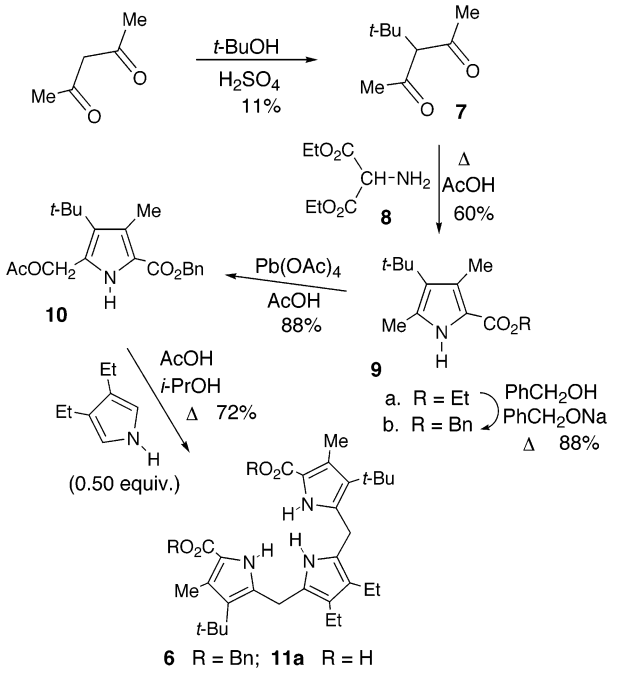
3 Benzocarbaporphyrin **4** X = CH (Oxybenziporphyrin) **5** X = N (Oxypyriporphyrin)

porphyrins **3**,[16,17] oxybenziporphyrins **4**,[7,18] and oxypyriporphyrins **5**[7,19] (Chart 2). In some cases, the porphyrinoid products have limited solubility due to aggregation of the near-planar macrocycles and this is restrictive placing limitations on the spectroscopic studies that are possible. For this reason, we were interested in the introduction of *tert*-butyl substituents on to the macrocyclic rings to interfere with π stacking interactions. Although it turned out that the presence of two *tert*-butyl groups only gave a small improvement in solubility, the results from these studies provide novel insights into the effects of peripheral substituents on the efficacy of the "3 + 1" methodology.[20]

Results and Discussion

To synthesize *tert*-butyl-substituted porphyrinoids, the novel tripyrrane **6** was targeted for synthesis (Scheme 1). Acetylacetone reacted with *tert*-butyl alcohol in sulfuric acid to give 3-*tert*-butyl-2,4-pentanedione (**7**) in modest yield. Although higher yields of diketone **7** have been reported with perchloric acid,[21] the low cost of the reagents and the relative safety of the procedure made this method preferable for our investigations. Condensation of **7** with diethyl aminomalonate (**8**)[22] in refluxing acetic acid afforded the pyrrole ethyl ester **9a** in 60% yield. Transesterification with benzyl alcohol in the presence of sodium benzyloxide then gave the benzyl ester **9b**, and subsequent regioselective oxidation with lead tetraacetate yielded the acetoxymethylpyrrole **10**. Further reaction of 3,4-diethylpyrrole with 2 equiv of **10** in refluxing acetic acid−isopropyl alcohol[13a,23] gave the required tripyrrane **6** in 72% yield. The benzyl ester protective groups were then cleaved by hydrogenolysis over 10% palladium-charcoal to generate the dicarboxylic acid **11a** (quantitative).

SCHEME 1



6 R = Bn; **11a** R = H

Tripyrrane **11a** was condensed with 4-hydroxyisophthalaldehyde (**12a**) in TFA-dichloromethane, and following oxidation with DDQ the di-*tert*-butyloxybenziporphyrin **13a** was isolated in very poor yields. The reaction of **11a** with 4-hydroxypyridinedialdehyde **12b**[19] was also investigated but again inferior yields of the porphyrinoid product **14a** were noted. By varying the reaction conditions, some improvements were obtained. Under more dilute conditions, the yield of oxypyriporphyrin **14a** was raised to 25%, although this is still not comparable to earlier results where yields of >80% were obtained in some cases when **11b** was reacted with **12b** to give **14b**.[7,19] Reaction of tripyrrane **11b** with **12a** has also been reported to give >40% yield of oxybenziporphyrin **13b**.[7,18] In the reaction of **11a** with **6a**, the best results were obtained under more concentrated conditions, but the yields of porphyrinoid product **13a** were still <5%. Reaction of indene dialdehyde **15** with **11a** gave benzocarbaporphyrin **16a** in 18% yield under the more dilute conditions, but again **13b** had previously been reported to give yields of **16b** that were consistently well above 40%.[17] The new di-*tert*-butyl-substituted porphyrinoids were isolated and fully characterized, but the lower yields obtained for this series limits possible applications.

Although the affects of the *tert*-butyl substituents had not been anticipated, analysis of the proton NMR spectrum for tripyrrane **6** gave a clear indication for the origin of the low yields observed. Previously, the NMR spectra of tripyrranes such as **17** (the precursor to **11b**) have been shown to be relatively unusual (Figure 1A).[13a,14a,23] Specifically, the resonances for the bridge methylene protons and the benzyl ester CH_2 units are broadened, and the latter absorption is shifted upfield from an expected chemical shift value of 5.3 to 4.5 ppm.[13a] In addition, significant shielding of the ortho protons for the benzyl unit can be observed. Variable-temperature proton NMR spectroscopic studies indicate that the signal broadening is due to the interconversion of two equivalent conformations.[14a] The data are consistent with the presence of

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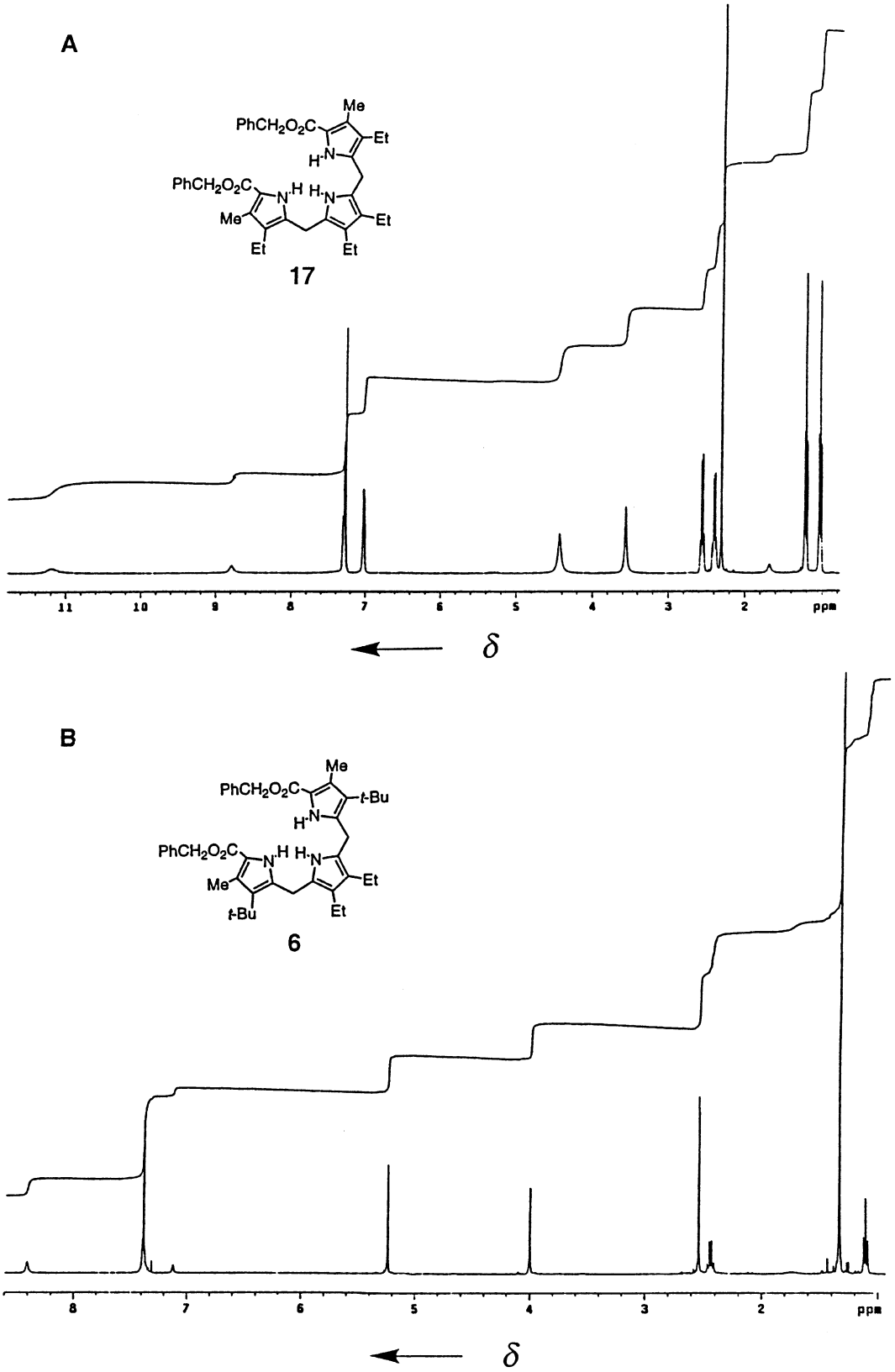
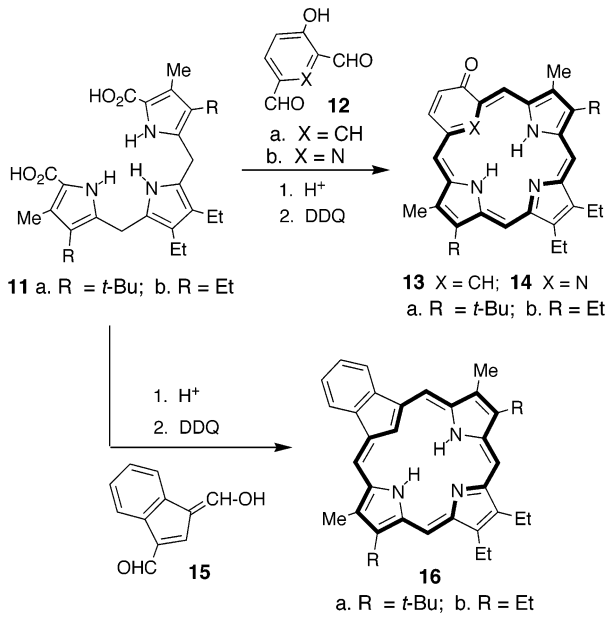


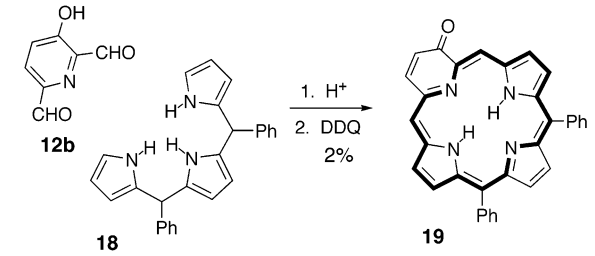
FIGURE 1. 400-MHz proton NMR spectra of tripyrranes **6** and **17** in deuteriochloroform. (A) Proton NMR spectrum of a typical tripyrrane **17** showing the 4H broadened upfield shifted methylene resonance for the benzyl esters at 4.5 ppm and a broadened 4H singlet for the bridge CH_2's at 3.6 ppm. (B) Proton NMR spectrum of di-*tert*-butyltripyrrane **6** showing an unperturbed benzyl methylene resonance at 5.3 ppm and a sharp singlet for the bridge CH_2's at 4.0 ppm.

helical structures that undergo a left-hand to right-hand helix-to-helix interconversion.[13a] The helical configuration causes the terminal benzyl esters to lie underneath the π system of the furthest removed pyrrole unit and this

SCHEME 2



SCHEME 3



results in the observed shielding effects.[13a] The proton NMR spectrum of di-*tert*-butyl tripyrrane **6** is quite different (Figure 1B). No broadening is observed and the benzyl ester units do not show any of the attributes observed for **17**. The profound differences in the spectroscopic data must be due to tripyrrane **6** taking on a completely different conformation from tripyrrane **17**. As the helical shape adopted by most tripyrranes provides a geometry that will facilitate macrocycle formation, it is little wonder that the *tert*-butyl-substituted system affords such poor yields of porphyrinoid products.

Diphenyltripyrrane **18** (Scheme 3) can be obtained directly from the reaction of pyrrole and benzaldehyde[24] and this system was also briefly investigated. As we had obtained our best yields in the synthesis of oxypyriporphyrins, we investigated the reaction of **18** with **12b** under standard "3 + 1" conditions (Scheme 3). However, the resulting porphyrinoid **19** was isolated in only 2% yield. Although this study allowed the new oxypyriporphyrin to be characterized, tripyrrane **18** does not appear to be well suited for these types of investigation. In this case, the low yields appear to be due to acidolysis of the tripyrrane rather than the sterically induced conformational changes that are observed for tripyrrane **6**. It is worth noting that this problem has been overcome for some related oxa-, thia-, and selenatripyrranes by using sterically encumbering mesityl substituents in place of phenyl groups.[25] This modification has allowed the synthesis of some heteroanalogues of oxybenziporphyrins and azuliporphyrins.[25]

Conclusions

The introduction of *tert*-butyl substituents onto tripyrranes appears to sterically inhibit the usual helical conformation and this results in much reduced yields of porphyrinoid products with use of the "3 + 1" methodology. These results further emphasize the complex interplay of factors that must be taken into account in porphyrin and porphyrin analogue synthesis.

Experimental Section

Chromatography was performed with Grade 3 neutral alumina or 70−230 mesh silica gel. EI and FAB mass spectral determinations were made at the Mass Spectral Laboratory, School of Chemical Sciences, University of Illinois at Urbana−Champaign, supported in part by a grant from the National Institute of General Medical Sciences (GM 27029). Elemental analyses were obtained from the School of Chemical Sciences Microanalysis Laboratory at the University of Illinois.

3-*tert*-Butyl-2,4-pentanedione (7). Concentrated sulfuric acid (48.0 g) was added dropwise to a stirred solution of 2,4-pentanedione (50.0 g) in nitromethane (100 mL) that was cooled with the aid of an ice bath. *tert*-Butyl alcohol (60.0 g) was then added dropwise to the stirred mixture while maintaining the temperature below 10 °C during the addition process. The resulting mixture was allowed to stir at room temperature overnight. Water (250 mL) was added slowly, and the mixture extracted (×3) with petroleum ether (500 mL; boiling range 30−60 °C). The combined organic solutions were washed with 2 M aqueous sodium sulfate solution (600 mL) and dried over potassium carbonate. The solvent was removed on a rotary evaporator and the residue purified by vacuum distillation to give 3-*tert*-butyl-2,4-pentanedione (8.9 g; 11%) as a pale yellow oil, bp 90−94 °C at 18 Torr (lit.[21] bp 76−79 °C at 11 Torr); IR (neat):ν 1723, 1699 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.08 (9H, s), 2.20 (6H, s), 3.65 (1H, s).

Ethyl 4-*tert*-Butyl-3,5-dimethyl-1*H*-pyrrole-2-carboxylate (9a). A mixture of diethyl aminomalonate[22] (7.0 g) and 3-*tert*-butyl-2,4-pentanedione (6.3 g) was added dropwise to refluxing acetic acid (40 mL). The resulting orange-red solution was refluxed for a further 2 h. The mixture was then poured into 200 mL of ice−water. The resulting precipitate was filtered and recrystallized from 95% ethanol to give the title pyrrole (5.35 g; 60%) as white crystals, mp 109−110 °C (lit.[26] mp 107−109 °C); IR (Nujol mull) ν 3306 (st, sh, NH), 1669 cm^{-1} (st, C=O); ^{1}H NMR ($CDCl_3$) δ 1.34 (3H, t, J = 7 Hz), 1.36 (9H, s), 2.37 (3H, s), 2.50 (3H, s), 4.29 (2H, q, J = 7 Hz), 8.60 (1H, br s); ^{13}C NMR ($CDCl_3$) δ 13.7, 14.8, 16.6, 32.0, 33.2, 59.8, 117.3, 127.7, 128.1, 128.9, 161.7. Anal. Calcd for $C_{13}H_{21}NO_2$: C, 69.92; H, 9.48; N, 6.27. Found: C, 70.08; H, 9.93; N, 6.44.

Benzyl 4-*tert*-Butyl-3,5-dimethyl-1*H*-pyrrole-2-carboxylate (9b). A solution of sodium benzyloxide was prepared by dissolving sodium (0.10 g) in benzyl alcohol (10 mL). The foregoing pyrrole ethyl ester (10.0 g) was taken up in benzyl alcohol (30 mL) in an open Erlenmeyer flask with a magnetic stir bar and a thermometer placed approximately 3 cm above the liquid level to monitor the vapor temperature. The stirred mixture was gradually heated on an oil bath so that the bath temperature increased from room temperature to 250 °C over

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a period of 90 min. During this time, small portions of the sodium benzyloxide solution were periodically added. When the vapor temperature reached 200 °C, a final portion of sodium benzyloxide was added, and stirring was continued for 5 min. The hot solution was then poured into an ice cold mixture of methanol (80 mL), water (50 mL), and acetic acid (1 mL). The resulting precipitate was suction filtered and recrystallized from ethanol to give the benzyl ester (11.33 g; 88%) as white needles, mp 109.5−110 °C; IR (Nujol mull) ν 3310 (st, sh, NH), 1660 cm^{-1} (st, C═O); ^{1}H NMR ($CDCl_3$) δ 1.42 (9H, s), 2.40 (3H, s), 2.58 (3H, s), 5.34 (2H, s), 7.30−7.41 (5H, m), 8.62 (1H, br s); ^{13}C NMR ($CDCl_3$) δ 14.0, 16.8, 32.0, 33.3, 65.6, 116.6, 128.1, 128.2, 128.4, 128.6, 128.8, 136.6, 161.1. Anal. Calcd for $C_{18}H_{23}NO_2$: C, 75.75; H, 8.12; N, 4.91. Found: C, 75.80; H, 8.40; N, 5.10.

Benzyl 5-Acetoxymethyl-4-*tert*-butyl-3-methyl-1*H*-pyrrole-2-carboxylate (10). Lead tetraacetate (95%; 18.1 g) was added to a solution of pyrrole **9b** (11.0 g) in acetic acid (90 mL) and acetic anhydride (9 mL), and the resulting mixture was stirred at room temperature for 3 h. The mixture was poured into ice−water, and the resulting precipitate was filtered and washed well with water. Recrystallization from chloroform−petroleum ether (60−90°) gave the acetoxymethylpyrrole (12.6 g; 88%) as white crystals, mp 104−105 °C. An analytical sample was obtained as fluffy white microneedles by recrystallization from hexanes, mp 108−109 °C. IR (Nujol mull) ν 3302 (st, sh, NH), 1740 (st, acetoxy-C═O), 1668 cm^{-1} (st, pyrrole-C═O); ^{1}H NMR ($CDCl_3$) δ 1.38 (9H, s), 2.08 (3H, s), 2.51 (3H, s), 5.19 (2H, s), 5.30 (2H, s), 7.30−7.43 (5H, m), 8.94 (1H, br s); ^{13}C NMR ($CDCl_3$) δ 13.6, 21.2, 31.8, 33.4, 59.9, 65.9, 119.2, 125.9, 127.6, 128.3, 128.4, 128.8, 131.8, 136.6, 161.2, 171.3. Anal. Calcd for $C_{20}H_{25}NO_4$: C, 69.95; H, 7.34; N, 4.08. Found: C, 70.14; H, 7.50; N, 3.90.

2,5-Bis(5-benzyloxycarbonyl-3-*tert*-butyl-4-methyl-2-pyrrolylmethyl)-3,4-diethyl-1*H*-pyrrole (6). 3,4-Diethylpyrrole[27] (0.50 g) and benzyl 5-acetoxymethyl-4-*tert*-butyl-3-methylpyrrole-2-carboxylate (2.46 g) were dissolved in 2-propanol (15 mL) and acetic acid (2 mL). The resulting solution was stirred and refluxed under an atmosphere of nitrogen for 16 h. The mixture was allowed to cool to room temperature and further cooled in an ice bath. The resulting precipitate was filtered, washed with cold ethanol, and dried in vacuo overnight to give the tripyrrane (2.02 g; 72%) as a white powder, mp 212−213 °C dec. ^{1}H NMR ($CDCl_3$) δ 1.16 (6H, t, J = 7.5 Hz), 1.33 (18H, s), 2.43 (4H, q, J = 7.5 Hz), 2.53 (6H, s), 4.00 (4H, s), 5.24 (4H, s), 7.14 (1H, br s), 7.3−7.4 (10 H, m), 8.40 (2H, br s); ^{13}C NMR ($CDCl_3$) δ 13.9, 16.4, 17.9, 26.8, 31.9, 33.3, 65.6, 117.4, 121.6, 121.8, 128.1 (2), 128.3, 128.5, 128.9, 129.0, 136.8, 160.6; ei ms (70 eV) m/z (rel intensity) 689.5 (M^+), 406 (100), 271 (19), 268 (40), 256 (30), 136 (54), 135 (60), 122 (28), 91 (94). Anal. Calcd for $C_{44}H_{55}N_3O_4$: C, 76.60; H, 8.04; N, 6.09. Found: C, 76.05; H, 8.14; N, 5.95.

2,5-Bis(5-carboxy-3-*tert*-butyl-4-methyl-2-pyrrolylmethyl)-3,4-diethyl-1*H*-pyrrole (11a). The foregoing tripyrrane dibenzyl ester (1.00 g) was dissolved in freshly distilled anhydrous THF (150 mL) and placed in a hydrogenation vessel. The solution was diluted with methanol (50 mL) and triethylamine (20 drops) was added. After air was flushed from the vessel with nitrogen, 200 mg of 10% palladium on activated carbon was added and the resulting mixture shaken under an atmosphere of hydrogen at 40 psi for 16 h. The catalyst was removed by suction filtration and the solvent evaporated under reduced pressure while maintaining the temperature below 30 °C. The residue was taken up in 3% aqueous ammonia solution (ca. 50 mL) and the mixture cooled to 5 °C with the aid of an ice-salt bath. The solution was neutralized to a litmus endpoint with glacial acetic acid, maintaining the temperature below 5 °C throughout. The mixture was allowed to stand for 1 h at 0 °C. Following suction filtration, the solid was washed exhaustively with deionized water to remove all traces of acid. The solid was dried overnight in vacuo to give the tripyrrane dicarboxylic acid (700 mg; 98%) was a pink powder, mp 109−110 °C dec. ^{1}H NMR ($CDCl_3$) δ 1.13 (6H, t, J = 7.4 Hz), 1.33 (18H, s), 2.45 (4H, q, J = 7.4 Hz), 2.52 (6H, s), 4.06 (4H, s), 7.20 (1H, br s), 8.55 (2H, br s); ^{1}H NMR (d_6-DMSO) δ 0.92 (6H, t, J = 7.6 Hz), 1.13 (18H, s), 2.17 (4H, q, J = 7.6 Hz), 2.34 (6H, s), 3.88 (4H, s), 8.31 (1H, br s), 10.22 (2H, s), 11.84 (2H, br s); ^{13}C NMR (d_6-DMSO): δ 13.3, 16.2, 17.1, 25.7, 31.4, 32.5, 117.6, 119.0, 122.2, 125.9, 127.6, 128.9, 162.4. Anal. Calcd for $C_{30}H_{43}N_3O_4$: C, 70.70; H, 8.50; N, 8.24. Found: C, 71.35; H, 8.73; N, 7.83.

9,18-Di-*tert*-butyl-13,14-diethyl-8,19-dimethyloxypyriporphyrin (14a). Tripyrrane dicarboxylic acid **11a** (100 mg) was stirred with TFA (5 mL) under an atmosphere of nitrogen for 10 min. The solution was diluted with dichloromethane (95 mL), followed immediately by the addition of hydroxypyridinedialdehyde **12b**[19] (29.7 mg), and the mixture was stirred under nitrogen, in the dark, for a further 16 h. After neutralization by the dropwise addition of triethylamine, DDQ (47 mg) was added and the resulting solution was stirred in the dark for an additional 1 h. The mixture was washed with water and chromatographed on Grade 3 alumina, eluting first with dichloromethane and then with chloroform. A deep green fraction was collected with chloroform and recrystallized from chloroform−methanol to give the title porphyrin analogue (26.2 mg; 25%) as dark bluish purple crystals, mp 288−290 °C. UV−vis ($CHCl_3$) λ_{max} (log ϵ) 320 (4.36), 350 (4.07), 427 (5.34), 442 (5.05), 590 (4.36), 609 (4.40), 658 nm (3.04); UV−vis (TFA-$CHCl_3$) λ_{max} (log ϵ) 436 (5.37), 594 (4.08), 633 (4.13), 649 nm (4.16); ^{1}H NMR ($CDCl_3$) δ −3.01 (1H, s), −2.89 (1H, s), 1.84 (6H, t, J = 7.6 Hz), 2.36 (9H, s), 2.37 (9H, s), 3.83 (3H, s), 3.89 (3H, s), 3.88 (4H, q, J = 7.6 Hz), 7.95 (1H, d, J = 9.6 Hz), 9.35 (1H, d, J = 9.6 Hz), 9.67 (1H, s), 10.34 (1H, s), 10.36 (1H, s), 11.09 (1H, s); ^{1}H NMR (TFA-$CDCl_3$) δ −1.2 (2H, br), 1.70 (6H, t, J = 7.6 Hz), 2.17 (9H, s), 2.18 (9H, s), 3.62 (3H, s), 3.66 (3H, s), 3.86−3.93 (4H, 2 overlapping quartets), 8.73 (1H, d, J = 9.6 Hz), 9.82 (1H, d, J = 9.6 Hz), 10.10 (1H, s), 10.73 (1H, s), 10.74 (1H, s), 10.97 (1H, s); ^{13}C NMR ($CDCl_3$) δ 14.8, 15.2, 18.4 (2), 20.0, 34.9, 36.4, 99.5, 99.9, 103.2, 107.7, 131.2, 133.6, 134.6, 135.6, 136.7, 137.8, 138.6, 139.3, 143.1, 143.5, 144.3, 145.1, 145.2, 154.1, 154.7, 185.5; ^{13}C NMR (TFA-$CDCl_3$) δ 15.0, 15.2, 16.9, 17.0, 20.2, 33.5, 36.8 (2), 101.8, 102.0, 103.8, 107.4, 132.5, 133.0, 134.1, 141.8, 141.9, 142.7, 143.3, 144.0, 146.1, 146.2, 148.6, 148.7, 149.2, 149.5, 176.0; ei ms (70 eV) m/z (% rel intensity) 534 (M^+, 100), 519 (12), 506 (3.7), 491 (4.0), 267 (M^{2+}, 4.9); hr ms calcd for $C_{35}H_{42}N_4O$ m/z 534.3358, found 534.3359.

11,16-Diphenyloxypyriporphyrin (19). 19 was prepared by using the foregoing conditions from diphenyltripyrrane **18** in 2% yield. Dark purple crystals (chloroform−methanol), mp >260 °C. UV−vis ($CHCl_3$) λ_{max} (rel intensity) 310 (0.10), 430 (1.00), 441 (infl., 0.65), 535 (0.055), 577 (0.059), 615 (0.033), 677 nm (0.0097); UV−vis (2% TFA-$CHCl_3$) λ_{max} (rel intensity) 448 (1.00), 461 (infl., 0.73), 601 (0.059), 650 nm (0.037); ^{1}H NMR ($CDCl_3$) δ −3.11 (1H, s), −2.99 (1H, s), 7.74−7.82 (6H, m), 7.93 (1H, d, J = 9.5 Hz), 8.14−8.18 (4H, m), 8.66−8.69 (2H, AB quartet, J = 4.5 Hz), 8.98 (2H, d, J = 5 Hz), 9.31 (1H, d, J = 9.5 Hz), 9.32 (1H, d, J = 4 Hz), 9.42 (1H, d, J = 4 Hz), 9.77 (1H, s), 10.93 (1H, s); ^{1}H NMR (TFA-$CDCl_3$) δ 0.4 (2H, br), 8.02−8.08 (6H, m), 8.45−8.48 (4H, m), 8.58 (1H, d, J = 10 Hz), 8.60−8.63 (2H, AB quartet, J = 4.8 Hz), 8.81 (2H, d, J = 4.8 Hz), 9.14 (1H, d, J = 5.2 Hz), 9.25 (1H, d, J = 4.8 Hz), 9.69 (1H, d, J = 10 Hz), 10.04 (1H, s), 10.93 (1H, s); ei ms (70 eV) m/z (% rel intensity) 492 (21), 491 (39), 490 (M^+, 100), 462 ([M − CO]$^+$, 19), 518 (12), 505 (3.3), 490 (6.6), 278 (M^{2+}, 10); hr ms calcd for $C_{33}H_{22}N_4O$ m/z 490.1794, found 490.1786.

9,18-Di-*tert*-butyl-13,14-diethyl-8,19-dimethyl-21-carbabenzo[*b*]porphyrin (16a). The title porphyrinoid was prepared from tripyrrane **11a** (100 mg), indene dialdehyde **15**[28] (34 mg), TFA (2 mL), and dichloromethane (98 mL) with the

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conditions described above for **14a**. Recrystallization from chloroform−methanol gave the carbaporphyrin (20 mg; 18%) as fluffy red-brown crystals, mp 271−272 °C. UV−vis ($CHCl_3$) λ_{max} (log ϵ) 307 (4.29), 377 (4.52), 427 (5.22), 515 (4.21), 547 (3.98), 602 (3.70), 661 nm (3.35); UV−vis (0.01% TFA-$CHCl_3$; monocation) λ_{max} (log ϵ) 307 (4.51), 403 (4.70), 429 (4.92), 442 (4.97), 476 (4.51), 515 (3.79), 551 (4.03), 612 nm (3.91); UV−vis (50% TFA-$CHCl_3$; dication) λ_{max} (log ϵ) 347 (4.54), 427 (5.21), 618 (3.87), 673 nm (4.33); ^{1}H NMR ($CDCl_3$) δ −6.69 (1H, s), −3.72 (2H, br s), 1.89 (6H, t, J = 7.6 Hz), 2.38 (18H, s), 3.87 (6H, s), 3.98 (4H, q, J = 7.6 Hz), 7.73−7.77 (2H, m), 8.84−8.88 (2H, m), 10.15 (2H, s), 10.39 (2H, s); ^{1}H NMR (trace TFA-$CDCl_3$; monocation) δ −6.50 (1H, s), −4.82 (1H, s), −3.86 (2H, s), 1.82 (6H, br t), 2.25 (18H, s), 3.75 (6H, s), 4.02 (4H, br q), 7.72 (2H, br m), 8.64 (2H, br m), 10.29 (2H, s), 10.53 (2H, s); ^{1}H NMR (50% TFA-$CDCl_3$; dication) δ −4.85 (2H, s), −1.20 (2H, br s), 1.70 (6H, t, J = 7.8 Hz), 2.24 (18H, s), 3.75 (6H, s), 3.95 (4H, q, J = 7.8 Hz), 8.89−8.92 (2H, m), 10.06−10.10 (2H, m), 10.96 (2H, s), 11.00 (2H, s); ^{13}C NMR ($CDCl_3$; free base) δ 14.9, 18.6, 20.4, 34.8, 36.6, 98.2, 99.3, 108.7, 120.5, 126.6, 132.1, 133.7, 135.5, 135.8, 141.9, 142.1, 144.6, 152.3; ^{13}C NMR (50% TFA-$CDCl_3$; dication) δ 14.7, 17.1, 20.3, 32.9, 33.5, 37.6, 107.7, 111.2, 124.9, 134.7, 137.8, 139.4, 140.5, 146.0, 146.2, 151.2, 151.6, 154.8; ei ms (70 eV) *m*/*z* (% rel intensity) 555 (M^+, 100), 540 (8), 499 (23), 278 (M^{2+}, 10); hr ms calcd for $C_{39}H_{45}N_3$ *m*/*z* 555.3613, found 555.3615. Anal. Calcd for $C_{39}H_{45}N_3 \cdot 0.6CHCl_3$: C, 75.81; H, 7.46; N, 6.70. Found C, 75.96; H, 7.39; N, 6.63.

9,18-Di-*tert*-butyl-13,14-diethyl-8,19-dimethyloxybenziporphyrin (**13a**). Tripyrrane dicarboxylic acid **11a** (100 mg) was stirred with TFA (1 mL) under an atmosphere of nitrogen for 10 min. The solution was diluted with dichloromethane (19 mL) followed immediately by the addition of 5-formylsalicylaldehyde (**12a**; 29.9 mg), and the mixture was stirred under nitrogen, in the dark, for a further 2 h. After neutralization by the dropwise addition of triethylamine, DDQ (50 mg) was added and the resulting solution was stirred in the dark for an additional 1 h. The mixture was washed with water and chromatographed on Grade 3 alumina, eluting first with dichloromethane and then with chloroform. A deep-green fraction was collected with chloroform and recrystallized from chloroform−methanol to give the porphyrin analogue (5.2 mg; 4.9%) as sparkling purple needles, mp 284−286 °C dec. UV−vis ($CHCl_3$) λ_{max} (log ϵ) 315 (4.45), 335 (4.49), 432 (5.27), 457 (4.96), 549 (3.88), 592 (4.35), 635 (3.87), 697 nm (3.63); UV−vis (5% TFA-$CHCl_3$) λ_{max} (log ϵ) 352 (4.69), 439 (4.91), 555 (3.67), 598 (3.96), 715 (3.83), 758 nm (3.93); ^{1}H NMR ($CDCl_3$) δ −6.01 (1H, d, J = 2 Hz), −2.4 (2H, br s), 1.80−1.92 (6H, 2 overlapping triplets), 2.33 (18H, s), 3.73 (3H, s), 3.76 (3H, s), 3.76−3.87 (4H, 2 overlapping quartets), 7.48 (1H, d, J = 9 Hz), 8.79 (1H, dd, ^3J = 9 Hz, ^4J = 2 Hz), 9.42 (1H, s), 9.99 (1H, s), 10.08 (s, 1H), 10.68 (1H, s); ^{1}H NMR (TFA-$CDCl_3$) δ 1.46−1.56 (6H, 2 overlapping triplets), 1.85 (18H, s), 3.07 (6H, s), 3.17−3.25 (4H, 2 overlapping quartets), 6.16 (2H, br s), 7.41 (1H, d, J = 8.4 Hz), 8.24 (1H, s), 8.28 (1H, s), 8.39 (1H, d, J = 8.4 Hz), 8.68 (1H, s), 9.22 (1H, s); ^{13}C NMR ($CDCl_3$) δ 15.0, 15.2, 18.3, 18.4, 20.2, 34.7 (2), 36.3, 36.4, 97.4, 98.9, 105.7, 111.3, 121.5, 126.2, 130.0, 132.1, 134.4, 135.2, 137.7, 138.9, 140.9, 141.5, 144.9, 145.4, 147.9, 154.3, 155.9, 188.1; ^{13}C NMR (TFA-$CDCl_3$) δ 14.3, 15.8, 15.9, 19.0, 30.0, 32.6, 32.7, 35.3, 35.4, 95.7, 96.7, 112.8, 120.3, 120.5, 121.3, 124.1, 127.6, 140.5, 141.6, 144.2, 144.4, 144.8, 145.4, 145.6, 146.5, 147.0, 148.3, 149.6, 156.5, 158.0, 159.4, 159.8, 160.7, 170.1; ei ms (70 eV) *m*/*z* (% rel intensity) 533 (M^+, 100), 519 (12), 518 (12), 505 (3.3), 490 (6.6), 266 (M^{2+}, 6.7); hr ms calcd for $C_{36}H_{43}N_3O$ *m*/*z* 533.3402, found 533.3406.

Acknowledgment. This material is based upon work supported by the National Science Foundation under Grant Nos. CHE-9732054 and CHE-0134472, and the Petroleum Research Fund, administered by the American Chemical Society.

Supporting Information Available: UV−vis, ^{1}H NMR, ^{13}C NMR, and mass spectra for selected compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

JO0207628