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GABLE-PORPHYRIN AS A CYTOCHROME-c_3 MODEL

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Cytochrome-c_3 has two quite different heme-heme interaction models, "gable"-type and "twist"-type. Bis m-(meso-triphenylporphinyl) benzene was newly prepared as a gable conformation model. This "gable" porphyrin exhibited moderate porphyrin-porphyrin and heme-heme interaction.

One of the most important biological functions of hemeproteins is electron transport. Among the electron transporting hemeproteins, cytochrome c_3 is unique and interesting one having four heme units in a single protein to transport electron very efficiently in biological systems[1] as well as across artificial membrane.[2] Also it *conducts electricity* in a solid state[3] as the first example in native proteins. This protein has large negative reduction potentials (-0.226, -0.278, -0.298 and -0.330) quite different from other cytochromes. These striking characteristics should originate from interprotein and intraprotein heme-heme interaction, and from this reason an appropriate model compound is necessary for elucidation of the nature of these remarkable interaction. Recently, the crystal structure of cyt-c_3 from two different origins have been reported, the essential configurational characteristics of which may be depicted as Fig 1. Although several dimeric porphyrins are known, none of

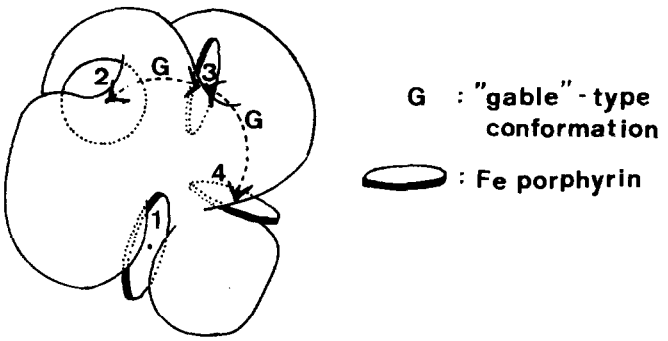
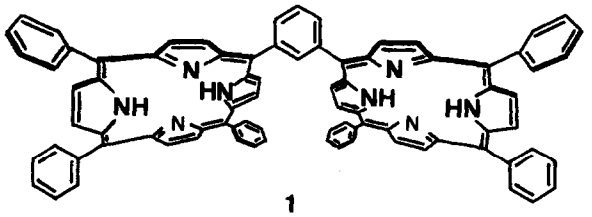


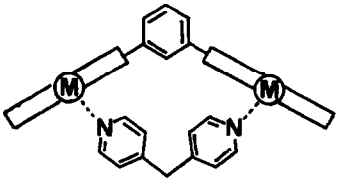
Fig. 1. Conformational characteristics of four heme units in cyt c_3.

them does not fit configurational requirements of cyt-c_3 and authors have been trying to prepare a new porphyrin as a cyt-c_3 model.[4-6]

The authors now wish to report the preparation of "gable porphyrin" 1 as a local model of cyt-c_3 and the significant porphyrin-porphyrin interaction or the heme-heme interaction observed for 1.



1

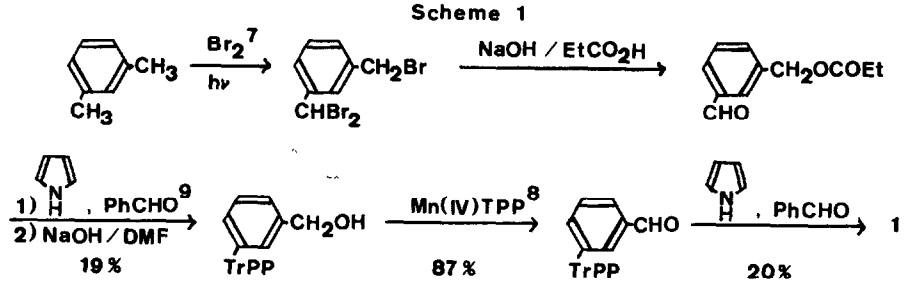


2

a M = Zn^{2+}
b Fe^{3+}
c Fe^{2+}
d Cu^{2+}

Preparation of 1 was achieved via the stepwise approach (Scheme I). Treatment of 1 with an appropriate metal salt gave the corresponding gable metal complex, 2a-d, in a practically

Scheme 1



TrPP : meso-triphenylporphynyl

quantitative yield.

IR spectrum of 1, 1585, 1460, 1430, 1390, 1340, 1000, 960, 920, 798, 725, 695 cm^{-1} practically the same as TPP except 920 cm^{-1} characteristics to m-disubstituted benzene. ^1H NMR spectrum; 7.6 - 7.9 δ multiplet, 8.3 - 8.6 δ multiplet, 8.64 δ doublet and 9.12 δ singlet (phenyl), 8.83 δ singlet (distal pyrrole), 8.98 δ and 9.30 δ AB quartet (J=4.6 Hz; proximal pyrrole). In Table I are listed ^{13}C NMR chemical shifts of 1, which are in good aggreements with expected values calculated by assuming additivity.

Porphyrin-porphyrin and/or metaloporphyrin-metaloporphyrin interaction was investigated by electronic spectrum, fluorescence spectrum and EPR spectrum. Moderate fluorescence quenching was observed for the present gable porphyrin (ca 30 % for free base and 45 % for Zn complex at 2.2 x 10^{-7} M where intermolecular quenching for TPP and TPP Zn at the same concentration are small (12 and 14 %, respectively at 4.4 x 10^{-7} M). This efficient quenching is comparable to that observed for strati-bisporphyrin (50 %) where interporphyrin distance is ca 6 Å[10] but much less effective than face-to-face porphyrin (89 % at 2.2 x 10^{-7} M) where interporphyrin distance is ca 4.2 Å[11].

Table I. Spectra of Gable Porphyrin and Its Metal Complexes.

a ^{13}C-NMR Chemical Shifts of Gable Porphyrin and TPP

	C1	C2	C3	C4	C1',C2'	C4'	C5'	Cmeso	Cα	Cβ
Gable (obs)	142.2	134.5	126.7	127.7	140.1 140.7	133.8	125.0	120.3(2.6)** 119.6(1)	146.8 (broad)	131.5(1) 131.1(2.2)
TPP[i]*	141.7	134.0	126.1	127.5	——	——	——	119.6	145.8	130.6
Gable‡ (calc)	——	——	——	——	139.6 139.7	133.1	124.0	——	——	——

* R. J. Abraham, G. E. Hawkes, M. F. Hudson and K. M. Smith, J. Chem. Soc., Perkin II, 204 (1975). ‡ calc. value is based on benzene C: 128.7 ppm ; P. Lauterbur, J. Amer. Chem. Soc., 83, 1838 (1961). ** : relative height

b IR(KBr)

1·$Fe^{3+}Cl^-$ 1600, 1440, 1340, 1000, 990, 930, 800, 750, 715, 690 cm^{-1}

1·Cu^{2+} 1595, 1440, 1340, 1000, 990, 925, 790, 740, 700, 690 cm^{-1}

c Electronic spectra ($CHCl_3$)

1·$Fe^{3+}Cl^-$ 417, 510, 686 nm

1·Fe^{2+}(CH_3-Py) 423, 530, 563 nm

1·Fe^{2+}(Py-CH_2-Py) 420, 483, 529, 563 nm

1·Cu^{2+} 410, 423, 540 nm

Table II. Characteristics of cyt c_3 and 1·Fe_2 PyCH_2Py as a cyt c_3 model.

	cyt-c_3*	1 Fe_2PyCH_2Py (2)**	1
Fe-Fe distance	12.4,11.3 Å	9.7Å	11Å
heme-heme angle	91, 98°	95°	120°
electronic spectra(Fe^{2+})	419,523,552 nm (aq pH 7)	420,529,563 nm (in $CHCl_3$)	416,428 nm (in $CHCl_3$)

* "gable" conformation only is taken out ** Based on CPK model

Remarkable line broadening in EPR spectrum was observed for gable Cu^{2+} but zero-field splitting was not well resolved at 77K in toluene. According to our simulation, D/gβ should be less than 40G, which again indicates that Cu^{2+}- Cu^{2+} interaction (ca 11 Å apart based on CPK model) in gable Cu^{2+} complex is considerably smaller than in face-to-face Cu^{2+} complex (405G, 4.2 Å). All of these spectroscopic characteristics except electronic spectra indicates that two porphyrin rings or its metal complexes are moderately (normally) interacting as expected from their structures (interporphyrin distance). Striking spectroscopic characteristics of the present "gable porphyrin" is the remarkable splitting of the Soret

band appeared at 418 nm for TPP into two well resolved peaks at 416 and 428nm for 1. This observation is in an interesting contrast to face-to-face porphyrin for which a remarkable blue shift was observed but without appreciable splitting. The remarkable splitting presently observed for 1 seems to reflect the interaction between the porphyrin-porphyrin orbitals since the Soret absorption is the inplane transition in nature. Interestingly, the splitting disappeared only for the Fe^{3+} and Fe^{2+} complexes (2b, 2c) while the Zn^{2+} complex (2a) also exhibits appreciable splitting.

Gable porphyrin and its metal complexes exhibit reasonable porphyrin-porphyrin interaction and deserves to be a "local" model for cyt-c_3. Further investigation on physical and chemical properties of this new porphyrin is now under way.

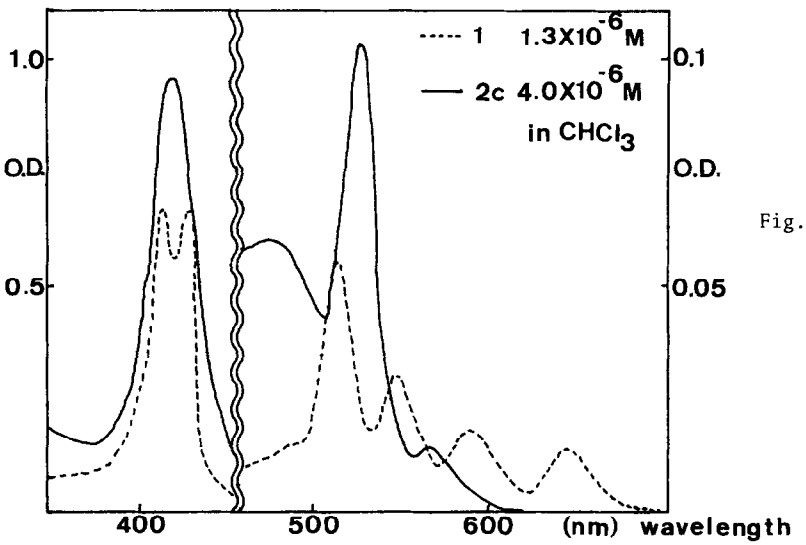


Fig. 2. Electronic spectra of 1 and 2c.

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