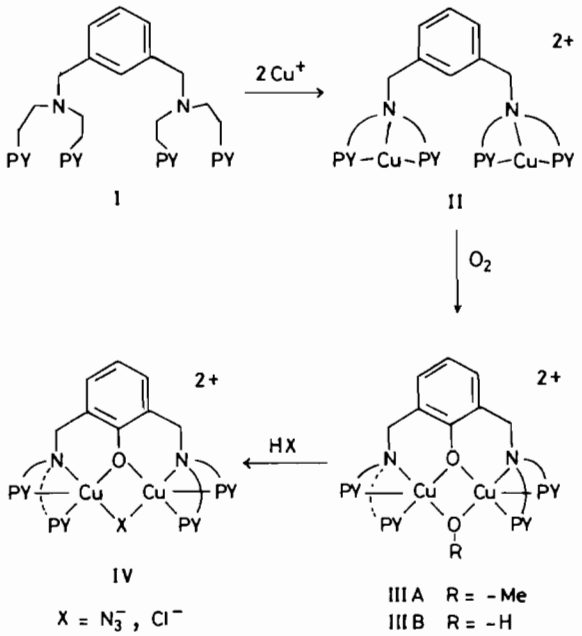
Manometric O_2 uptake experiments with *II* and mass spectrometric analyses of the oxidation product *III* utilizing isotopically labeled dioxygen demonstrate that both atoms of oxygen in *III* are derived from $^{18}O_2$ [6, 7]:



The structures of compounds *II* and *III* have been proven by X-ray crystallographic studies [5–7]. Compounds *III* contain tetragonally coordinated Cu(II) ions which are phenolate bridged (Cu...Cu = ~3.1 Å), making them excellent structural models for the proposed active sites in hemocyanin and tyrosinase. Reaction of *III* (R = H) with HX ($X = N_3^-$, Cl^-) results in the replacement of the bridging ligand (-OH) by X with the formation of complexes *IV*. These have also been structurally characterized and they exhibit coordination geometries very similar to *III*. In the case of the azide complex ($X = N_3^-$), a novel μ-1,1-azido type of bridging is observed [7]. This mode of coordination has not been previously proposed to take place in the protein copper centers. Its possible occurrence should be considered in studies where azide ligand binding is used as a spectral probe of the protein copper centers.

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N3

Models for Hemocyanin

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Our attempts to understand oxygen binding at the active site of the binuclear copper protein hemocyanin (Hc) [1] encompass two strategies. The first of those is the investigation of the structures and reaction chemistry of Cu(I) complexes ligated by nitrogenous donors since the deoxy form of hemocyanin is of this form. Unfortunately, Cu(I) species have the d^{10} electron configuration, and direct spectroscopic observations of the metal ion environment are severely limited. The reaction of carbon monoxide with Cu(I) complexes circumvents this problem by generating a derivative which is spectroscopically observable. By comparing the physical and spectroscopic properties of synthetic Cu(I)–CO complexes with those for the carbonyl adduct of hemocyanin, we hope to confirm the proposed structure of the deoxy site in Hc [2].

This report reviews the synthesis and characterization of a series of two- and three-coordinate Cu(I) complexes ligated primarily by nitrogen heterocycles, especially pyrazole derivatives. The two-coordinate species are characterized by having a linear geometry with short Cu–N bond lengths (1.87 Å) [3, 4]. For the most part, such compounds are inert towards carbon monoxide unless an additional donor is added. The three-coordinate species adopt structures in which steric effects of the ligand distort the coordination geometry. All of the three-coordinate complexes bind carbon monoxide to varying degrees, depending on the nature of the ligating atoms [5]. The structures of some binuclear Cu(I) complexes are also reported, in addition to the results of their reaction with dioxygen [6].

Our second strategy for probing the nature of the active site in hemocyanin involves the study of binuclear Cu(II) complexes. Spectroscopic studies of oxyhemocyanin suggest an active site comprising two pentacoordinate Cu(II) ions bridged both by a phenolate and a peroxide ion [1]. The phenolate bridge promotes strong antiferromagnetic coupling between the two metal ions. We report the synthesis

of some binuclear Cu(II) complexes bridged by oxy anions. The ligands are prepared by a multistep route from phenol derivatives and provide tetracoordinate chelation in a manner that allows binding of an additional 'exogenous' ion to each copper. Magnetic susceptibility studies of the resulting bis(bridged) species show varying degrees of antiferromagnetic coupling including a strongly coupled system with a μ-hydroxy-μ-phenoxy ligand set [7].

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N4

Synthesis and Oxygenation Studies of Monomolecular Hemoprotein Models

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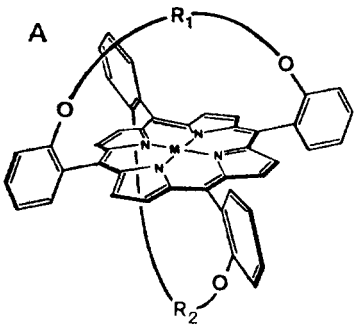
The preparation and properties of molecules modeling the active site of natural oxygen carriers have received considerable attention in recent years for the elucidation of the factors that control the binding reactions of molecular oxygen and carbon monoxide in some hemoproteins. Such compounds have been synthesized following three requirements which seem necessary in the biological functions of natural systems:

(a) pentacoordination of the iron(II) ion by a nitrogenous base on the proximal site;

(b) steric protection of the heme in order to prevent it from irreversible oxidation into μ-oxo iron(III) dimers;

(c) control of the dioxygen environment on the distal site.

Several groups have investigated these three problems separately [1]. As part of our studies of the stereochemical influences on the formation and stability of oxygenated model compounds, we have prepared two series of porphyrin derivatives which correspond to the three structural conditions mentioned above.

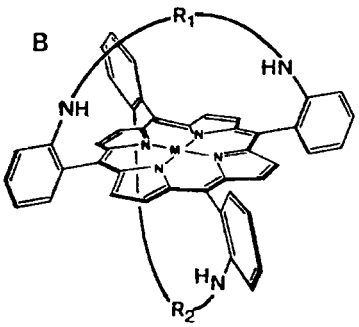


1 R_1 = $-(CH_2)_3$-(pyridine)-$(CH_2)_3-$ $R_2 = -(CH_2)_{10}-$

2 R_1 = " $R_2 = -(CH_2)_{12}-$

3 R_1 = " $R_2 = -(CH_2)_3$-(benzene)-$(CH_2)_3$

4 R_1 = " $R_2 = -(CH_2)_4$-(benzene)-$(CH_2)_4$



5 $R_1 = -CO-(CH_2)_2$-(pyridine)-$(CH_2)_2-CO-$ $R_2 = -CO-(CH_2)_8-CO-$

6 R_1 = " $R_2 = -CO-(CH_2)_{10}-CO-$

7 $R_1 = -CO-(CH_2)_3$-(pyridine)-$(CH_2)_3-CO-$ R_2 = "

8 $R_1 = -CO-(CH_2)_4-CH(\text{imidazole})-(CH_2)_4-CO-$ R_2 = "

M = Fe^{II}

All the compounds were synthesized following the concept of both face hindered tetraphenylporphyrins ('basket handle' porphyrins) in which two opposite mesophenyl rings are bridged by a convenient chain [2, 3]. The proximal base (pyridine or imidazole) was inserted into one of the handles. The size and polarity of the cage on the distal side can be modified to some extent by suitable chemical changes of the second handle. The newly 'hanging base' porphyrins were prepared either from 5,10,15,20-tetrakis(*o*-hydroxyphenyl)porphyrin (series A, compounds *1–4*) or from 5,10,15,20-tetrakis(*o*-aminophenyl)-porphyrin (series B, compounds *5–8*). Thus the main structural difference between the two series lies in the presence of non polar ether groups in the former and of polar amide linkage in the latter [4].