# Bis-Faced Aminoporphyrin Templates for the Synthesis of Chiral Catalysts and Hemeprotein Analogues

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Tetraarylporphyrins with differently substituted aryl groups attached at the *meso* positions have, in the past, been obtained through the condensation of pyrrole with a mixture of two different benzaldehydes.[1] We are interested in making *meso*-(2,6-diaminophenyl)porphyrins that are useful in the synthesis of porphyrin complexes with superstructure functionality on both faces. Our preliminary epoxidation studies using the metalated Mosher's amide derivative (**1c**, Figure 1)[2] of the parent octaaminoporphyrin (**1b**) failed for the moment to produce good enantiomeric excesses and a good turnover number. We believe this catalyst with eight Mosher's pickets is too bulky to perform efficient or selective epoxidation. The results reported here provide evidence that placing fewer chiral groups on each face of a porphyrin can generate a more active *and more selective* metal center. These results are in keeping with those of Jacobsen et al. which indicate that efficient chiral induction can be achieved with one very modest chiral diamine.[3] The sterics of the remaining chiral passage must be tuned so as to maximize both $\Delta\Delta G$ and overall epoxidation. Just enough chiral bulk must be present to destabilize exactly one enantioapproach. It is our belief that the failure of many enantioselective catalysts stems from restriction of both enantioapproaches to the metal center.

Our new family of aminoporphyrins provides templates for making less hindered catalysts. The "blank" picket (the *p-tert*-butyl or pentafluoro-*meso*-phenyl group) can-

not be derivatized. This means catalysts made from these new templates always have at least one unencumbered approach which can serve as a chiral substrate passage to the metal center. We are currently working on strategies to add a variety of chiral substituents to these porphyrin templates.

Recently, we reported the synthesis of 5,10,15,20-tetrakis(2′,6′-diamino-4′-*tert*-butylphenyl)porphyrin **1b**.[2] This octaaminoporphyrin, which, thanks to *p-tert*-butyl substituents, is slightly soluble in $CH_2Cl_2$, was obtained by mixing pyrrole and 2,6-dinitro-4-*tert*-butylbenzaldehyde in the presence of $BF_3 \cdot OEt_2$ followed by oxidation of the porphyrinogen with tetrachlorobenzoquinone.

In the present paper, we report the extension of this work to the synthesis of hexaaminoporphyrins **5c** and **5d**, tetraaminoporphyrins **7c** and **7d**, and diaminoporphyrin **8d** (see Figure 2). These porphyrins were obtained via condensation of pyrrole and a mixture of 2′,6′-dinitro-4′-*tert*-butylbenzaldehyde and an unfunctionalized benzaldehyde in the presence of $BF_3 \cdot OEt_2$,[4] followed by reduction[5] of the two, four, or six nitro groups to amines. Incorporation of an unfunctionalized benzaldehyde gives rise to a "blank" *meso*-phenyl picket. Two different blank pickets have been used: porphyrin **5c** was made by incorporating a single 4-*tert*-butyl phenyl "blank" picket into the macrocycle (eq a, Scheme 1) while one, two, and three pentafluorophenyl groups were incorporated into porphyrins **5d**, **7d**, and **8d**, respectively (eq b and Figure 2). Interestingly, the condensation reaction showed a strong preference for cis over trans arrangement of two dinitrobenzaldehyde moieties: with either "blank" picket, geometry **7** was a major product, while geometry **6** was barely observed. These results underscore the steric demands of *o*-dinitro substitution on the porphyrin *meso*-phenyl groups and help explain the low yields observed in the condensation reaction that gives rise to the parent octanitro compound (**1a**). The structure of these compounds was confirmed by the equivalence and the nonequivalence of the $\beta$-pyrrolic protons[6] by $^1H$ NMR, which gave insight into the symmetry of the molecules.

Reaction of **5d**, **7d,** and **8d** with Mosher's acid chloride gave chiral porphyrins **5f, 7f,** and **8f**. The latter two were directly metalated using excess $FeBr_2$ to give **7f′** and **8f′** (Scheme 2). However, as with **1c**,[2] metalation of free base hexa-Mosher's amide porphyrin **5f** could not be accomplished using the standard $FeBr_2$ method. Instead, iron(III) hexaamino porphyrin (**5d′**) was made first (Scheme 2), and this was condensed with Mosher's acid chloride to give **5f′** (Figure 3).

Catalytic expoxidations of styrene were carried out using these three iron porphyrins (**5f′**, **7f′**, and **8f′**) as catalysts. An interesting trend emerged. The most bulky analogue, **5f′**, gave the lowest selectivities for the epoxidation of styrene (<1% ee), while the least bulky ana-

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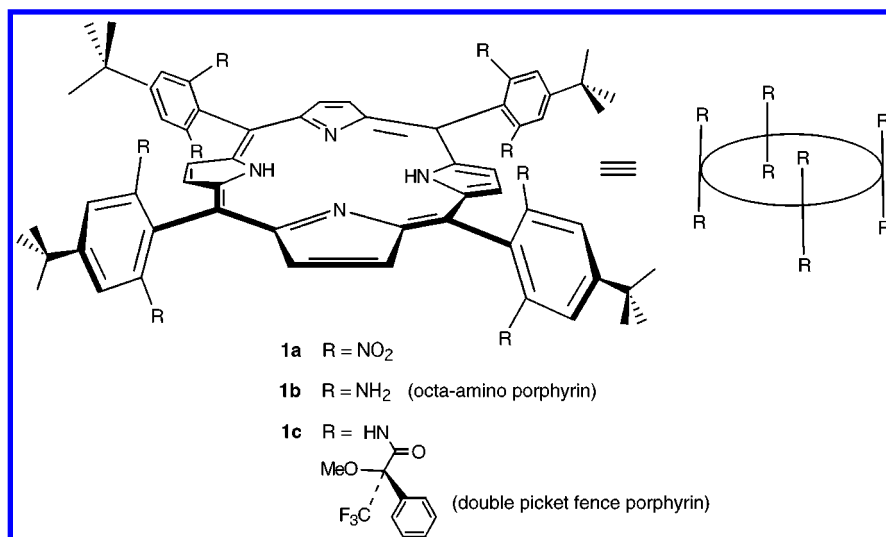
**Figure 1.** Octanitro- (**1a**) and octaaminoporphyrin (**1b**) and the Mosher's amide derivative (**1c**).
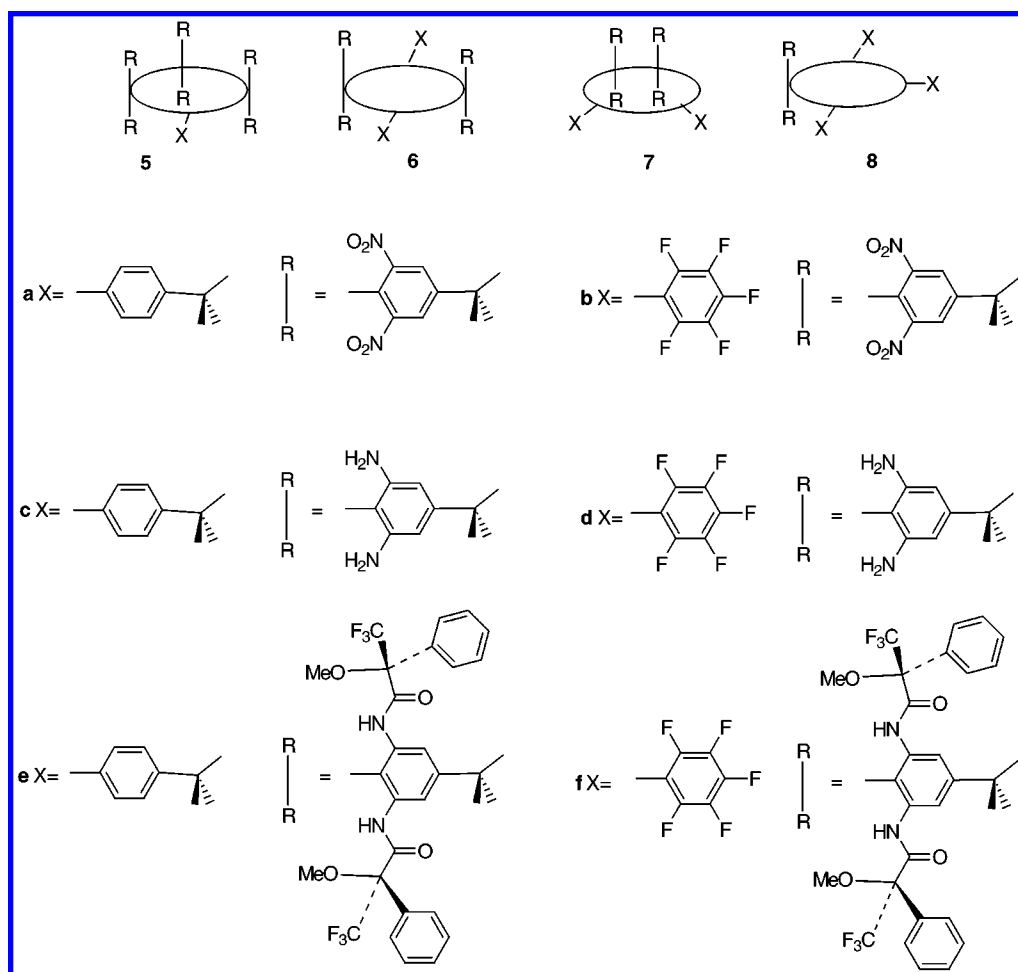


**Figure 2.** Novel chiral catalyst templates.

logue (**8f′**) gave the highest ee (6%). The selectivity of **7f′** was halfway between the other two (3% ee). While the selectivities of all three are very low, the differences between them are statistically significant, and the trend is quite clear. Providing more access to the catalytic metal center, in this case, increases the selectivity of the epoxidation reaction.

In conclusion, porphyrins with one, two, or three 2,6-diamino-4-*tert*-butyl-*meso*-phenyl groups, and a comple-

mentary number of unfunctionalizable "blank" *meso*-phenyls represent versatile templates for the synthesis of a new class of asymmetric bis-faced porphyrins. The "blank" pickets facilitate substrate access by creating a gap in the chiral wall that would otherwise completely surround the catalytic center. Preliminary studies with Fe(III) Mosher's amide derivatives of these templates support our supposition that many previously described catalysts may have suffered from over-restricted access

**Scheme 1. Mixed Aldehyde Condensations**[a]
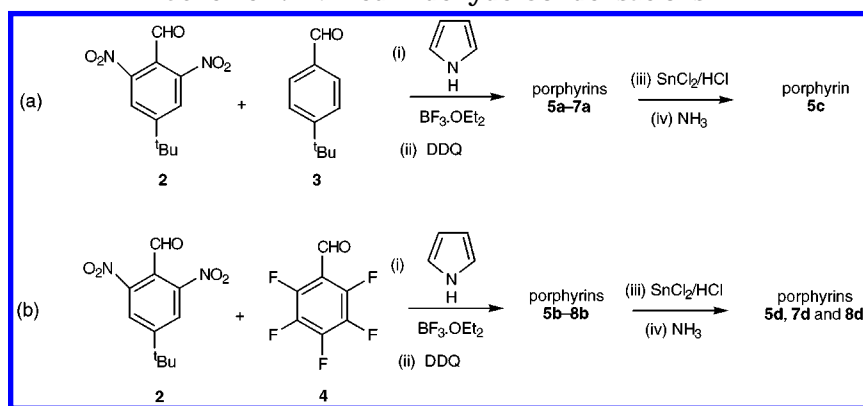


[a] (i) 20 h at rt under $N_2$ in $CH_2Cl_2$ with 3 Å molecular sieves, (ii) reflux in air for 90 min, (iii) 2 h at rt in $CH_2Cl_2$ with excess tin chloride and *exactly* six equiv of HCl per $NO_2$ group.

**Scheme 2. Synthesis of Chiral Catalysts 5f′, 7f′, and 8f′** [a]
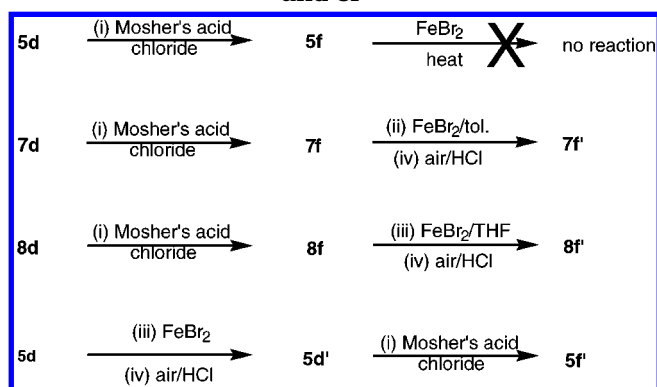


[a] (i) 24 h at rt in THF with excess *N,N*-diethylanaline, (ii) 12 h at 110 °C under $N_2$ with excess 2,6-lutidine, (iii) 12 h at 65 °C under $N_2$ with excess 2,6-lutidine, (iv) stir in air for 30 min and wash with 10% HCl solution.
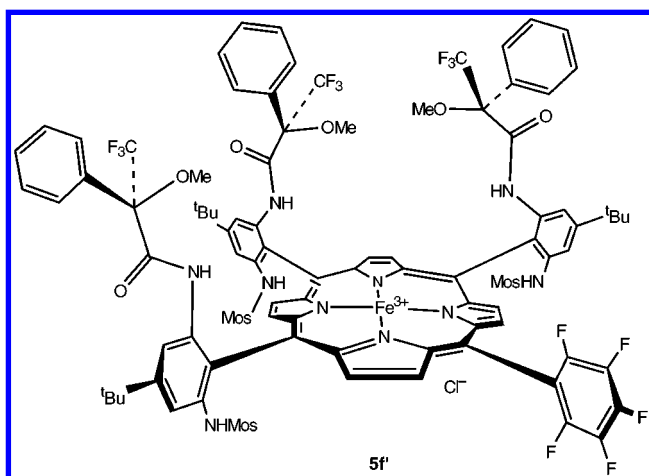


**Figure 3.** Fe(III) hexa-Mosher's amido porphyrin **5f′**.

to the metal center. We are currently engaged in further studies that use our new templates to explore the effects of providing more liberal substrate access a catalytic metal center. Thus, we are preparing chiral "seat"[7a] porphyrins **9**, **10** and "gyroscope"[7b,c] porphyrins **11** using new chiral linkages or chiral acid chlorides (Figure 4).
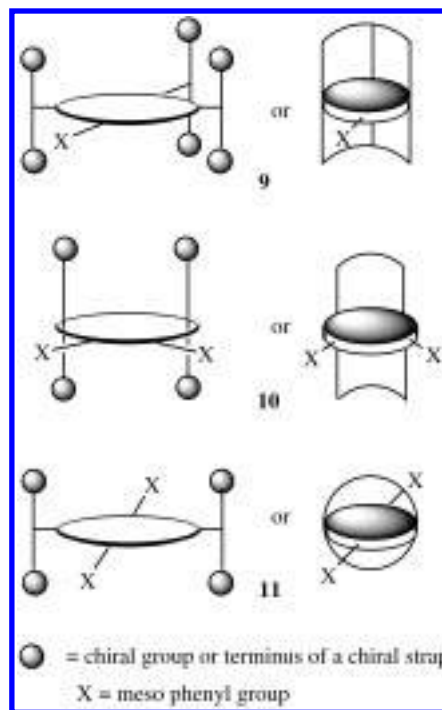


**Figure 4.**

**Supporting Information Available:** Experimental procedures and spectral data for the new compounds dicussed (7 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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