A Convergent Approach to Unsymmetrical Porphyrin Oligomers

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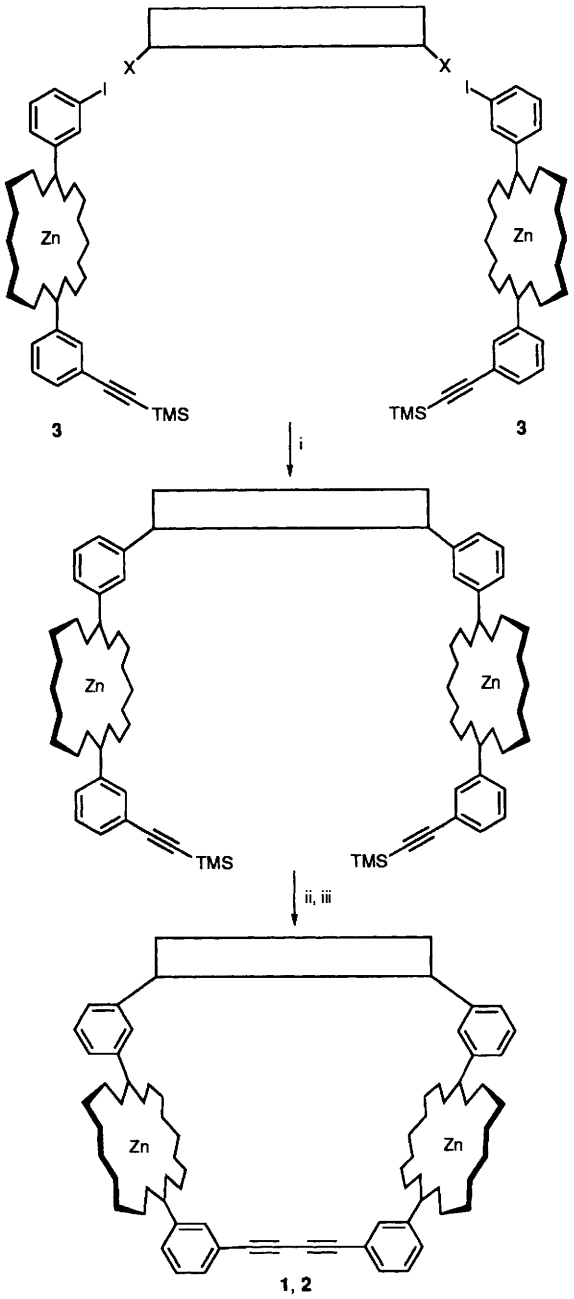
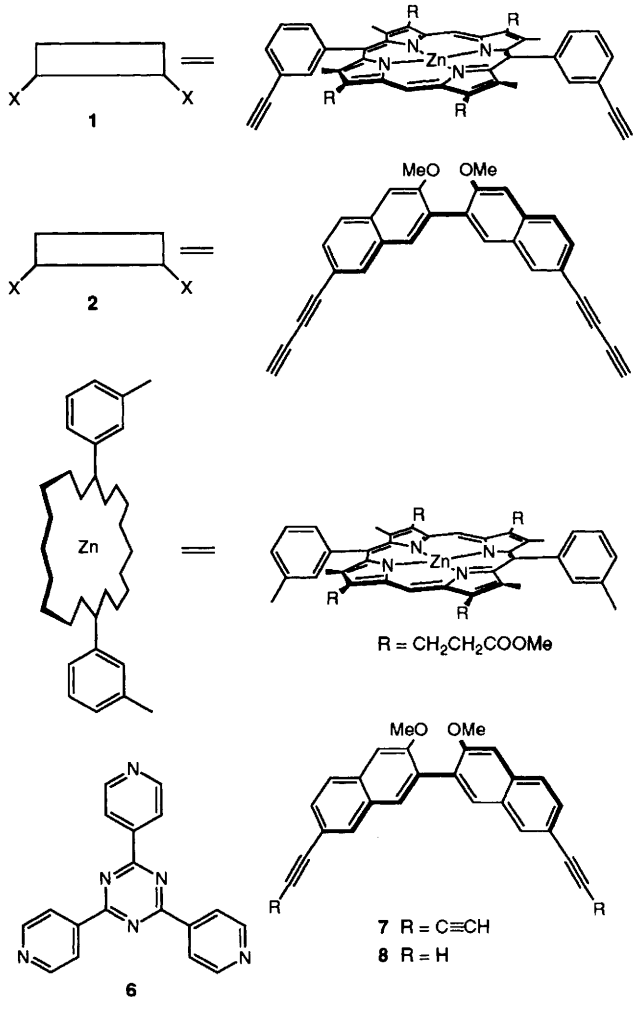
Unsymmetrical capped porphyrin dimers are prepared by coupling two alkynyl monomer units to a central core, followed by intramolecular cyclisation of the alkynes; the approach is illustrated by the synthesis of an unsymmetrical trimer with a 'small' cavity and of a dimer equipped with a chiral binaphthyl cap.

We report here a versatile new approach to unsymmetrical porphyrin oligomers. Symmetrical butadiyne-linked porphyrin oligomers have proved to be versatile objects for molecular recognition: for example, the trimer stereoselectively accelerates an *exo*-Diels–Alder reaction,[1] and also catalyses acyl transfers.[2] However, statistical synthesis of oligomers from monomer limits the range of architectures which can be readily prepared, even when templating is used to direct the reaction.[3] Our new route, which is summarised in Scheme 1, leads to a butadiyne-linked dimer which is capped by a central unit. The resulting host should possess at least the recognition and catalytic properties of the original butadiyne-linked trimer but enhanced by such features as are programmed into the cap. This new approach is illustrated by the synthesis of the unsymmetrical trimer, **1**,† which has a 'small' cavity, and the dimer, **2**, which is equipped with a chiral binaphthyl cap.

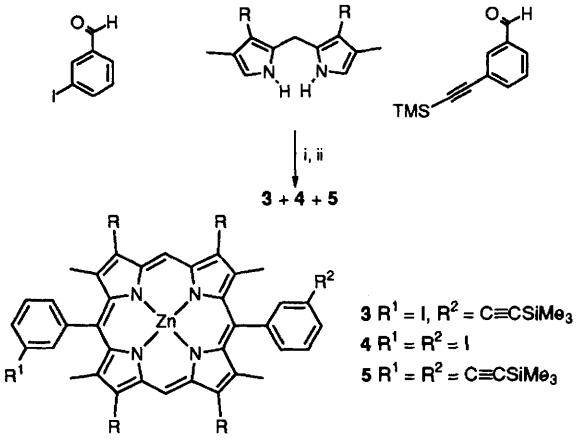
The key features of the synthesis in Scheme 1 are (*a*) preparation of the unsymmetrical porphyrin monomer **3** on a gram scale by the mixed aldehyde route shown in Scheme 2;‡ (*b*) Pd-catalysed coupling of this monomer to a central core possessing two identical terminal alkynes;[5] and (*c*) deprotection and intramolecular Glaser–Hay coupling of the porphyrin alkyne units, so that the central unit becomes the cap. Given that the final relationship between these two porphyrins is effectively the same as in our standard trimer, there was good reason to believe that this intramolecular coupling would be high-yielding and controllable by templating if necessary.



Scheme 1 i, $Pd(PPh_3)_4$, CuI, NEt_3/THF, 70–85 °C; ii, $Bu_4N^+ F^-$/THF, CH_2Cl_2; iii, CuCl, TMEDA, CH_2Cl_2, room temp.



The small trimer **1** was prepared by coupling of monomer **3** with the symmetrical monomer **4** to give linear trimer in 84% yield, followed by deprotection (95% yield) and intramolecular coupling in 45% yield. The yield of the cyclisation step was improved to 65% by addition of the tripyridyltriazine template, **6**. In CH_2Cl_2 solution at 25 °C, the linear and cyclic trimers complex **6** with binding constants of *ca.* 7×10^8 and 5×10^9 dm^3 mol^{-1}, respectively, providing a thermodynamic driving force for the templated cyclisation. Under the same conditions, the larger tris(butadiyne)-trimer binds to **6** with an affinity of 1×10^9 dm^3 mol^{-1}; this weaker affinity confirms the prediction[4] that the larger host is slightly too spacious to be ideal for **6**. The ^1H NMR spectrum of the **1·6** complex shows two *meso* signals (intensity ratio 2 : 1) and six equal intensity methyls (three ester methyl and three ring methyl) as expected from the predicted symmetry (Fig. 1). The strength of binding to this small cyclic trimer is demonstrated by the unexpected observation of two sharp sets of multiplets for the bound ligand, with intensity ratio 2 : 1; the intramolecular exchange of the pyridyl groups by rotation within the cavity is occurring remarkably slowly. The upfield shifts for H_α are δ 7.00 and 7.05, and for H_β are δ 2.73 and 2.76. These shifts are slightly larger than for the tris(butadiyne)-trimer, as expected for the closer average proximity to the porphyrin units which is enforced in a smaller cavity.



Scheme 2 i, TFA/MeOH; ii, DDQ

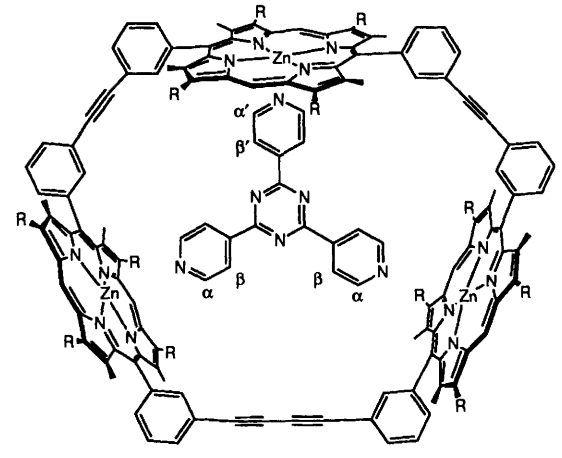


Fig. 1 The **1·6** complex

The racemic binaphthyl core **7** was prepared from **8**[6] by mixed Glaser–Hay coupling with trimethylsilylacetylene and removal of the $SiMe_3$ groups.[7] Pd-catalysed coupling with monomer **3** gave the linear porphyrin–binap–porphyrin species in 60% yield, then deprotection (88%) and intramolecular coupling gave the binaphthyl-capped dimer **2** in 60% yield. Templating is not needed in this case as cyclisation is so powerfully structure directed: the two porphyrin units are forced to face in the correct orientation. Successful cyclisation is readily apparent from the ^1H NMR spectrum, which shows the expected doubling of the *meso* and most other porphyrin signals now that rotation of the porphyrin units is prevented. Model building suggests that the binaphthyl cap imposes a strong helical twist between the two porphyrin units. Clearly, we hope this helicity will impose some enantioselectivity on the binding and catalytic properties of **2** without destroying its ability to bind. Preliminary results show that **2** binds bifunctional ligands such as 1,3-bis-(4-pyridyl)propane with essentially the same affinity, 5×10^8 dm^3 mol^{-1}, as the symmetrical parent butadiyne-linked trimer.

The binding and catalytic properties of **1** and **2** are currently being investigated. More importantly, the approach described here opens the way to a new generation of trimer-derived catalysts, but with additional features which can be incorporated separately or together: the central core may be a porphyrin with different peripheral substitution or metallation, or it may be an entirely different building block possessing additional recognition or catalytic features.

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Footnotes

† All new compounds gave satisfactory spectroscopic or analytical results. FABMS: **1** Calc. M^+ for $C_{164}H_{150}N_{12}O_{24}Zn_3$ 2869, found M^{2+} 1434; **2**, Calc. M^+ for $C_{138}H_{116}N_8O_{18}Zn_2$ 2305, found M^+ 2305, M^{2+} 1152.

‡ This is essentially the route used previously for symmetrical porphyrins.[4] The three monomers are separated by chromatography; **3** and **4** are used in the syntheses described here, while **5** is used for the preparation of symmetrical oligomers.

References

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