# Dynamic Helical Inversion in a Metal-Peptide Framework

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## Research Background

Helix is a unique structural motif in nature and its structurally dynamic behavior plays a crucial role in various events such as chiral sensing. Inspired by helical structures in nature, a great interest has been paid to the design of artificial systems with helical motifs that exhibit dynamic behaviors.[1] Peptides containing achiral amino acids such as 2-aminoisobutyric acid (Aib) that adopt stable hydrogen-bonded helical conformations can undergo helix inversion between right-handed (*P*) and left-handed (*M*) helices in response to external stimuli.[2] However, the helix inversion process has been exclusively investigated in solution (Fig. 1a), while there are only few studies in the "solid state", where molecular motions are greatly restricted (Fig. 1b).

Our current research focuses on the helix inversion of peptides occurring in the crystalline solid state. To prevent peptides from being tightly packed without sufficient space for dynamic conformational changes, we designed a pyridyl-appended Aib hexamer as a ligand for porous metal–organic frameworks (**$^{Aib}$MOF**, Fig. 1b). With this strategy, the peptide helices in the frameworks are expected to exhibit dynamic helix inversion even in the solid state.

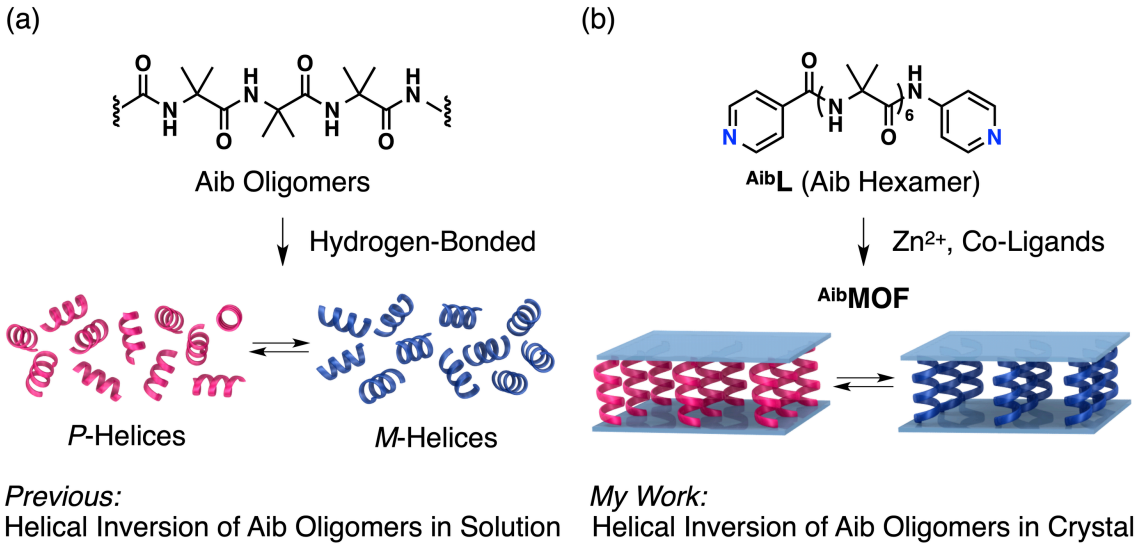


**Figure 1** (a) Helix inversion of Aib oligomers in solution. (b) Molecular structure of **$^{Aib}$L** and schematic representation of **$^{Aib}$MOF** to realize helical inversion in the crystalline state.

## Results and Discussions

We designed and synthesized an Aib hexamer with terminally appended pyridyl groups (Py-(Aib)$_6$-Py, $^{Aib}$**L**, Fig. 1b). We successfully synthesized $^{Aib}$**MOF** ([$Zn_2$($^{Zn}$Por)($^{Aib}$**L**)]) by the reaction of $^{Aib}$**L** with $Zn(NO_3)_2$•$6H_2O$ and tetrakis(4-carboxyphenyl)porphyrin ($^{2H}$PorH$_4$) in a mixture of DMF and EtOH (*v*/*v*, 3/1), where $^{2H}$PorH$_4$ was quantitatively transformed into its Zn complex ($^{Zn}$Por). Single-crystal X-ray analysis revealed that $^{Aib}$**MOF** comprises a 2D Zn porphyrin sheet where Zn dinuclear paddlewheel units are bridged by four carboxylates from $^{Zn}$Por. $^{Aib}$**L** forms a hydrogen-bonded $3_{10}$ helix, which is sandwiched by two porphyrin sheets as the pillar ligand. Due to a 2-fold disorder, equimolar amounts of *P* and *M* helices are present in the crystal as a racemic mixture.

The temperature-dependent dynamic nature of peptide helices in $^{Aib}$**MOF** was demonstrated by NMR spectroscopy. To probe the handedness of $^{Aib}$**L**, one of the methyl groups in $^{Aib}$**L** was labeled with $^{13}$C. $^{Aib}$**MOF** synthesized with $^{13}$C-labeled $^{Aib}$**L** was soaked in DMF and subjected to variable-temperature solid-state $^{13}$C NMR. The signals assignable to the *P* and *M* helical structures reversibly coalesce and split with a coalescence temperature of 333 K (Fig. 2), indicating that the helices are dynamically inverting on the NMR timescale even in the crystalline state. It is noteworthy that such dynamic motion of $^{Aib}$**L** in $^{Aib}$**MOF** do not deteriorate the crystalline framework of $^{Aib}$**MOF**. This is accomplished by the intrinsic porosity of $^{Aib}$**MOF**, allowing the space required for the inversion motion.

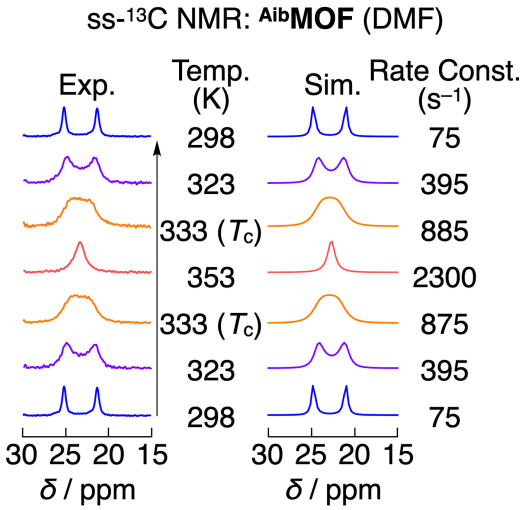


**Figure 2** Variable temperature solid state (ss) $^{13}$C NMR spectra show the helical inversion dynamics of $^{Aib}$**L** in $^{Aib}$**MOF** soaked in DMF.


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## References


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2. T. Aida *et al*, *J. Am. Chem. Soc.* **126**, 716-717 (2004).