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Supramolecular chemistry

Host in translation

Length- and chirality-matching between hydrogen-bond paired polycarbamate templates and polyamide hosts provides a way of translating structural information from one molecule to another.

Jonathan Clayden

Although the living world is built from chemical structures, biology is distinguished from chemistry by its highly evolved ability to handle information.¹ A characteristic unique to molecular biology is its ability to use information stored in the structure of one molecule to encode the structure of another. Genetic information, for example, is stored in the linear sequence of nucleic acid polymers and translated into a functional protein sequence using the remarkable translating machinery of ribosomes. Chemically, the translation process requires the hydrogen-bond patterning of each triplet of nucleic acid bases to be matched with a complementary triplet attached to each amino acid monomer.

Chemists are making steps towards devising synthetic systems that can process and manipulate information in an artificial manner, without recourse to the evolved complexity of cell-based biological systems.^{2,3,4} Writing in Nature Nanotechnology, Gan et al.⁵ now report a synthetic chemical system with the ability to translate the structure of one polymer into another. In particular, a linear polymer built from alkyl chains linking carbamate functions can play the role of a template for the association of a polyamide. Characteristics such as chain length, molecular stereochemistry, and sequence information are translated into the corresponding features in the structure of the polycarbamate-polyamide complex.

Gan et al.'s approach takes inspiration from biology in the use of hydrogen-bonded pairing between the templating polycarbamate 'host' and the encapsulating polyamide, but takes the innovative step of using their relative lengths to ensure reliable translation of information. Only polyamides of the correct length are able to bind strongly to the polycarbamate. The alkyl chain length selects the length of the bound polyamide, with short alkyl chains binding single polyamide chains, and longer alkyl chains binding helical polyamides as interlocked pairs.^{6,7}

The bound structures take the form of a helical polyamide twisted around the polycarbamate chain. Because the polyamides (unlike nucleic acids) are achiral, twisting can take place either to the left or to the right, and it is essential that

multiple amides bound to a single chain all twist on the same direction. Using NMR, Gan et al. showed that this can be the case, providing that the paired binding sites for the twisting polyamides are separated by just the right distances. Molecules carrying more than one encapsulating polyamide display helical selectivity, with the multiple amides twisting around each polycarbamate all adopting the same screw sense. Furthermore, with a chiral unit terminating the polycarbamate template, twisting of the polyamide is induced in predominantly one of the two possible screw senses.

Because the distances between carbamate functions match only with certain polyamide partners, an oligomer built up of a defined series of alkyl chain lengths selectively induces formation of a specific polyamide sequence. In their most ambitious example, Gan et al. showed that a polycarbamate template containing ten carbamate functions in five pairs separated by respectively five, nine, three, nine and five carbon atoms was found to bind selectively to a matching sequence of polyamides containing respectively 20, 24 (as a double helix), 16, 24 (as a double helix) and 20 monomers (see Figure 1). The information encoded in the arbitrarily selected lengths of the monomers in the sequence of the polycarbamate was thus translated into the structure of the polycarbamate-polyamide complex.

Gan et al. have achieved an important first step in the templated translation of sequence information, but there is a long way still to travel. Three features of the polycarbamate are translated – the length of the alkyl chains linking the carbamate functions, the length sequence of the alkyl chains in the polycarbamate, and the configuration of chiral groups at the polycarbamate termini. However, at present, the 'product' of the translation process exists only in association with the template – the polyamides assemble around the polycarbamates, but do not yet have a separate identity. Some form of ligation of the individual polyamide chains followed by dissociation should be envisaged to complete the translation process. Moreover, polycarbamate templates could be made to encode for polyamide structures with specific functions, such as encapsulation⁸ or catalytic activity.

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Caption (for layout with symbols see image):

A polycarbamate template with chiral termini (shown in blue) and hydrogen-bonding sites spaced by alkyl chains of defined lengths is treated with a library of polyamides of different lengths, bearing complementary hydrogen-bonding termini. The lengths of the polycarbamate spacers (short, medium or long) are translated into matching lengths of bound amides, while the configuration of the chiral termini is translated into the screw-sense conformation of the amides.

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