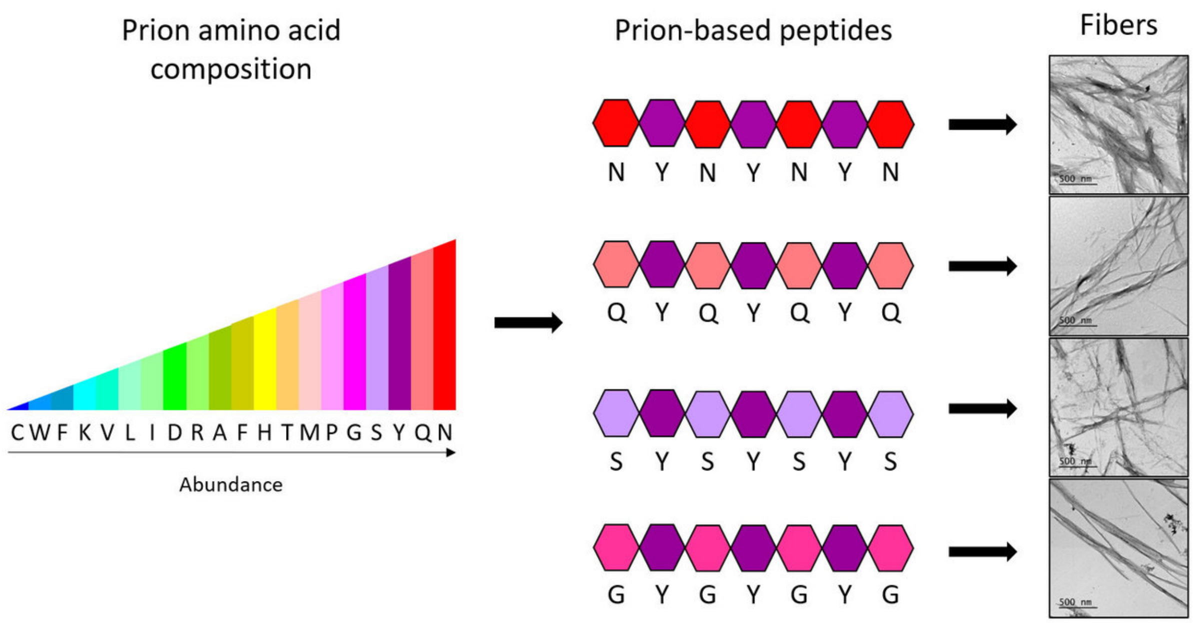
Minimalist biostructures designed to create nanomaterials

June 15 2018



With the new heptapeptides, researchers from the IBB-UAB demonstrate that only four different types of amino acids, distributed in a specific manner and combined always with another fifth type, are enough to obtain the complete code needed to form synthetic prion fibres. Credit: IBB-UAB

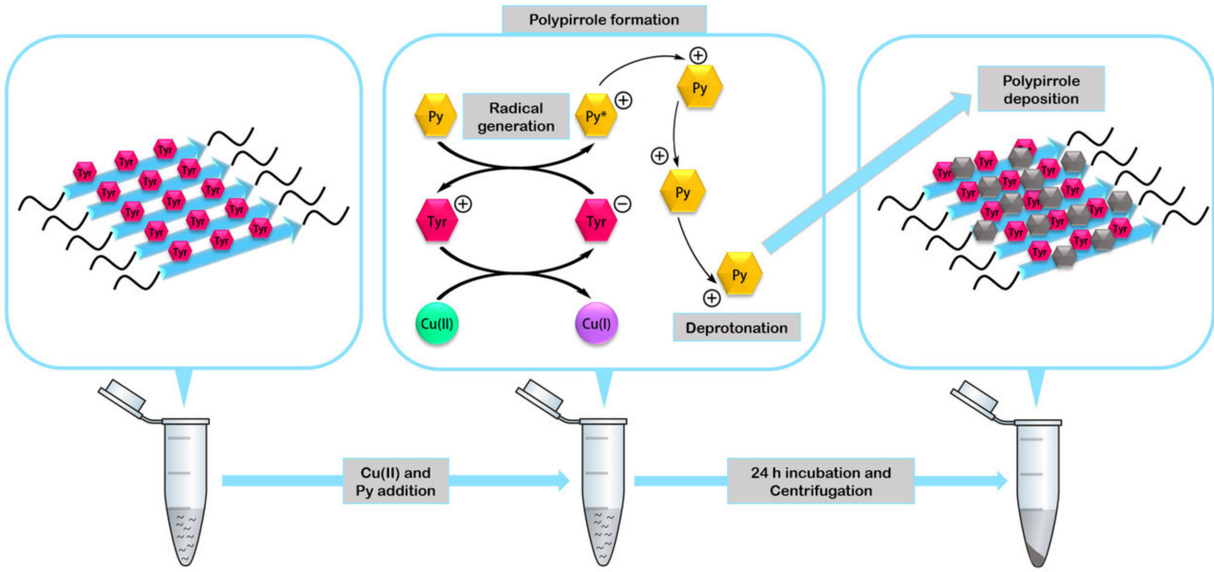
Researchers of the Institute of Biotechnology and Biomedicine (IBB-UAB) have generated four peptides, molecules smaller than proteins, capable of self-assembling in a controlled manner to form nanomaterials. The research, published in the journal *ACS Nano*, was conducted by Salvador Ventura, Marta Díaz Caballero and Susanna Navarro (IBB-UAB), and included the collaboration of Isabel Fuentes and Francesc Teixidor (Institute of Materials Science of Barcelona, ICMAB-CSIC).

The new molecules are formed by a chain of seven amino acids, each of which are made up of only two amino acids, thus significantly speeding up and reducing the cost of creating functional synthetic amyloid structures with which to generate nanomaterials for biomedicine and nanotechnology.

In biotechnology, generating functional synthetic amyloid structures to form nanostructures by imitating the natural generation process is not new. The assembly of proteins into stable fibres allows creating supramolecular shapes that no isolated protein can create, and which are used as nanoconductors, photovoltaic structures, biosensors and catalysts.

Quite recently, researchers began synthesizing prion protein sequences to form nanomaterials. The interest in these sequences lies in the fact that the proteins assemble in a slower and more controlled manner, forming highly ordered, nontoxic nanostructures. However, the fact that the sequence is so long, with over 150 amino acids, makes it very difficult and expensive to synthesise.

"We have demonstrated that an adequate design can permit the size of synthetic prion sequences to be reduced down to only 7 amino acids, while conserving the same properties. The four peptides we have fabricated are the shortest structures of this type created until now, and are capable of forming stable fibril assemblies," says Salvador Ventura, researcher at the IBB and the UAB Department of Biochemistry and Molecular Biology.



The peptides assemble to form miniature enzymes capable of acting as catalysts in the formation of nanomaterials such as the conductive polymer polypyrrole. Credit: IBB-UAB

In the study, the researchers verified the stability and functionality of the four fabricated peptides. They built one of the most degradation-resistant biological nanomaterials described to date, nanocables covered in silver that can act as electrical nanoconductors and fibrillar mini enzymes capable of acting as catalysts in the formation of organic nanomaterials.

The new molecules have numerous applications, but the researchers aim to focus on "the generation of electrical nanoconductors and make use of the knowledge of the amyloid structure to generate synthetic fibres capable of being catalysts for new chemical reactions. The final objective will be to generate hybrid peptide-inorganic materials capable of making complex reactions, as those created by the photosystems of plants," the IBB researcher points out.

Prion Domains, at the Heart of the Matter

In order to generate new peptides, IBB researchers based their work on specific sequences of prion proteins, known as prion domains (PrDs). "We studied which amino acids are more frequent and how they are distributed in these regions, demonstrating that only 4 different types of amino acids distributed in a specific manner and always combined by a fifth type of amino acid is sufficient to have the complete code needed to form synthetic prion fibres. In fact, each of the heptapeptides (mini-PrDs) designed only contains two different types of amino acids," says Salvador Ventura.

The study demonstrates the assembling ability of mini-PrDs into highly ordered nanostructures, a process thought to be impossible given the large presence of polar amino acids. The resulting peptides are more polar than any other similarly-sized peptide used until now to form synthetic amyloids; this, for example, allows them to function in the same conditions as natural enzymes.

This study has served to help researchers of the IBB Protein Folding and Conformational Diseases group, directed by Dr. Ventura, to open a new line of research focused on the design of nanomaterials.

"We have never worked on nanotechnology, but at the same time we have always had it near, because our strength lies in the knowledge of the molecular mechanism of protein assembly into amyloid structures. For a long time we have been working to create strategies with which to avoid this phenomenon in neurodegenerative diseases. This knowledge has allowed us to design new molecules which we now propose for the fabrication of new nanomaterials," Dr. Ventura concludes.

More information: Marta Díaz-Caballero et al, Minimalist Prion-Inspired Polar Self-Assembling Peptides, *ACS Nano* (2018). DOI: 10.1021/acsnano.8b00417

Provided by Autonomous University of Barcelona