Preface

These are exciting times for peptide based materials. The number of investigators in this field and consequently the number of publications in this area have increased tremendously in recent years. Not since the middle of the past century has there been so much activity focused on the physical properties of peptidic materials. Then, efforts were focused on determination of the fundamental elements that make up protein structures, leading to the discoveries of the $\alpha-$helix and the β-sheet. Many years of study followed where the propensities of individual and combinations of amino acids to adopt and stabilize these structures were investigated. Now, this knowledge is being applied to the preparation, assembly, and use of peptide based materials with designed sequences. This volume summarizes recent developments in all these areas.

Natural evolutionary processes have produced structural proteins that can surpass the performance of man-made materials: e.g. mammalian elastin in the cardiovascular system that lasts half a century without loss of function, and spider webs composed of silk threads that are tougher than most synthetic fibers. These biological polypeptides are all complex copolymers that derive their phenomenal properties from the precisely controlled sequences and compositions of their constituent amino acid monomers. Peptide polymers have many advantages over conventional synthetic polymers since they are able to hierarchically assemble into stable ordered conformations. Depending on the amino acid side chain substituents, polypeptides are able to adopt a multitude of conformationally stable regular secondary structures (helices, sheets, turns), tertiary structures (e.g. the β-strand-helix-β-strand unit found in β-barrels), and quaternary assemblies (e.g. collagen microfibrils). The peptide materials field is nearing the point of being able to develop synthetic routes for preparation of these natural polymers as well as *de novo* designed polypeptide sequences to make candidate materials for applications in biotechnology (artificial tissues, implants), biomineralization (resilient, lightweight, ordered inorganic composites), and analysis (biosensors, medical diagnostics).

Synthetic peptide based polymers are not new materials: homopolymers of polypeptides have been available for many decades and yet have only seen limited use as materials. However, new methods in chemical synthesis have made possible the preparation of increasingly complex polypeptide sequences of controlled molecular weight that display properties far superior to earlier ill-defined homopolypeptides. Chapter 1 describes the state of the art methods for polypeptide synthesis via ring-opening polymerization of aminoacid-N-carboxyanhydrides, which is an attractive, economical route when exact sequence control is not necessary. Recent work in this area has led to preparation of polypeptides of unprecedented functionality. In cases where precise sequence control is desired, for example to replicate a specific folding motif found in nature, solid-phase synthesis (Chapter 2) and recombinant DNA (Chapter 3) methodologies are required. Chapter 2 focuses on design of sequences that assemble into fibril forming β-sheet motifs, and Chapter 3 describes use of biosynthesis to prepare elastomeric mimics of elastin and resilin proteins.

Peptides and polypeptides are well suited for applications where polymer assembly and presentation of functionality need to be at length scales ranging from nanometers to microns. In recent years, synthetic peptide materials have been used extensively for the preparation of self-assembled fibrils and membranes. These materials typically employ amphiphilic residues in combination with ordered chain conformations that are easily accessed using the peptide backbone. Peptidic vesicles are intriguing encapsulants that lie in a realm between liposomes and viral capsids. Chapter 4 discusses recent work in this area covering preparation of these assemblies, their properties, and their uses in drug delivery. Natural peptidic fibrils have been studied for many years, but now these are being designed to incorporate distinct self-assembly characteristics that allow them to form 3D hydrogel networks. The preparation, properties, and potential biomedical uses of peptide hydrogels are reviewed in Chapter 5. A key discerning feature of these peptidic materials are their regular secondary structures that provide opportunities for hierarchical self-assembly unobtainable with typical block copolymers or small-molecule surfactants.

With such improvements in synthesis and processing, as well as the emergence of distinct classes of materials with predictable properties (i.e. vesicles, elastomers, gels), the field of peptidic materials has come a long way. As should be expected, considerable challenges remain for this field, especially if these materials are to solve real biomedical problems. Our understanding of peptidic folding and assembly is still rather limited, especially when considering the possibilities for formation of designer tertiary (3D) structures. Efficient methods to synthesize more complex peptidic materials, such as those with post-translational modifications or branched structures are still much in need. While bioconjugation methods are better than ever, broadly applicable, high yielding methods for combining biological and chemical synthesis would open up many new areas of study. I believe that peptidic materials need to encode multiple levels of functionality and structure in their

sequences in order to succeed in biomedical applications. Since these applications present many constraints, some which vary from patient to patient, the ability to reliably tune properties via many handles is also essential. There are numerous obstacles ahead, but I, like many others, cannot ignore the opportunities presented by the unique properties of the peptide bond.

Los Angeles
Winter 2011

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http://www.springer.com/978-3-642-27138-0

Peptide-Based Materials
Deming, T. (Ed.)
2012, XIV, 174 p., Hardcover
ISBN: 978-3-642-27138-0