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Biopolymers from Renewable Resources

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With 118 Figures

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Preface

Biopolymers from Renewable Resources is a compilation of information on the diverse and useful polymers derived from agricultural, animal, and microbial sources. The volume provides insight into the diversity of polymers obtained directly from, or derived from, renewable resources. The beneficial aspects of utilizing polymers from renewable resources, when considering synthesis, processing, disposal, biodegradability, and overall material life-cycle issues, suggests that this will continue to be an important and growing area of interest. The individual chapters provide information on synthesis, processing and properties for a variety of polyamides, polysaccharides, polyesters and polyphenols. The reader will have a single volume that provides a resource from which to gain initial insights into this diverse field and from which key references and contacts can be drawn. Aspects of biology, biotechnology, polymer synthesis, polymer processing and engineering, mechanical properties and biophysics are addressed to varying degrees for the specific biopolymers. The volume can be used as a reference book or as a teaching text.

At the more practical level, the range of important materials derived from renewable resources is both extensive and impressive. Gels, additives, fibers, coatings and films are generated from a variety of the biopolymers reviewed in this volume. These polymers are used in commodity materials in our everyday lives, as well as in specialty products. Aside from describing some of the more established products derived from biopolymers, this volume also presents some of the new directions in research and development that are being pursued for biopolymers. Some of these new directions are driven by biotechnology, novel chemistries, and enzymatic processing. These new options are extending the utilization of traditional biopolymers into new value-added products. This volume highlights some of these new applications, such as for biodegradable polymers, while also providing insights into the current level of understanding of the synthesis and processing of these polymers to achieve these new applications.

The study and utilization of polymers from renewable resources is an ancient science. Examples include the development of processes to make paper and the evolution of sericulture for the production of silk fibers thousands of years ago. These ancient arts are rapidly evolving in new directions. This new evolution is due to renewed interest in biopolymers because of the availability of new research tools to help elucidate structure-function relationships. These insights are being obtained at the molecular level as well as at higher orders of complexity. This new level of understanding has resulted in the establishment of new opportunities for the use of biopolymers from renewable resources. An improved understanding of biological synthesis and processing methods, and the growing importance of "green chemistries" in industry due to environmental concerns and regulations, are helping to drive this new level of interest. The explosion of new analytical techniques, new understanding of molecular-level structure-function relationships, insights into mesophase formation in biological systems, and the development of a plethora of biotechnology tools are driving this renewed interest in biopolymers. The ability to generate biopolymers with tight control of structural features leads to the manipulation of functional properties. In addition, the need to develop more environmentally compatible processes suggests a strong and important future for these materials. Importantly, once the useful life of these polymers is completed, they can be recycled back into natural geochemical cycles due to their inherent biodegradability and environmental biocompatibility.

The volume also highlights the growing interface between biology and materials science. This interdisciplinary endeavor has been referred to as biomimetics, bioengineering, biomolecular materials, bioinspired materials, and biomaterials. In general, these concepts are based on the use of the biology for inspiration, blueprints, or building blocks from which materials scientists can develop new concepts in materials science. The primary reason for this interest derives from the level of structural control demonstrated by biological systems, including molecular size, stereochemistry and regioselectivity in building biopolymers. This level of structural control, in turn, drives self-assembly and organization at higher levels of complexity. Thus, biopolymers from renewable resources can be used directly as new materials, while also serving as guides for future designs of synthetic materials that capture the key features of the natural polymers. The biological world is constantly yielding new insights, new inspiration, and new blueprints into novel approaches for the design, synthesis and processing of materials. Whether dealing with intracellular synthesis and processing, or extracellular self-assembly and self-directed hierarchical organization to complex macroscopic materials, there is a wealth of information to be tapped into and utilized in the broader community of materials science.

I wish to thank the authors for their contributions and my many collaborators over the years on the subject of biopolymer engineering. A special thanks is due to Carmela Bailey, U.S. Department of Agriculture, for her unyielding help in helping to make this volume possible.

D. L. Kaplan Medford, USA, January 1998

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Abbreviations

ASTM	American Society for Testing and Materials
CDNA	Complementary Deoxyribonucleic Acid
CMO	Chinese melon oil
CO	castor oil
Da	Daltons
DCO	dehydrated castor oil
DLO	dehydrated lesquerella oil
DNA	Deoxyribonucleic Acid
DSC	differential scanning calorimeter
ECH	epichlorohydrin
ECHLO	epichlorohydrin lesquerella oil
ECHLO-10	epichlorohydrin lesquerella oil with 10 units
ECHLO-2	epichlorohydrin lesquerella oil with 2 units
ECHLO-5	epichlorohydrin lesquerella oil with 5 units
ESA	eleostearic acid
HDI	hexane diisocyanate
HPLC	high performance liquid chromatographic
IPDI	isophorone diisocyanate
IPTG	β-Isopropylthiogalactoside
LO	lesquerella oil
MDI	diphenylmethane diisocyanate
Mefp	*Mytilis edulis* foot protein
mRNA	Messenger Ribonucleic Acid
NCA	*N*-carboxyanhydride
P_R, P_L	Phage lambda right and left promoters
PVC	polyvinylchloride
RNA	Ribonucleic Acid
TDI	toluene diisocyanate
TO	tung oil
tRNA	Transfer Ribonucleic Acid
T_t	Inverse transition temperature
UV	ultraviolet
VOC	volatile organic content

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