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PREFACE

Cellulose was first described by Anselme Payen in 1838 as a "resistant fibrous solid that remains behind after treatment of various plant tissues with acid and ammonia." In its simplest form, cellulose is composed of β-1,4-linked glucan chains that can be arranged in different ways giving rise to different forms of cellulose. In nature, cellulose is produced in a hierarchical manner with the glucan chains associating with each other to form crystalline and noncrystalline regions that are assembled into higher-order structures such as the microfibril. Depending on how the glucan chains associate, different crystalline forms of cellulose may be observed within the same microfibril. In nature, cellulose is generally obtained as the cellulose I crystalline form in which the glucan chains are aligned parallel to each other. Two forms of the native crystalline polymer, cellulose, Iα, and Iβ, have been shown to be present in differing amounts obtained from different sources. Other crystalline and noncrystalline forms of cellulose have also been identified, and many of these forms can be converted from one form to the other form by chemical or physical treatments. Although much is known about the structure and properties of the different forms of cellulose and these studies are still continuing, only recently has it been possible to understand the molecular basis of cellulose biosynthesis.

The chapters in the present volume highlight the wide range of topics that deal with not only the structure and biosynthesis of cellulose, but also some of the more exciting and novel applications of cellulose. Since the first identification of genes for cellulose biosynthesis in the bacterium *Acetobacter xylinum* in 1990, significant progress has been made in identifying similar genes in a large group of organisms. Polymerization of glucose residues into the β-1,4-linked glucan chains is catalyzed by cellulose synthase, and genes encoding this protein have been identified not only in most of the cellulose-producing organisms, but also in a number of other organisms suggesting that cellulose biosynthesis may be much more widespread than previously thought. Analyses of the cellulose-synthesizing genes and specifically the cellulose synthase genes has led to interesting views on the evolution of cellulose biosynthesis and the cellulose synthase gene family, and this is discussed in the chapters by Nobles and Brown, Roberts and Roberts, and Youngs et al. In plants, a large number of genes encoding cellulose synthases have been identified by sequence and mutant analyses. Mutant, sequence, and expression analyses have provided information on the role of specific synthases during cellulose biosynthesis in the primary and the secondary cell wall in a number of plants. The significance of these studies is discussed in the chapters by Taylor and Turner (Arabidopsis), Barreiro and Dhugga (maize), and Blomqvist et al. (*Populus*). Whereas, the role of cellulose is well understood in plants, it is not as well understood in the other organisms where cellulose biosynthesis genes have been identified. In bacteria, cellulose is secreted as an extracellular polysaccharide, and in some cases it is shown to be associated with other components as part of bacterial biofilms. The organization of genes and regulation of cellulose biosynthesis is well understood in bacteria belonging to the pathogenic *Enterobacteriaceae*, and this is summarized by Römling.

One of the major challenges in understanding cellulose biosynthesis in plants is the biochemical characterization of the cellulose synthase. Although some success has been achieved in synthesis and characterization of cellulose *in vitro* using membrane fractions from plants, purification and structural characterization of the cellulose synthase from plants is still far from complete. In the present volume, Bulone discusses steps in the characterization of cellulose synthase and other glycosyltransferase activities. At the same time, a number of other proteins are involved in regulating cellulose synthesis in plants; Haigler covers the role of substrate supply during cellulose synthesis in the cotton fiber.

Among the more interesting aspects of cellulose biosynthesis is the phenomenon of coupled polymerization-crystallization, and it is a matter of faith in the field that the parallel arrangement of glucan chains in crystalline cellulose I result because of an organized arrangement of cellulose-synthesizing sites in the membrane. Determining how these sites are organized is a major goal for a complete understanding of cellulose biosynthesis. A perspective on how the cellulose-synthesizing complexes may be assembled in plants and the role that the membrane-bound endoglucanase (KORRIGAN) and microtubules may have in the assembly of this complex and the cellulose microfibril is discussed by Saxena and Brown. Emons *et al*. review a few hypotheses and a theory to explain the assembly of cellulose microfibrils and the architecture of the cell wall in plants. While it is not clear as to how the cellulose-synthesizing sites are assembled, these complexes are being identified in many more organisms. Okuda and Sekida report on the identification of cellulose-synthesizing complexes in a dinoflagellate and some unique algae and discuss the diversity and evolution of these complexes. Among animals, tunicates are unique in synthesizing cellulose. Cellulose-synthesizing complexes have been observed in a number of organisms within this group. The cellulose-synthesizing complexes and the function of cellulose in tunicates is described by Kimura and Itoh. Although cellulose-synthesizing complexes could be identified in membranes by freeze-fracture analysis, it was not possible to identify the components of these complexes. The breakthrough that led to the localization of cellulose synthases to these complexes in plants and associated proteins in bacteria came about with freeze-fracture labeling of replicas using antibodies. This technique and its application with respect to understanding the composition of the cellulose-synthesizing complexes is discussed by Itoh *et al*.

The structure of cellulose is closely tied to its synthesis, and although many of the chapters discuss the synthesis of cellulose, the nature of the cellulose product is always kept in mind. A comprehensive account of the structure of cellulose and its polymorphism is provided by French and Johnson, and the structure and properties of a novel form of cellulose (nematic-ordered cellulose) is described by Kondo. Cellulose is the most abundant biomacromolecule in nature, and it is used in a variety of applications. In almost all cases, the applications of cellulose as an industrial material are dependent on its physical and chemical properties. Two chapters discuss novel applications of cellulose. Czaja *et al*. describe the use of microbial cellulose for applications in wound care and Kim discusses the usefulness of cellulose as a smart material, specifically the production of cellulose-based electroactive paper.

The field of cellulose research spans the interests of molecular biologists to industrial chemists, and we are pleased to provide this collection of articles to a broad audience with a central interest in cellulose. Cellulose has always been an important product for human endeavors, and we predict that with novel approaches in molecular and structural biology, the uses of this invaluable biomaterial will diversify and grow.

Cellulose has been used for centuries as an industrial material, but for the first time, this product is being seriously considered as an alternative source of energy for biofuels. The use of plants and other sources of cellulose for producing ethanol will change not only our perspective of how we look at cellulose as a natural product but also how it can be used to satisfy humankind's appetite for energy!

We are grateful to all the authors for their excellent contributions and their patience during the assembly of this volume.

R. Malcolm Brown, Jr. and Inder M. Saxena
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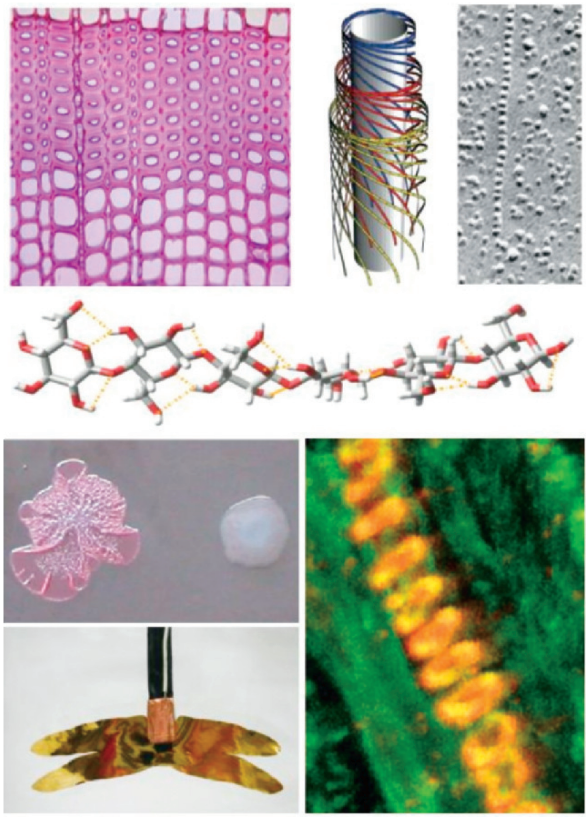

Multiple representations of cellulose (selected from chapter articles in this book)

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