Secondary Xylem Biology

Origins, Functions, and Applications

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00018-8; Author: KIMENGLISH; Document ID: 00018; Chapter ID: c0090

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Origins, Functions, and Applications

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AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Academic Press is an Imprint of Elsevier

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Academic Press is an imprint of Elsevier
125, London Wall, EC2Y 5AS, UK
525 B Street, Suite 1800, San Diego, CA 92101-4495, USA
225 Wyman Street, Waltham, MA 02451, USA
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK

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British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

ISBN: 978-0-12-802185-9

Typeset by Thomson Digital

Printed and bound in XXX

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00019-X; Author: KIMENGLISH; Document ID: 00019; Chapter ID: c0095

Contents

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00020-6; Author: KIMENGLISH; Document ID: 00020; Chapter ID: c0100

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00020-6; Author: KIMENGLISH; Document ID: 00020; Chapter ID: c0100

Part II
Function and Pathogen Resistance of Secondary Xylem

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00020-6; Author: KIMENGLISH; Document ID: 00020; Chapter ID: c0100

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00020-6; Author: KIMENGLISH; Document ID: 00020; Chapter ID: c0100

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00020-6; Author: KIMENGLISH; Document ID: 00020; Chapter ID: c0100

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00020-6; Author: KIMENGLISH; Document ID: 00020; Chapter ID: c0100

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00020-6; Author: KIMENGLISH; Document ID: 00020; Chapter ID: c0100

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00020-6; Author: KIMENGLISH; Document ID: 00020; Chapter ID: c0100

Preface

INTRODUCTORY REMARKS

p0010 Wood (secondary xylem) is the most important sustainable and renewable material on this planet from an economic as well as an environmental perspective, serving as a raw material for the processing of a wide range of useful products. Wood is the final product of complex integrated physiological, biochemical, and molecular activities accompanying the development and differentiation of cambial derivative cells.

p0015 During the course of discussions with close international colleagues, the stimulus and need for a book arose that can bring together up-to-date information not only on processes related to wood formation but also on aspects of functions and applications, and thus can serve as an important text or source of reference for undergraduate and postgraduate students in wood biology. The information available on these aspects is scattered and fragmentary and not covered in a single volume.

p0020 This book is divided into four major parts. The first part deals with advanced techniques for investigating secondary xylem biology and wood ultrastructure.

p0025 G. Daniel covers the diverse microscopy techniques, giving examples and pointing out limitations, with particular emphasis on sample preparation for studying secondary xylem biology. K. Takabe describes the novel rapid freezing and freeze substitution method that has provided new information on cell wall formation in woody plants. In combination with immunocytochemistry, detailed information on the localization of enzymes involved in the biosynthesis of cell wall components has been provided. K. Fukushima focuses on the application of time-of-flight secondary ion mass spectrometry in studying the main polymer components of woody plant cells as well as inorganics and low-molecular-weight extractives, which are detectable with submicron lateral resolution by this technique.

p0030 The second part deals with various endogenous and exogenous effects on secondary xylem formation – information crucial for understanding xylogenesis.

p0035 U. Schmitt gives an overview of seasonal cambial activity, environmental control of related processes, and also the importance of cambial activity in the restoration of tissues after wounding.

p0040 R. Funada outlines the sequences of xylogenesis in trees, from reactivation of the cambium in the early spring by temperature to programmed cell death, leading to maturation of the secondary xylem. The dynamics of cortical

ISBN: 978-0-12-802185-9; PII: B978-0-12-802185-9.00021-8; Author: KIMENGLISH; Document ID: 00021; Chapter ID: c0105

microtubules closely related to the orientation and localization of newly deposited cellulose microfibrils are also covered.

p0045 E. Liang reviews the effect of moisture stress on the times and dynamics of xylem formation, with information on how drought in the spring could largely delay the onset of xylogenesis, leading to smaller numbers of xylem cells during the growing season, and likely early cessation of xylem differentiation in water-limited environments, such as in the Himalayan regions.

p0050 J. Fromm provides an overview of the major stress types affecting wood formation, with information on the negative consequences of chemical and physical environmental stresses the physiology, biochemistry, and structure. Among various abiotic stresses, nutrient deficiency, drought, temperature, soil salinity, and air pollution are mainly highlighted.

p0055 F. Telewski introduces flexure wood formed by mechanical loading on the trunk or branches of a tree. The alterations in the physical and chemical structures of the secondary xylem by loading result in the formation of flexure wood characteristics, with an increase in xylem production and cellulose microfibrillar angle and a decrease in the elastic modulus.

p0060 L. Donaldson describes the reaction wood formed as a geotropic response of trees and shrubs, which generally occurs in leaning stems and branches. Anatomical, physical, and chemical properties of reaction wood, in comparison with normal wood, are described. In addition, the wood qualities of reaction wood are briefly mentioned.

p0065 The third part of the book deals with the function and resistance of the secondary xylem. Pits in the secondary wall in woody plants play an important role in the conduction of water in living trees and penetration of treatment liquids into timbers. Linking the structure of pits with the physiology provides insights into the regulation mechanisms of pit membrane in water flow against progressing cavitation.

p0070 Y. Sano reviews recent studies on the structure of bordered pit membranes and its relevance to resistance against cavitations. The relationship between micromorphological characteristics and conduit cavitation resistance is clarified for pit membranes in conifers and angiosperms.

p0075 G. Daniel outlines the main morphological changes produced in wood cell walls following colonization and decay by brown-, white-, and soft-rot fungi, resulting from biomineralization of wood's main structural components. Modes of wood degradation by wood decay fungi are described, with examples from light and electron microscopic studies. The enzymatic and nonenzymatic systems used by wood decay fungi are also briefly reviewed.

p0080 Compared to wood-decaying fungi, bacteria can tolerate more extreme conditions, such as highly toxic preservatives and extremely low levels of oxygen. A.P. Singh reviews the micromorphological changes in wood cell walls attacked by wood-degrading bacteria, with an emphasis on the ultrastructural aspects of the micromorphological patterns produced.

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p0085 The fourth part of the book deals with the economic utilization of woody plants. Many attempts are being made to maximize the added-value of lignocellulosics, such as genetical design of woody plants, bioconversion of woody material for renewable energy, and bioinspired functionalization of wood. In addition, wood as cultural heritages and bamboo as a substitute for woody biomass are treated.

p0090 Molecular biology has been employed for the modification and improvement of secondary xylem, particularly targeting cell wall characteristics. K.-H. Han outlines the genetic regulation of the biosynthesis of secondary cell walls, with a focus on genes encoding secondary wall-associated cellulose synthases, enzymes involved in lignin and hemicelluloses synthesis, and transcriptional regulators of secondary wall biosynthesis. Woody biomass can be converted into biofuels and useful biochemicals to replace fossil resources, using environmentally benign processes.

p0095 S. Saka briefly covers chemical pretreatments of lignocellulosic biomass and details enzymatic bioconversion. The obstacles to enzymatic bioconversion of woody biomass are also pointed out. Wood is a natural biomaterial with intrinsic evolutionary optimization of its formation and structure, and the knowledge has served in developing high-performance engineering applications.

p0100 I. Burgert describes the recent developments and advances in generating bioinspired wood products. An intimate human link, representing human life and values, is embedded in wood from time immemorial.

p0105 Viewing wood as cultural heritages, Y. S. Kim describes the influences of biotic and abiotic agents on the anatomical, physical, and chemical characteristics of wooden cultural heritages.

p0110 Unlike woody plants, bamboo does not produce a cambium, which is responsible for the production of secondary xylem. However, bamboo shares many similarities with woody plants, while marked differences occur in the cell wall ultrastructure. B. Fei outlines the anatomical, biological, and chemical characteristics of bamboo and the recent progress made in bamboo molecular biology, in relation to extending the potential of bamboo as an important biomass resource and as a substitute for wood biomass.

p0115 The main aim of this book has been to provide a comprehensive coverage of areas relevant for understanding wood biology in a single volume, which can be useful as a text in undergraduate and postgraduate courses. However, satisfactorily fulfilling this aim is not without difficulties, mainly because of differing writing styles and levels of treatment of the topics covered. Nevertheless, we hope that the contents and presentations in this book stimulate further exploration of knowledge on wood biology.

p0120 We are much indebted to the authors who shared with us their valuable time and enthusiasm in writing their chapters. The book could not have been completed without their passion and kindness. It was Dr H.-J. Bae of Chonnam National University who provided the initial stimulus and continued pushing

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for the preparation of this volume. Prof R. Funada pointed out how this kind of book in English is urgently needed for university-level wood biology courses. We are deeply grateful to the publishers for their constant encouragement and support and to Mary Elisabeth for the editorial work. Our grateful thanks also go to the anonymous reviewers for their valuable comments and constructive criticisms. We are so fortunate to have had enthusiastic support and backing from our families and are very grateful for their patience and tolerance throughout the preparation of this book.

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