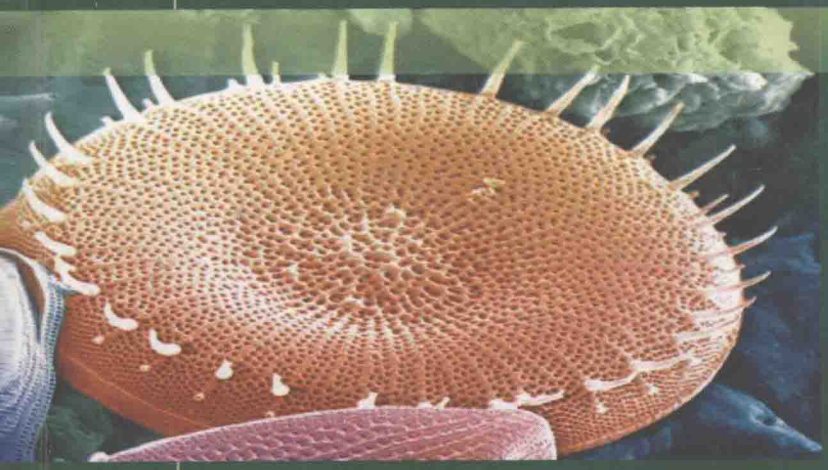
Plant Cell Biology



Editors
William V. Dashek
Marcia Harrison

PLANT CELL BIOLOGY

Editors

William V. Dashek
Retired from Adult Degree Program
Mary Baldwin College, Richmond/
Staunton, Virginia, USA

Marcia Harrison
Department of Biological Sciences
Marshall University, Huntington
West Virginia, USA

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Preface

Although there is a copious supply of cell biology textbooks, most are animal-oriented. The few plant cell biology textbooks are, in the main, not textbooks but expensive, methods-oriented, research volumes. Thus, there is need for a plant cell biology textbook for university undergraduates.

This textbook stresses concepts and is inquiry-oriented. To this end, there is extensive use of original research literature. As we live in an era of literature explosion, one must be selective. These judgements will naturally vary with the investigator. In establishing significance the input of colleagues was considered.

In addition to provision of select research literature, this volume presents citations and summaries of certain laboratory methods. In this connection, the textbook stresses quantitative data to enhance the student's analytical abilities. Thus, the volume contains computer-spread sheets and references to statistical packages, e.g. Harvard Graphics and Statistica.

In short, while the volume contains basic facts, the intent is to gain an appreciation for the scientific method and major research trends in plant cell biology.

William V. Dashek
Marcia Harrison

Dedication and Acknowledgment

Dr. Dashek dedicates this volume to his children, Kristin Ann Simpson and Karin Ann Bryant, who patiently dealt with his need for scholarship. He also thanks the following for his scientific development: Dr. W.G. Rosen, the late Dr. W.F. Millington, Dr. D.T.A. Lamport and the late Dr. J.E. Varner. Dashek extends his gratitude to Ms. Deanna Smith for her patience with clerical assitance.

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List of Contributors

Bowlby, Neil

Department of Biochemistry and Molecular Biology, Michigan State University, 212 Biochemistry, East Lansing, MI 48824, USA

Brewer, Karen J.

Department of Chemistry, Virginia Tech, Blacksburg, VA 24061-0212, USA

Dashek, William V.

Retired from Adult Degree Program, Mary Baldwin College, Staunton, Virginia, USA

Harrison, Marcia

Department of Biological Sciences, Marshall University, Huntington, West Virginia 25755, USA

Hoober, J. Kenneth

School of Life Sciences, Center for Photosynthesis, Arizona State University, P.O. Box 874501, Tempe, Arizona 85287, USA

E-mail: khoober@asu.edu

Kaneko, T.S.

Japan Women's University, Department of Biological and Chemical Sciences, Tokyo, Japan

Malmström, Susanna

Laboratoire de Biochimie et Phisiologie Moleculaire des Plantes, Agro-M/Université Montpelier II/INRA/CNRS UMR 5004, Place Viala, 34060 Montpellier cedex 1, France

Miglani, G.S.

Department of Genetics and Biotechnology, Punjab Agricultural University, Ludhiana, Punjab 141004, India. E-mail: gsmiglani45@yahoo.co.in

Shepherd, Virginia

University of New South Wales, Department of Physics, Sydney 2052, Australia

Śnieżko, Renata

Maria Curie-Sklodowska University, Institute of Cell Biology, Academicka 19, 20-033 Lublin, Poland

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CHAPTER 1

Introduction

William V. Dashek

WHAT IS CELL BIOLOGY?

Cell biology is the study of cellular form and function at a microscopic and biochemical level. In contrast, molecular biology is concerned with investigating the structure and function of the biological macromolecules which comprise cells. Cell biology draws upon microscopy, biochemistry, immunology and to some extent molecular genetics. The topics that cell biology encompasses are: chemistry and function of biomolecules, cells and their organelles, movement of molecules across membranes, mitosis and meiosis, metabolism, photosynthesis, and cell signaling. Some cell biologists may have additions to this list.

RESEARCH METHODS OF CELL BIOLOGY

Table 1.1 presents the microscopical methods for investigating plant cells and their inclusions. It is apparent that immunology and microscopy have been wedded as immunocytochemistry and immunoelectron microscopy for the localization of cellular antigens. In addition, these immunomicroscopic methods have been employed to elucidate the "machinery" of mitosis and meiosis. Biochemical methods (Tables 1.2–1.9) have often been used by certain cell biologists to gain an understanding of the chemical composition and function of cells and their organelles. The reader is referred to Dashek (1997) for biochemical methods to isolate and characterize molecules other than macromolecules. There has been a growing trend to link cellular and molecular biology with a special interest in elucidating the genes regulating the biosynthetic pathway of cellular chemicals.

LITERATURE ON CELL BIOLOGY

The supply of cell biological research literature is copious, as evidenced by the bibliographies presented here. A useful Internet source book for cellular and molecular biologist is that of Cabibbo *et al.* (2004). With regard to cell biology facts, there is a variety of cell biology textbooks and monographs as well as cell and molecular images and videos on line (http://www.cellbio.com/images.html).

TABLE 1.1 Summary of light and electron microscopic techniques

Light microscopy		*Electron microscopy and ancillary methods*	
Technique	*Application*	*Technique*	*Application*
Bright field	Conventional microscopy	Atomic force	Mapping of surfaces to an atomic scale
Confocal scanning optical microscopy	Examination of cells in live tissue in bulk samples	Cryoelectron microscopy	Imaging of biological macromolecules in the absence of specimen dehydration and staining
Confocal fluorescence	DNA labeled with more than one fluorescent tag		
Dark field	Visualization technique for ashes produced by micro-incineration and fluorescence microscopy; useful for low-contrast subjects	Electron systems imaging EM shadowing	Detection, localization and quantitation of light elements Structural information from ordered arrays of macromolecules
Reflection contrast	Quantification in gap between light and EM microscopies	Immunoelectron	Localization of cellular antigens
Reflection-imaging microscopy	Useful for imaging highly reflective particles such as silver grains in autoradiographs		
Field ion microscopy	Atomic structure of crystals		
Nearfield scanning optical	Determination of single molecules on surface	Negative staining	Useful for detergent-extracted cytoskeletons, membrane fractions, organelles
Nuclear magnetic resonance microscopy	High-resolution 3-D imaging of living plants; forms images if H_2O in the body; water distribution and binding in transpiring plants and H_2O transport in plants with light-stressed foliage	Scanning electron microscopy	Surface topography
Nomarski differential interference contrast	Reveals edges in biological structures, e.g. organelle and nuclear boundaries, cell walls; also images fibrous subcellular components, e.g. microtubules	Scanning tunneling microscopy surface spectroscopy	Surface topography, image internal structure of macromolecules such as proteins, liquid crystals, and DNA
Phase contrast microscopy	Produces visible differences in retardation of light waves, useful for biological material which possesses limited inherent direct contrast	Transmission electron microscopy	Subcellular morphology
Polarization microscopy	Most useful for highly birefringent objects, e.g., cellulose microfibrils in cell walls and distinguishing crystalline and noncrystalline inclusions	X-ray microanalysis	Detection, localization and quantitation of elements
Raman microscopy	Analysis of bioaccumulations in plant vacuoles		

N.B. See microscopy reference at end of this chapter

TABLE 1.2 Summary of methods for separating and/or detecting sugars

Technique	*Reference*
Colorimetric detection of sugars	Dische (1962)
Chromatographic separations of sugars	
Column-carbon, celite, extrusion, gel permeation, ion exchange	Ares.umimet.edu.ve/quimica/bpqi/O2chromatog.pdf.
Gas liquid chromatography	Eklund et al. (1977)
High performance liquid chromatography	Rassi (1995)
Paper and thin layer chromatographies	Dashek (1997)

TABLE 1.3 Methods for the structural analysis of carbohydrates[a]

Technique	*Reference*
Chiral determination	James (1995)
Glycosidic link determination	Charlson *et al.* (1962)
Melting point determinations	Thompson and Wolfrom (1962)
C-Methyl determination	Maciak (1962)
Nuclear magnetic spectroscopy	Carpita *et al.* (1991) Vliegenthart *et al.* (1983)
Oligosaccharide sequencing	GlycoFace (1994)
Primary hydroxyl group determination	Lewis *et al.* (1962)
Structural determination of glycoprotein N-glucans	Schaumann *et al.* (1993)

[a]The reader is referred to Dashek, W.V. 1997 for methods pertaining to other molecules in plant cells and tissues.

TABLE 1.4 Summary of lipid separation techniques

Procedure	*Reference*
Solvent fractionation–Acetone precipitation	Kates (1982)
Column chromatography Adsorption Ion exchange Partition	Kates (1982)
Gas liquid chromatography	Shibamoto (1994)
High-pressure liquid chromatography	Kautsky (1981) Moreau (1990)
Paper and thin layer chromatography	Kates (1982)

TABLE 1.5 Summary of macromolecular lipid analysis

Method	*Application*
Acid analysis	Measures extent to which hydrolysis liberates fatty acids
Anisidine method	Measures of oxidation of secondary products
Gas chromatography/mass spectrometry	Lipid structure analysis, e.g. sphingolipid profiling
Liquid chromatography	Separation of lipid classes
Nuclear magnetic resonance	Structural change of lipoprotein lipids
Saponification value	Mean molecular weight of the component fatty acids
Unsaponifiable matter content	Measure of proportion of lipid material other than fatty acids

TABLE 1.6 Summary of nucleic acid and separation techniques

Procedure	*Reference*
Gel electrophoresis	Allen and Budowle (1994)
High-pressure chromatography	Jones (1995) Lai and Birren (1991) Rickwood and Harris (1990) Tietz (1998) Brown (1984)

TABLE 1.7 Summary of nucleic acid structure research techniques

Procedure	*Reference*
DNA sequencing	Alphey (1997) Ball (1996) Brown (1984) Howe and Ward (1990)
Hybridization techniques	Hanes and Higgins (1985)
Nuclear magnetic resonance	Roberts (1993) Jones (1995)

TABLE 1.8 Methods for the separation of amino acids and peptides

Technique	*Reference*
Electrophoresis	Hedges *et al.* (1992) Rabilloud (2000)
Gas chromatography	Husek and Macek (1975) Kataoka *et al.* (2000) Zumwalt and Kuo (1987)
High performance liquid	Hill *et al.* (1979) Jen-Kin (1984) Hancock (1998) Wilkinson (1998) Cohen (2000) Kochhar *et al.* (2000)
Ion exchange chromatography	Jandik (2000)
Paper chromatography	Heilman (1992) Brenner and Niederwiser (1960)
Thin layer chromatography	Heilman (1992)

TABLE 1.9 Some relevant references for advanced methods for determining protein structure

Method	*Reference*
Gas chromatography/ mass spectrometry	McMaster and McMaster (1998)
High performance liquid chromatography	Tempst *et al.* (1987) Wakefield (1986) Hearn (1991) Mant and Hodges (1991)
Infrared spectroscopy	Singh (2000) Twardowski and Anzenbacker (1994)
Mass spectrometry	Chapman (1996) Johnstone and Rose (1996) Chapman (2000) Corthals *et al.* (2000)
Nuclear magnetic resonance	Cavanaugh *et al.* (1996)
Spectroscopy	Reid (1997)
Raman spectroscopy	Pelletier (1999) Twardowski and Anzenbacker (1994)
Sequence analysis	Inman and Apella (1986) Wittman-Liebold *et al.* (1986) Jornvall *et al.* (1991) Bryan and Smith (1996) Imahori and Sakiyama (1986)

These include: cells alive, common molecules page, the MIT hypertextbook, molecules and online service for biology. Table 1.10 displays certain biology online services. Of special is the online cell biology lab manual of W.H. Heidcamp. Finally cell biology practice problems have been published by MIT (http://www.cellbio.com/images.html). Karp and Pruitt (1999) have published problems in paperback form.

TABLE 1.10 Summary of certain cell biology online sources[a]

www.Cellbio.com
www.Nature.com/ncb/
cellbio.utmb.edu/cellbio/
www.ingenta.com/journals/browse/urban
www.cbc.umm.edu/nmwd/cell.html
www.mcb.harvard.edu/biolinks.html
users.vcn.com/jkimball.ma.ultranet/biologypages
www.trends.com/tcb/default/htm
www.campcell.appstate.edusun.science.wayne.edu/'cellbiol/

[a]There are 2,260,000 online cell biology sources. It is important that the students discriminate between websites by educators and those of noneducators. Those with edu in the address are usually prepared by educators.

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