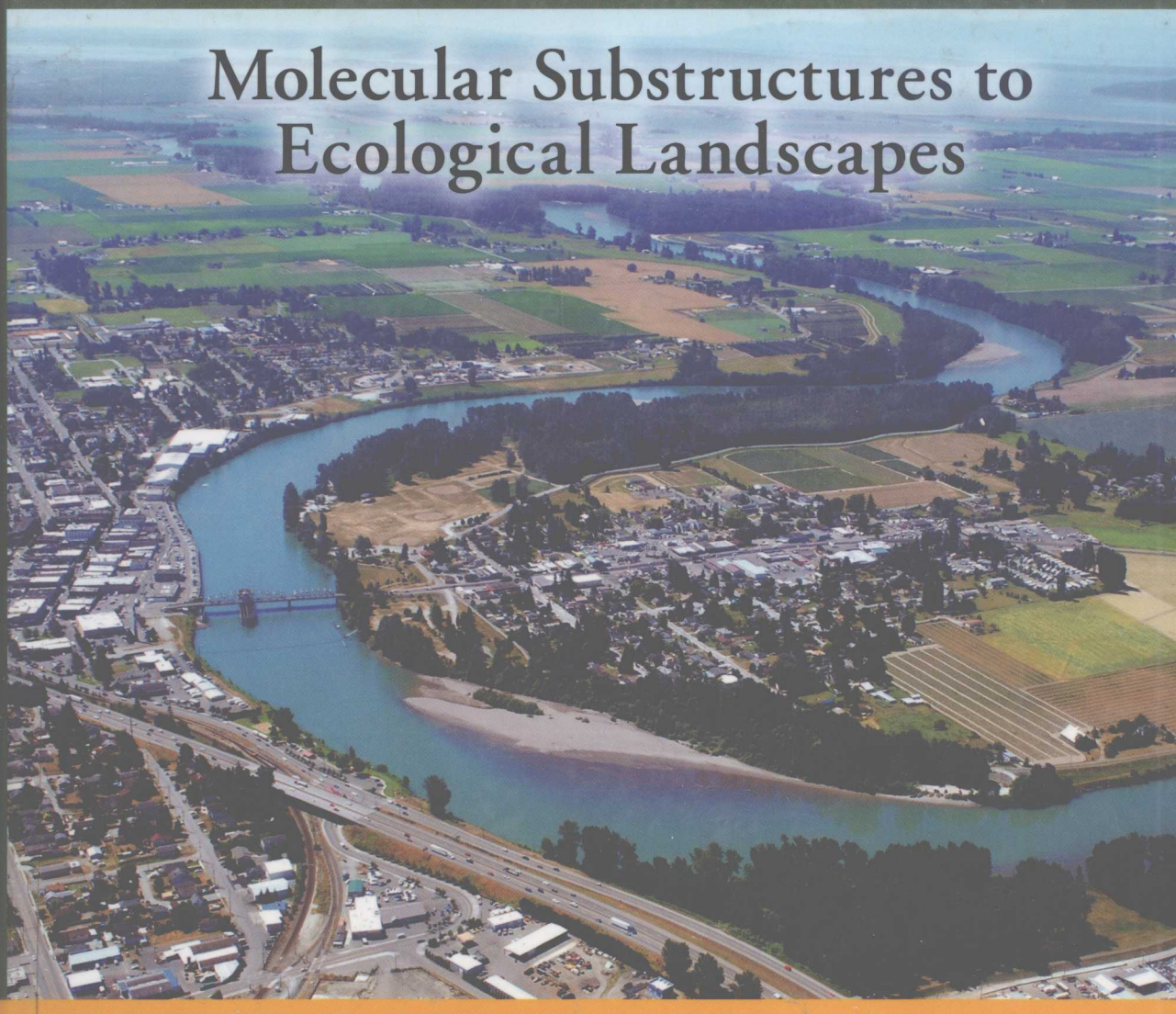
Fourth Edition

Introduction to ENVIRONMENTAL TOXICOLOGY

Molecular Substructures to Ecological Landscapes



Wayne G. Landis | Ruth M. Sofield | Ming-Ho Yu

CRC Press
Taylor & Francis Group

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Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number: 978-1-4398-0410-0 (Hardback)

Library of Congress Cataloging-in-Publication Data

Landis, Wayne G.
Introduction to environmental toxicology : molecular substructures to ecological landscapes. -- 4th ed. / Wayne G. Landis, Ruth M. Sofield, Ming-Ho Yu.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-4398-0410-0 (hardcover : alk. paper)
1. Pollution--Environmental aspects. 2. Environmental toxicology. I. Sofield, Ruth M. II. Yu, Ming-Ho, 1928- III. Title.

QH545.A1L35 2011
571.9'5--dc22 2010026488

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¥ 844 —

Preface to the Fourth Edition

Fifteen years ago we submitted the original text because we had no suitable book for teaching courses introducing environmental toxicology and biochemistry. The current edition still reflects those origins. A good textbook presents not just lists of information but also has a design to teach students how the science is connected and how to delineate the frontiers. These connections and frontiers are the items that will stay with the student long after the "facts" are displaced by better information.

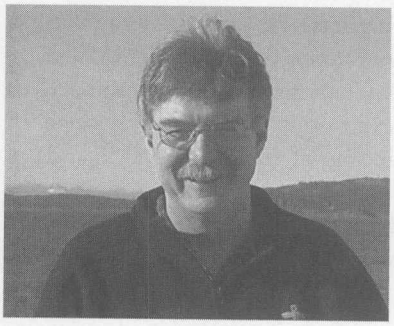
The mid-1990s were long ago and our understanding of environmental toxicology was very basic. Computation was still hard, genes stayed put, and it was only then becoming recognized that xenobiotics could have hormonal effects. Ecological risk assessment was in its very early stages and the consideration of the effects of toxicants on landscapes was nascent. These developments are now taken for granted.

The third edition was noteworthy as the work of D. Moore, P. Caux, and M. Newman demonstrated that curve fitting is superior to hypothesis testing for the modeling of concentration-effects data. Endocrine disruption was a major part of the text and risk assessment became a stand-alone chapter. The unifying construct of the hierarchical patch dynamics paradigm was introduced early and used in following chapters to integrate the spatial and temporal scales in environmental toxicology. The third edition explicitly recognized that ecological structures were complex systems being dynamic, not in equilibrium, and historical.

This fourth edition sees the inclusion of a new author, Dr. Ruth M. Sofield, who prepared the chapter on the fate and transport of contaminants. This chapter is a major addition to the text and emphasizes the relationships between chemical structure and the resultant properties with regard to the fate and transport of the material. The relationship between structure and toxicological properties has been a major theme of this book since its inception. In this edition, this fundamental concept is expanded to fate and transport as well. Our current students have the background to utilize the mathematical approaches necessary to predict fate and transport in many systems. Indeed, modeling has become a major theme of this edition.

One of the major enhancements to the fourth edition has been a new emphasis on the use of all types of models in understanding nature. In the early chapters, the use of models in science is discussed and this theme carries throughout the remainder of the book. Inevitably this emphasis on using models to describe toxicological relationships continues to lead to the fundamental flaws in using hypothesis testing to describe toxicity. It is time to move toward the use of models that describe concentration-response relationships and all the diversity of form that may exist. Because the use of biotic indices is incompatible with our current model of how ecological systems operate, the treatment of them recommends a number of methods that take advantage of the increase in

Authors



Wayne G. Landis, Ph.D., has been the Director of the Institute of Environmental Toxicology and Chemistry, part of Huxley College of the Environment at Western Washington University, Washington State, since 1989. A graduate of Wake Forest University with a BA in biology in 1974, he subsequently received an MA and a Ph.D. in zoology from Indiana University in 1978 and 1979, respectively. Prior to Dr. Landis's university experience he was a toxicologist for the Chemical Research Defense and Engineering Center at Aberdeen Proving Ground, Maryland.

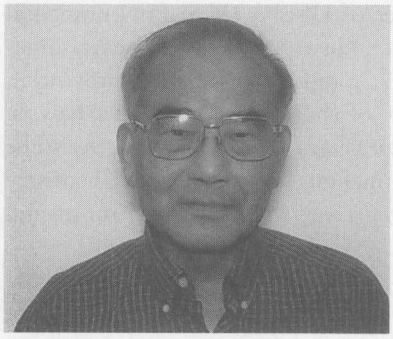
Dr. Landis has authored more than 120 publications and 300 scientific presentations. He has served on a number of USEPA (U.S. Environmental Protection Agency) and other committees, and consulted for industry; nongovernmental organizations (NGOs); print and electronic media; and federal (U.S. and Canada), state, provincial, and local governments. In 2007, he was selected as a Fellow of the Society for Risk Analysis. Currently, Dr. Landis serves on the board of editors for *Human and Ecological Risk Assessment*; he is one of the founding editors for the new Society of Environmental Toxicology and Chemistry (SETAC) journal *Integrated Environmental Assessment and Management*; and is the environmental risk assessment editor for *Risk Analysis.*

Dr. Landis has had a varied research program. During the 1980s and early 1990s, he discovered and characterized enzymes that degrade organophosphates and bacteria that metabolize riot control materials. He also conducted an extensive research program using microcosms to investigate the effects of jet fuels and other materials on the dynamics of ecological structures. Using patch dynamics models, he also formulated the theory of how to incorporate landscape scale effects as part of environmental toxicology. He is the codeveloper of the Community Conditioning Hypothesis and the Action at a Distance Hypothesis. Dr. Landis's most recent efforts have been to apply ecological risk assessment at regional and landscape scales using the relative risk model. The use of the relative risk model has now been applied to contaminated sites, invasive species, and forestry and species conservation. The approach has been used to estimate risk to sites across the world.

Ruth M. Sofield, Ph.D., is an Associate Professor at the Huxley College of the Environment at Western Washington University. She has been at the university since 2003, and is one of the faculty specializing in environmental toxicology and chemistry. She routinely teaches environmental toxicology, and fate and transport courses at the university, as well as workshops in aquatic toxicology throughout the United States.

Dr. Sofield has a BA in biology from West Virginia University (1993), an MS in environmental science from McNeese State University (Louisiana) (1995), and an MS and Ph.D. in environmental science and engineering from the Colorado School of Mines (1999, 2002). She completed her Ph.D. work in collaboration with the Center for Coastal Environmental Health and Biomolecular Research, Marine Ecotoxicology Branch, National Ocean Service, National Oceanic and Atmospheric Administration (NOAA), Charleston, South Carolina. This work focused on the genetically based tolerance to chemical exposures in *Palaemonetes pugio*. In 2003, Dr. Sofield completed her postdoctoral work on the binding of environmental ligands to uranium and plutonium.

Her current research program is focused on the effects of altered water chemistry and other environmental parameters on metal fate, transport, and aquatic toxicity. These studies range from laboratory bench scale to field scale investigations and include organism exposures combined with chemical modeling.



Ming-Ho Yu, Ph.D., is Professor Emeritus at the Department of Environmental Sciences, Western Washington University. He received his BS degree from National Taiwan University, and MS and Ph.D. from Utah State University. He did his postdoctoral research at Utah State University and the University of Alberta, Canada. Dr. Yu was a visiting professor and conducted research for a year at the Department of Public Health and Hygiene, Iwate Medical University, Morioka, Japan; and also at the Institute of Whole Body Metabolism in Chiba, Japan, for three months. He serves as an associate editor of *Fluoride*, the official journal of the International Society for Fluoride Research. Dr. Yu is coeditor of *Environment Fluoride 1985* (Elsevier, 1986); and the author of *Environmental Toxicology—Impacts of Environmental Toxicants on Living Systems*, Second Edition (CRC Press, 2005), and coauthor of *Introduction to Environmental Toxicology*, Third Edition (CRC Press, 2005).

Contents

Chapter 1

Introduction to Environmental Toxicology

As all textbooks do, this volume reflects the points of view of each of the authors, developed from being active researchers, teachers, and participants in various professional societies and governmental panels. Since the early 1990s at Huxley College of the Environment there has been a two-course fundamental introduction to the science of environmental toxicology for which this text was originally developed. That series is supplemented by courses in aquatic toxicology, risk assessment, fate and transport, air pollution, and risk assessment. Since its first edition this book was designed to provide a keystone for the program in environmental toxicology.

The approach is to blend the classic aspects of the field with new developments as they prove fundamental to the understanding of environmental toxicology. Our approach is quantitative, recognizes the connection between molecular interactions and alterations of ecological functions, and understands that the findings of the field can have major implications for the making of environmental policy. We begin by defining the field of environmental toxicology.

1.1 Environmental Toxicology as an Interdisciplinary Science

Environmental toxicology is the study of the impacts of pollutants upon the structure and function of ecological systems. For the purposes of this text, the emphasis will be upon ecological structures, from the molecular to the individual organism to the community and to the ecosystem. The broad scope of environmental toxicology requires a multidisciplinary approach of a variety of specialists. These specialists interact with a variety of other persons, decision and policy makers, the public, educators, and other key individuals, in making decisions about the management