Ecotoxicology offers a comprehensive overview of the science underpinning the recognition and management of environmental contamination. It describes the toxicology of environmental contaminants, the methods used for assessing their toxicity and ecological impacts, and approaches employed to mitigate pollution and ecological health risks globally. Chapters cover the latest advances in research, including genomics, natural toxins, endocrine disruption and the toxicology of radioactive substances. The second half of the book focuses on applications, such as cradle-to-grave effects of selected industries, legal and economic approaches to environmental regulation, ecological risk assessment, and contaminated site remediation. With short capsules written by invited experts, numerous case studies from around the world and further reading lists online, this textbook is designed for advanced undergraduate and graduate one-semester courses. It is also a valuable reference for graduate students and professionals. Online resources for instructors and students are also available.

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Almost 20 years ago, we published *Environmental Toxicology*. That book drew on the previous quarter-century, which had seen the gestation and adolescence of the environmental movement, and emphasized the emerging science of environmental toxicology. Students of today will have a different perspective from ours at the end of the twentieth century. Nevertheless, the current ecotoxicology text has been conceived as a follow-up. As a product of the subsequent 20 years of rapidly advancing research, technological progress, scholarly and popular writing, and media communications, it is in no sense a second edition. It is a new book, but it is tempting to review and reflect on the way that we saw the whole topic of toxic substances in the environment at the turn of the century. In our concluding chapter in 2002, we wrote:

At the beginning of the twenty-first century, there is a clear need to reformulate our thinking about the relationship between society and nature. All the preceding viewpoints were initially conceived without any clear evidence of widespread environmental pollution. Well-publicised instances of major contamination events and recent emphases on adverse effects at the population, community, and transboundary ecosystem levels now indicate the pervasiveness of problems. While science and technology have more sophisticated tools than ever before to identify and remediate environmental contamination, global problems will require global solutions and the political will to drive them. Such political decisions can only be made in the light of informed public opinion. This will increasingly involve scientists in the role of communicators and the engagement of politicians, economists, social scientists and philosophers in providing a balanced, realistic framework for ecosystem management.

How much has changed?

Pamela M. Welbourn and David A. Wright
PREFACE

Ecotoxicology is the study of the effects of toxic chemicals on biological organisms, especially at the population, community and ecosystem levels. It falls under the umbrella of environmental science and represents one of the aspects of environmental studies, along with the conservation of species, habitats and ecosystems, the protection of endangered species, and various levels of management for water, soil, wildlife and fisheries.

As is the case for other branches of environmental science, in ecotoxicology, there are reciprocal relationships among scientific investigations and social problems. Although this textbook focuses on the scientific and technological features of ecotoxicology (i.e., the things that we can measure), we think it is important to offer some historical background concerning the social context in which the science has developed. We describe the increasing public awareness and concern about toxic chemicals, and discuss the role that environmental nongovernmental actions have played in the development of ecotoxicology. For example, the role of endocrine disrupting chemicals was brought to public attention by the publication of Our Stolen Future in 1996 (co-written by Theo Colborn). Research on endocrine disrupting chemicals now constitutes a very significant domain in ecotoxicology.

In choosing the title ‘Ecotoxicology’, we aim to emphasize the ecosystem and its components at all levels of organization, and – to some extent – downplay the effects of toxicants on humans (often referred to as environmental toxicology). Nevertheless, we acknowledge that on many occasions, studies in environmental toxicology have led to the discovery of unexpected effects on ecosystems. For example, the food chain transfer and magnification of methylmercury, first recognized as causing disease in human populations in the late 1950s, were shown to have similar effects on top-level consumers in the animal kingdom.

Our textbook aims to provide a clear understanding of the broad scope of the discipline of ecotoxicology, informed by the latest scientific analysis and thinking. Some of the key features are:

- A unique blend of the chemistry, the biology and the regulatory aspects of ecotoxicology.
- The inclusion of chapters on endocrine disruption and ecotoxicogenomics, and considerations of how the recent findings in the field of genomics are beginning to provide tools that may assist our understanding of how chemicals can impact on ecosystem health.
- Consideration of novel contaminants such as engineered nanomaterials, polyfluoroalkyl substances (PFAS) and technology-critical elements (TCEs).
- The coverage of a range of countries in the discussion of regulatory toxicology, including the European Union, the USA, Australia, Canada and New Zealand, as well as international agreements.
- Up-to-date case studies and capsules throughout the text, some written by guest authors, to engage students and provoke interest in topics that touch their daily lives.
- Review questions at the end of each chapter to test the students’ knowledge.
- Online resources for instructors (at www.cambridge.org/ecotoxicology), which include solutions to student questions and problems. Online resources for students include the glossary of all the key terms highlighted in brown within the book and additional reading lists.
- The presentation of future visions, emerging concerns, novel contaminants and new technical approaches to understand and mitigate pollution and ecological health risks globally, which can be debated in targeted student discussion sessions or seminars.

This book has been designed for advanced undergraduate and graduate students taking courses on ecotoxicology, environmental toxicology and environmental pollution. It assumes knowledge of some fundamental and widely accepted concepts and biological processes. Students should have some background in basic natural sciences,
Preface

chemistry, biochemistry and biology. Professional consultants and practitioners may also find this a useful guide in specific areas.

The book was planned with a one-semester senior undergraduate course in mind, but it is also appropriate for graduate students who need to expand their background in ecotoxicology. In designing a particular course, instructors will be able to choose the chapters or chapter sections that fit with the course objectives, knowing that there are frequent cross-references among the chapters that will help the students to make the necessary connections. With few exceptions, the references cited date from 2000 or later. A few earlier references have been included, because we judged these to be seminal.

Book Organization

Throughout, this textbook provides more than a catalogue of toxic chemicals and their effects. It links ecotoxicology to the basic sciences of biology and chemistry that explain why some chemicals are more bioavailable and toxic than others and how chemicals interact with life at the molecular and cellular levels. It links these fundamental interactions to subsequent effects at higher levels of organization, from whole-organism performance to ecological change, with implications for the provision of ecological services such as natural resources.

Within Part I, ‘Approaches and Methods’, Chapter 1 discusses the history and evolution of this originally hybrid science and provides an overview of the structure of the whole book. Chapters 2, 3, 4 and 5 deal with the ‘tools of the trade’, some well-established (Chapter 2), some rapidly emerging (Chapter 5). In a number of places in the text, including the Epilogue, we refer to the challenges and pitfalls of relating experimental (lab-based) studies to the real world. We include methods and approaches for determining how potentially toxic substances can affect living organism at all levels of organization, from the gene to the whole ecosystem, and how these effects can be quantified. In the course of so doing, recent research and technical advances are included, along with selected examples to illustrate the major issues and current approaches to the subject. Recognizing the contribution of technology to the progress of the science of ecotoxicology, significant technological advances are highlighted and evaluated. As such, Chapter 5 is a state-of-the-art overview of the developing science of ‘Oomics’, which underpins the development of Adverse Outcome Pathways, linking effects at the molecular level to successively higher levels of organization, including ecosystems.

Part II, ‘Toxicology of Individual Substances’, addresses categories of chemicals in classes, with their sources, chemistry and modes of action. This includes Metals and Metalloids (Chapter 6), Organic Compounds (Chapter 7), Endocrine Disrupting Chemicals (Chapter 8), Natural Toxins (Chapter 9) and Ionizing Radiation (Chapter 10). The inclusion of natural toxins is a departure from most ecotoxicology textbooks, but natural plant, animal and microbial metabolites constitute some of the most toxic substances known. Further, there is increasing interest in the use of natural products in pest control and medicine.

Part III, ‘Complex Issues’, deals with real-world complex issues, covered in Chapter 11. These issues were chosen to illustrate the effects of multiple stressors, the potential implications of ‘nanotoxicity’, interactions among toxicants and cradle-to-grave effects of industrial processes such as metal extraction/refining and pulp and paper processing. In Part IV, ‘Management’, Chapter 12 deals with environmental regulation and risk assessment, and Chapter 13 with recovery of ecosystems damaged by chemical contamination. Finally, Chapter 14 looks at emerging issues and anticipated future developments in ecotoxicology. Perhaps you, the readers of this volume, will contribute to an updated edition in another 20 years!
ACKNOWLEDGEMENTS

Many people have contributed to the publication of this textbook and we would like to express our gratitude here for their help. Some of these contributors will be evident to our readers, notably the authors of our capsules and several case studies (see page iv). For more subtle help, for example in chasing down and suggesting relevant references, we thank Charles Driscoll (Syracuse University), Cynthia Gilmour (Smithsonian Environmental Research Center), Bill Keller (Ontario Ministry of the Environment), Gerrit Schüürmann (Helmholtz Centre for Environmental Research) and Shaun Watmough (Trent University). In several cases, data were kindly made available by external colleagues (Matthew Graham, Environment and Climate Change Canada; Thomas Graedel, Yale University).

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As this book progressed from conception to completion, we have profited from the sage contributions of CUP staff, notably Emma Kiddle, Ilaria Tassistro and Rachel Norridge. In its final stages, the book also benefited from the meticulous analysis of our draft chapters by Lindsay Nightingale in her role as the copy editor.

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