PREFACE

The discipline of biology is growing at an unprecedented rate as more is understood of life at every level—from molecular biology to interactions at the global scale. Such developments in human knowledge about biology place great demands on teachers who, when they were at school, may well have been taught certain things that would now be regarded as being misleading or even wrong.

This book is therefore intended to help teachers of biology, whether they are long-experienced or just beginning their teaching career. The majority of chapters deal with specific areas of the biology curriculum, looking at the misconceptions that students often have, at the rationale for teaching in the area and at the principal concepts that students should learn if they are to manifest sound understanding. In addition, as described later in more detail, we have a number of chapters, rarely seen in books about science teaching, that are intended to help readers deal with important aspects of pedagogy that apply regardless of the specific content area one is focusing on.

An Introduction discusses the notion of biology didactics that contributors to this book share, describes the aims of the book and provides an outline of its contents. A brief account is given of issues in biology didactics. The chapter also explains why this book will be useful to science teachers and educators and how it can be used both as a resource for teaching and as a major sourcebook in teacher preparation courses.

Chapter 2 focuses on the foundational role that intuitive reasoning, such as essentialist and teleological reasoning, and intuitive language forms, such as generics (e.g. 'all birds have feathers'), play in the development of students' understanding of biology. Intuitive reasoning and language are frequently castigated, yet they can play a valuable role in the acquisition of more scientifically valid knowledge.

Chapter 3 highlights children's potential to engage in meaningful learning about the biological world when at kindergarten or primary school. It draws on research in developmental psychology about the emergence of biological knowledge and on biology education research about children's own ideas and the design of learning environments that may contribute to their elaboration.

Arguably the most significant changes in biology over the past century have been in molecular biology. Schools and higher education institutions are thus tasked with finding ways to help students develop deep and meaningful understandings of the myriad of molecular mechanisms that drive life. Chapter 4 discuss what is important to learn in this domain. It presents a progression for deepening students' ideas about molecular biology over the course of schooling and examines the role of technology, instruction and curriculum in fostering student learning.

Chapter 5 presents a consideration of cell biology, a key unifying concept in biology. A recommendation is made for how cell biology instruction might be scaffolded, and there is an extensive review of students' understandings and conceptions related to cell biology, as well as an outline of typical laboratory experiences to support learning about the cell. Specific recommendations are made about designing instruction plans and teaching cell biology.

Chapter 6 examines how human biology might be taught, considering the human body as a complex system. Complex systems are often challenging subjects, because they are characterised by many elusive and non-intuitive elements (emergence, multilevel organisation, interconnections, heterogeneous components and invisible dynamic processes) that can be difficult for teachers to explain and for students to perceive. This chapter offers several principles for overcoming this challenge.

Health and wellbeing is a broad and diverse topic. Teachers need to be well versed in the many aspects that this topic covers, from the effects of communicable and non-communicable diseases and the need to understand and maintain a healthy lifestyle by having a balanced diet and taking regular exercise, to the effects of drugs on physiological functioning. Chapter 7 explores how health and disease are defined, some of the barriers to teaching the subject in schools and some misconceptions held by students. It outlines some examples of successful interventions that support students' knowledge attitudes, and behaviours relating to health.

Chapter 8 looks at reproduction and sex education. School biology often pays little or no attention to reproduction in taxa other than humans and a small number of 'typical' flowering plants; it is argued that there is still much value in a traditional introduction to life cycles and reproduction in a large range of taxa. The chapter goes on to consider what makes for an appropriate sex education course, considering such issues as comprehensive sex education versus abstinence education and how school sex education can address questions to do with sexual orientation.

Biology education often focuses on adult forms when describing structure, function, physiology, adaptations, heredity and more. However, the features of all adult body parts are the outcomes of complex developmental processes, and they also evolve through complex evolutionary processes. In Chapter 9, it is therefore argued that the teaching and learning of development should occupy a central place in biology education, although this is not often the case.

In Chapter 10, on genetics, a central question that is addressed is the relationship between classical (Mendelian) genetics and molecular genetics. A second important issue is that school genetics consists of both knowledge about genetics and knowledge of doing genetics. It is therefore important to examine whether genetics is taught so as to enable scientific literacy or academic knowledge.

As is widely acknowledged, many school students find plant biology uninteresting. In Chapter 11, a case for teaching plant science in the secondary curriculum is presented using the 'big ideas' approach to school biology. In so doing, an assemblage of teaching approaches, in which student-centred learning complements practical experiments, is suggested for one strand of plant science, namely the process of photosynthesis.

The concept of energy is central for learning biology at school. Photosynthesis and respiration are the two fundamental, complementary biological processes that describe the fixation, processing and release of energy, interwoven with the synthesis and decomposition of organic matter. These processes are highly complex and abstract and relate to different system levels, which makes them very difficult to learn. Chapter 12 explores difficulties in learning, proposes conceptualisations of these concepts and provides some recommendations for teaching energy, photosynthesis and respiration, drawing on findings from empirical science education research.

The teaching of ecology poses important challenges to educators due to the nature of ecological relationships and processes. Deficiencies in teaching approaches that result in generating and transmitting misconceptions through ecology education are discussed in Chapter 13, and an educational framework for teaching ecology is proposed. The proposed framework combines outdoor activities, computer simulations and laboratory experiments in a series of learning sequences to help students grasp the complexity of ecosystems' functions and human–nature interactions.

Evolution is one of the most challenging biology topics to teach, learn and assess. Chapter 14 focuses on conceptual issues relating to the teaching and learning of evolutionary change, and is grounded in research on student thinking. Teleology, typological thinking, intentionality, use-inheritance, evolutionary 'pressures' and other intuitive ideas are widely documented barriers to evolutionary understanding. Robust explanatory models have been shown to be the exception in novice learners. Cross-case comparisons, highlighting surface feature dissimilarity while also illustrating causal unity, can foster robust understanding of evolutionary change.

The field of microbiology has led to significant advances in health and in industrial, agricultural and environmental processes. The rapidly expanding knowledge base in this area has resulted in some concern about how microbiology should best be taught in school science. For example, there is a perceived concern about safety when students grow and handle microorganisms and the controversial nature of some human activity related to microorganisms (e.g., germ warfare) is sometimes considered too difficult to manage in the classroom. Yet, the complex nature of this topic and the fascinating intersection with human beings and society provides an opportunity to engage students with school science. Chapter 15 discusses what good teaching about microbiology might look like.

Chapter 16 focuses on teaching biotechnology in the context of socio-scientific issues. This involves fostering students' understanding as to what biotechnology is and what techniques and processes are used, the values that are involved and what benefits and risks are associated with specific biotechnological techniques and applications, as well as what multiple (often competing) political, social, legal, economic and ethical claims are made for and against biotechnology.

Chapter 17 examines how authentic texts can be used to promote disciplinary literacy in biology. It advocates the use of Adapted Primary Literature articles. Such articles are designed to enable the use of scientific research articles in high school. They represent authentically the structure, claims, content and uncertainties that are found in the original research articles, and may therefore serve as models of scientific reasoning and communication.

Chapter 18 deals with the nature of scientific knowledge and the nature of scientific inquiry in biology teaching. It focuses on empirically based approaches to facilitating students' understandings of these, and argues that scientific literacy requires that an individual understands subject matter, the nature of scientific knowledge and the nature of scientific inquiry.

Chapter 19 describes the nature and structure of biological explanations. It then focuses on causal explanations in biology, and distinguishes between developmental and evolutionary explanations for the origin of biological phenomena and between causes of effects and the processes through which these effects are brought about.

Chapter 20 discusses research findings about argumentation in biology education. It asks how the practice of argumentation relates to biological knowledge and addresses questions related to why students should engage in argumentation in biology and to how teachers can support this engagement.

Finally, Chapter 21 examines the worth of the concept of 'worldviews' for understanding why some students choose to reject certain elements of what they are taught in biology. One notable topic where an approach based on worldviews has proved useful is evolutionary biology, which students from fundamentalist religious backgrounds often reject. Other biological topics that may benefit from a worldviews approach include anthropogenic climate change, vaccination advocacy and the use of animals for human purposes.