PREFACE

Biology has become more and more quantitative in recent years and the change has brought new insights and new questions. However, not every student of the subject is yet in tune with that kind of thinking, so that, in writing this introduction to quantitative biology, I have made a point of helping those who do not take to it naturally. Thus, I encourage the making of simple 'back-of-envelope' calculations, make the most of simple domestic arithmetic and, in mathematical terms, go barely beyond logarithms and exponentials. I have thus written for two extreme kinds of reader, that is to say not only those who take mathematics in their stride and turn to the book for its biology, but also (paradoxically perhaps!) those many people, uneasy with calculations and equations, who have least natural inclination to read about them. I hope the former will not mind if they find themselves led overmuch by the hand, for I know that advanced knowledge does not preclude ignorance of the elementary, and that ability does not stop one liking an easy read. I assume no prior knowledge of logarithms, knowing that readers who are well able to manipulate them in the context of a mathematics class (especially since the advent of calculators) may yet be unsure of their meaning and usefulness.

My title '*Biology by Numbers*' is intended to suggest both simplicity and numerical emphasis. To avoid misconceptions, I must explain not just what the book is, but what it is not. It is little concerned with the mechanical calculations associated with particular techniques and apparatus (though I like to think that a reading of this book might facilitate these), and it has little to say on the vital topic of statistics that is so amply covered by other writers. Also, it is far from being a book on biomathematics in the usual sense; the less mathematically inclined may turn to such books (some of which contain rather few numerical quantities, by the way) when the ice is broken or necessity dictates. The first chapter illustrates, through varied examples, a number of general points concerning the use of simple arithmetic in biology. The role of the second is to confront various obstacles that can get in the way of such quantitative thinking, and is therefore about the diversity of units of measurement, the art of approximate arithmetic, cultivating a feeling for biological magnitudes, and making sense of formulae. There are actually rather few formulae and equations in the book that are not just variants of each other, and some serve as little more than passing subjects for dissection. A few recur, and illustrate the important theme that ideas learnt in one context (mathematical or otherwise) may prove useful in other quite different contexts.

That is the key to the ordering of much of the biological material in subsequent chapters. I move, for example, from the link between carbon dioxide uptake and water loss in leaves to the loss of carbon dioxide and water from mammalian airways, from the exponential decline in a population of robins to an exponential decline in the numbers of viable seeds in soil, from differential growth in fiddler crabs to differential growth in gourds. Botany and zoology are intermingled, therefore, as is inevitable with some of the ecology topics. The required background knowledge is generally modest, however, and could largely come from school biology and a general interest in natural history. No biology topic is covered exhaustively, but references are provided for further reading. Where there is simplification, I trust that this will be recognized for what it is, and its point appreciated.

In Chapter 15 the emphasis changes briefly from numerical quantities towards algebra and simple 'mathematical modelling'. This is partly to point the way to those particular kinds of mathematical biology and partly to build on ideas from earlier chapters. Chapter 16, the last before my Epilogue, outlines a topic deliberately unlike the others but simple in its arithmetic, namely a method for the characterization of the branching patterns of trees. Its appeal, aesthetic to my mind as well as practical, lies in its general applicability – to branching rivers as much as to branching nerve cells and airways.

I make less mention than I might of human physiology, for I have already treated quantitative aspects of this in another book, *Physiology by Numbers* (1994). The present text is both less specialized, and more suited to students at what is likely to be an earlier stage in their education, but there is also a different character to the subject matter that is worth comment. Textbooks on human physiology tend to be full of 'standard' quantities such as blood volume and arterial blood pressures, the concentration of a blood component, the volume of a breath. This is not to say that all our bodies are exactly alike, but it is at least meaningful to refer to averages and standard values. Indeed, the medical student must learn many of these in order to recognize the abnormal. All these values are immediately available for arithmetical manipulation. The situation is rather different in general biology in spite of the greater abundance of measurable entities for there is no such thing as a standard lake or pine forest, defined in quantitative terms like the physiologist's 'standard 70-kg man', no standard beech tree, hedgehog or termites' nest. Such data on means and typical values as do exist are rarely to be found in elementary textbooks and must be sought elsewhere. Useful compilations of data may be found, often from theses and other rather inaccessible sources, but it is a sad fact that costs of publication have often permitted presentation of hard-won data not as tables, but only as the graphs (scattergrams) that serve the authors' immediate purposes. (Fortunately, the data from such graphs can be recovered by computer scanning now.) Some of these graphs have to do with 'allometry', the subject matter of Chapters 13 and 14 and an approach that can uncover simple, and often enlightening, quantitative patterns within the diversity of organisms. To the extent that the associated equations are predictive, they may sometimes yield the required data for tentative back-of-envelope calculations when more exact information is unavailable, and thus take the place of those standard quantities in human physiology. In this way one might, for example, make a sensible guess at the nutritional energy requirements of an abominable snowman if one did but know its mass. Whether or not information on other mammals exists, I have sometimes had deliberate recourse to data on the human body, as in some calculations on buoyancy and ecology. The point is that one should not be deterred from quantitative thinking through minor inadequacies of data; if it is information on the human body that is most readily to hand, rather than on the gazelles or tigers one happens to be interested in, it should be pressed, tentatively, into service. In this I am not advocating a cavalier attitude to science, but an uninhibited approach in one's private quantitative thinking. In this spirit, I invite the reader to join me sometimes in 'armchair science', a phrase that is sometimes used dismissively but, if it covers bathtubs and countryside as well as chairs, suggests quite well that enjoyable phase of thinking that may propel one later to library or laboratory. Favouring this armchair approach, I have mostly avoided the huge number of neat and clearcut examples of quantitative biology that are provided by self-contained studies and experiments.

I have used data published by many authors and apologize if I have in any way misrepresented them; indeed, I thank Paul Harvey for moderating my analysis of antler size. I also thank Francis Burton for preparing the graphs and Sarah Price for so meticulously checking my final manuscript.