Preface

Welcome to the second edition of *Quantitative Human Physiology*! This new edition has been updated with numerous enhancements, many of which were suggested or inspired by instructors and students who used the first edition. These important changes include (but are not limited to):

- Substantial updating of the text throughout to reflect the latest research results, with many sections expanded to include relevant and important information
- Enhanced, updated, and improved figures for better understanding and clarification of challenging topics
- Addition of several new appendices covering statistics, nomenclature of transport carriers, and structural biology of important items such as the neuromuscular junction and calcium release unit
- Addition of new problems within the problem sets and example calculations in the text
- Addition of some Clinical Applications such as dual energy X-ray bone densitometry
- Addition of commentary to power point presentations.

The goal of this new edition was to make important improvements while retaining the features that make this text uniquely suited to the needs of undergraduate bioengineering students. While it is sometimes very tempting to make drastic and sweeping changes in an attempt satisfy everyone, this new edition focuses on refinements and updates that, we hope, most instructors and students will find helpful, informative, and instructionally sound.

THIS TEXT IS A PHYSIOLOGY TEXT FIRST, AND QUANTITATIVE SECOND

The second edition of this text remains faithful to its primary goals: it remains, first and foremost, a physiology text. It is explicitly designed for a certain class of students, those majoring in Biomedical Engineering at Virginia Commonwealth University, and their suggestions, limitations, and desires have shaped the text from the outset. Specifically, the text is designed for students who have never been exposed to Physiology, students who know neither the language nor the concepts of the subject. The text contains all elements of physiology in nine units: physical and chemical foundations; cell physiology; excitable tissue physiology; neurophysiology; cardiovascular physiology; respiratory physiology; renal physiology; gastrointestinal physiology; and endocrinology. The course is best taught in the order of the text but it is possible to present the material in other sequences.

Secondly, the text affirms its aim to be quantitative. Being quantitative has two aspects. The first is about knowing the numerical value for the ranges of crucial aspects of physiology, such as the flows or forces within the body. The second is about discovering the relations between physiological parameters. For many aspects of physiology, there currently is not enough information to make a detailed quantitative analysis, or the analysis at that depth is beyond the scope of this text. In these cases, this text is not very different from more traditional texts. Where possible, the text takes an analytical and quantitative approach.

THE TEXT USES MATHEMATICS EXTENSIVELY

Carl Frederick Gauss famously said, "Mathematics is the queen of sciences." Mathematics is not just about the numerical value of something, such as the magnitude of the arterial blood pressure or the rate of salivary secretion, although that is what many people think of when they think of quantitation. Rather, mathematics is about the relationship between things that can vary with time or position. These relationships cannot be fully understood with words alone. They require the language of mathematics. Students should be able to articulate these relationships with words, but this text demands more. Mathematical statements—equations—are simply logical sentences. You can read an equation in words. But the mathematical statement uses an economy of words. Mathematics also has specific rules for the manipulation of the logical parts of the sentences, so that rearrangement or combination of equations leads to new insight.

NOT ALL THINGS WORTH KNOWING ARE WORTH KNOWING WELL

This text uses lots of mathematics at the level of the calculus and elementary differential equations. These mathematical tools are used to encode the physics or chemistry of processes into mathematical symbolism, and mathematical manipulation leads to useful equations.

The point of the derivations is the useful equation, not the derivations themselves. The derivations are included, sometimes as an appendix, to satisfy the students that the final equations are not magical, but come from the application of mathematics to physical and chemical principles that apply to the body. The point is to be able to apply the final equations. Physics, chemistry, and math at the level of calculus are used to get the equations, but generally algebra is all that is required to apply them. In my view, the derivations are important to teach students the process of encoding the physics and chemistry and deriving the relationship between variables that constitute the useful equations, but rote memorization of derivations is boring and useless.

PERFECT IS THE ENEMY OF GOOD: EQUATIONS AREN'T PERFECT, BUT THEY'RE OFTEN GOOD ENOUGH

The text does not say what I tell my students about the applicability of equations in general. I tell my students in lecture that all of these equations are wrong. They are wrong in something of the same sense that Newtonian mechanics is wrong. Relativity and quantum mechanics supplant Newtonian mechanics (even in the macroscopic world) but Newtonian mechanics will still get the rocket ship to the moon. So I tell them that these equations are theoretically wrong but they give satisfactorily correct answers, in much the same way that Newtonian mechanics still does, even though theoretically incomplete. Fick's Law of Diffusion depends on continuum mathematics for an inherently discrete process. But the discreteness is so finely divided that the distinction is unimportant.

EXAMPLES AND PROBLEM SETS ALLOW APPLICATION OF THE USEFUL EQUATIONS

There are several aids in the text to foster a quantitative and analytical understanding. First, there are some worked calculations in the text that are set apart in text boxes as Examples. These aim to show the students how to apply some of the ideas presented in the text. Second, there are a total of 17 problem sets scattered throughout the text. All units have at least one, most have two, and the cardiovascular section has three. These are meant to cover about three chapters each, so that a problem set can be assigned approximately once a week, for three lectures per week. Students have repeatedly told me that they want a solution set to the problems to see how they can do them, but this makes them useless as a graded assignment. There is no better teacher than wrestling with a problem. The second edition has expanded on these problem sets with new problems.

The problems themselves are generally meant to cover some new idea or concept that could not be, or was not, effectively covered in the text itself, and to expand on the student's understanding of the material. They are not merely busy work or "plug and chug" exercises. The alert student should not merely do the problem, but think about what the result means. In many cases, the problems are written as a sequence of questions, each of which sets up the student for further questions or insights. These illustrate the process necessary for answering a larger question, breaking it up into parts of the answer that must come first. This method aids the students in thinking about larger problems: break it down into its simpler components. Some subject matter unfortunately does not lend itself easily to such problems, but I have attempted to find problems that students can do. The students in my classes find the problems challenging. I allow them to work on them collaboratively, because they are meant to be part of the instruction and less of the evaluation, but the problem sets are graded and contribute significantly to the final grades. Of course, such policies are set at the discretion of the instructor.

LEARNING OBJECTIVES, SUMMARIES, AND REVIEW QUESTIONS GUIDE STUDENT LEARNING

The Learning Objectives are meant as a guide to the construction of examination questions, either directly or indirectly. These learning objectives are fairly broad and together they cover the breadth of physiology. This is my advice to students: read the Learning Objectives first, the chapter Summary second, and then read the text. Next, attempt to answer the Review Questions and return to the Learning Objectives. If you are mystified by any of the Review Questions or Learning Objectives, read the pertinent part of the text again.

CLINICAL APPLICATIONS PIQUE INTEREST

Pathological situations often illuminate normal physiology. Clinical Applications are scattered throughout the text. Because it takes a lot of background material to understand these clinical applications, Clinical Applications are less prevalent in the early parts of the text, which are foundational, than in the latter parts of the text. There are more than 50 such Clinical Applications, with several new additions in the second edition. The students like them because these Clinical Applications tell them that there is a reason for learning what might otherwise appear arcane.

HOW INSTRUCTORS CAN USE THIS TEXT

This text is meant for anyone with a fairly modest level of mathematical skill, at the level of the calculus with elementary differential equations. Students without this level of training will find this book too difficult. I have developed this book specifically with undergraduate Biomedical

Engineering students in mind, and have taught this material for 16 years. Each Chapter is intended to be a single lecture, and the length of the chapter is meant to be readable in a single sitting. There are 77 chapters, so it is most useful in a two-semester sequence. I cover all chapters in that time, and all problem sets. The text would also be useful for instructors with less time by adjusting the breadth and depth of coverage. Units 1, 8, and 9, (Physical and Chemical Foundations, Gastrointestinal Physiology and Endocrinology, respectively) for example, could be eliminated or covered more superficially. Unit 1 could be eliminated because it is a review, Units 8 and 9 because they are relatively peripheral to Biomedical Engineering. Unit 2, Cell Physiology, could be covered more superficially or eliminated if students previously have had Cell Biology. Alternatively, it is possible to cover the breadth of physiology if the depth is reduced. This can be done by focusing on the chapter summaries, which give a broach picture of what is happening with less detail, and combining lectures or omitting some topics. In this regard, the text is useful similarly to a cafeteria: the instructor is free to choose those sections of most interest and to downplay those of lesser interest. Some instructors may feel that knowing how to think about problems is the most important thing, and that the details of the physiology are secondary. Such an instructor may want to focus more on the appendices than on the chapter matter themselves, and more on the problems and how to solve them.

ANCILLARY MATERIALS FOR INSTRUCTORS

For instructors adopting this text for use in a course, the following ancillaries are available: Power Point lecture slides, electronic images from the text, solutions manual for the problem sets, laboratory manuals with example data, and examination questions with answers. The Power Point slides have been updated to include the new figures and more commentary as appropriate for the lectures. Please visit http://textbooks.elsevier.com/9780128008836.

HOW STUDENTS CAN USE THIS TEXT

A student's goal ought to be to learn as much physiology as possible within the constraints of available time. This text is written with considerable detail. The Learning Objectives and Review Questions set the stage for the kinds of things you should be able to do, and the kinds of questions you should be able to answer. The Chapter Summaries encapsulate each chapter in an economy of words and detail. Start with the Learning Objectives, read the Summary, and then look at the Review Questions. Then read the chapter and repeat Learning Objectives, Summary, and Review Questions. What you cannot answer at that point requires you to re-read the pertinent sections a second time.

The approach to the problem sets is different. The first job is: find a bright fellow student to work with. Second, read the question for understanding of what it is asking. Then ask yourself, what is needed to answer this question? How can you find out what is needed? If it is a physical constant, where can you find it? Do you know a relationship or equation that relates what is being asked to what is given? Write it down and rearrange it to give the desired answer. Plug and chug what is given and what else you have looked up to get a numerical answer. It is very simple in principle but sometimes very difficult in execution.

ANCILLARY MATERIALS FOR STUDENTS

Student resources available with this text include a set of online flashcards, a selection of animations based on the figures in the text, and online quizzes for self-study. Please visit http://booksite.elsevier.com/9780128008836.

STUDENT FEEDBACK

Students who have completed the course regularly tell me that it is both one of the most challenging and one of the most rewarding courses of their undergraduate career. This is generally the case: what you get out of an educational enterprise is proportionate to what you put in. Physiology is an integrative science. There is great satisfaction in understanding how a system works from the cellular and subcellular level all the way up to the organism level. Human beings do not come with an owner's manual. The idea that this text is a first approximation to an owner's manual resonates with the students.

Joseph Feher