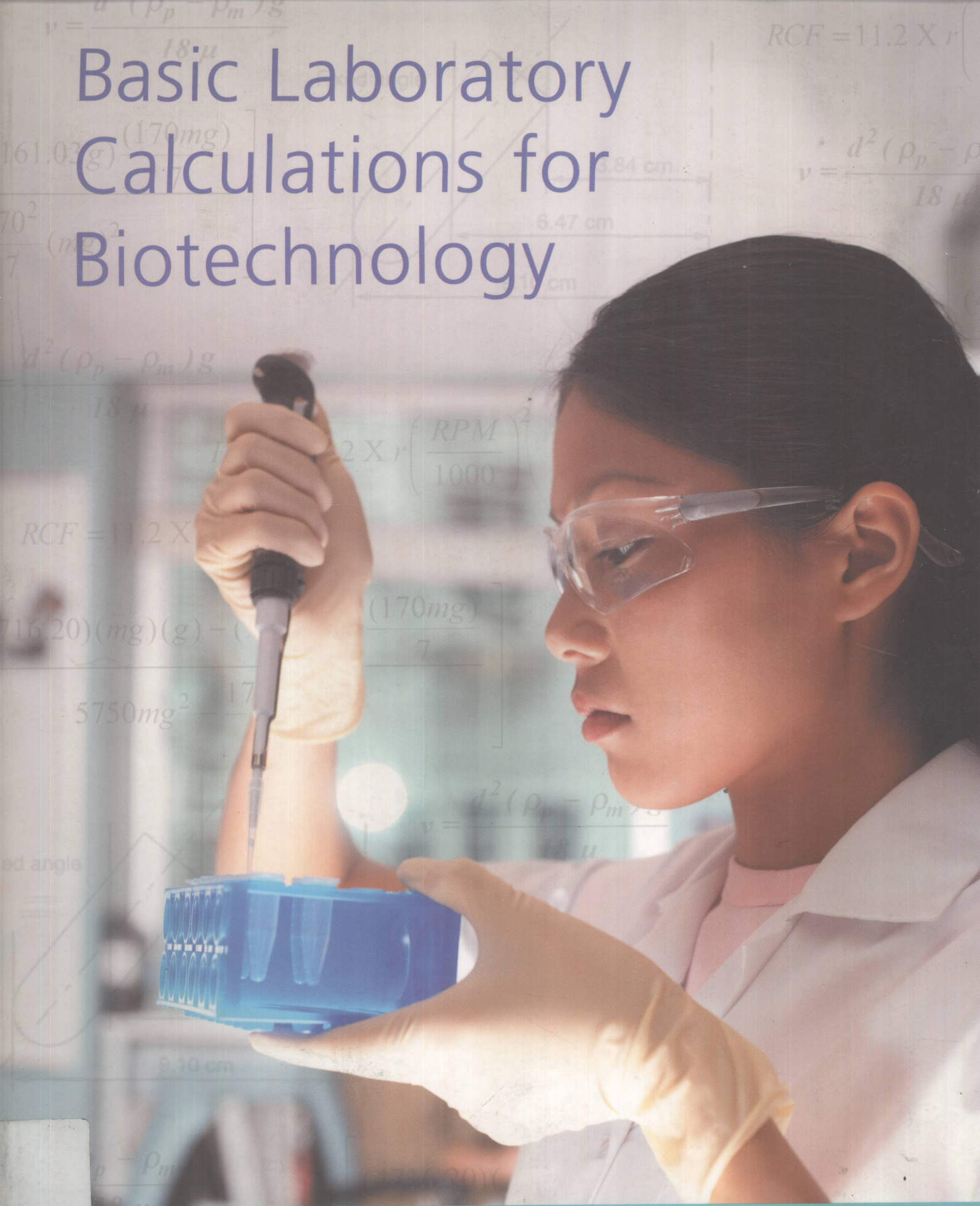
Basic Laboratory Calculations for Biotechnology



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BASIC LABORATORY CALCULATIONS FOR BIOTECHNOLOGY

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DEDICATION: For my students and my colleagues

PREFACE

This book was developed over the last 17 years as my colleagues and I have worked with beginning college students who are preparing for entry level technical positions in biotechnology companies and research laboratories. People who work in labs perform a wide variety of math calculations as part of their routine work. The math required in the biotechnology laboratory is often simple, but for the new student the situation is unfamiliar and the laboratory becomes a series of math "story" problems where no one has written down the story and where there are consequences for wrong answers.

This text and workbook is intended to provide biotechnology students with an accessible introduction to common, basic laboratory calculations. This book is not intended to replace a math textbook nor a math course. Rather, these chapters roam through various areas of math, discussing problems commonly encountered in the laboratory and providing strategies to solve those problems. The book is primarily organized around laboratory applications, beginning with more general topics and moving into more specific biotechnology laboratory techniques at the end. Unit I provides a quick review of some basic math tools that are used commonly in the laboratory. Unit II explores the many examples of proportional relationships in the biology laboratory. Units III and IV explore how data are manipulated, both graphically and using some introductory statistical methods. Unit V discusses specialized applications in the biotechnology laboratory.

Since this book was designed to be helpful to students, it includes a number of practice problems. These problems were written for beginning college biotechnology students, but they may also provide applied problems for math classes, or for high school biology/biotechnology courses. Individuals who already work in a laboratory may find certain sections helpful as a refresher and as a resource for solving common problems.

This book briefly mentions a number of laboratory techniques, such as centrifugation and spectrophotometry, to show how math calculations are applied to these applications. For more information about basic laboratory techniques, refer to: "Basic Laboratory Methods for Biotechnology: Textbook and Laboratory Reference", by Lisa A. Seidman and Cynthia J. Moore, Pearson Benjamin Cummings.

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INTRODUCTION

MATH IS A TOOL!
(IT DOESN'T MATTER WHETHER OR NOT YOU "LIKE" IT)

Math is an important tool for scientists and technicians, just as a hammer is a tool for a carpenter and a blender is a tool for a chef. Mathematical descriptions and operations permeate daily life in the laboratory work place. The purpose of this guide is to provide a brief review of common math tools used in bioscience laboratories and to introduce applications of math relevant to biotechnology laboratory work. It was written for students preparing for careers in bioscience laboratories. Although these chapters review some basic math concepts, it is assumed that readers can manipulate fractions and decimals, prepare simple graphs, solve an algebraic equation, and use a scientific calculator. It is also assumed that readers have had a beginning chemistry course and have some knowledge of chemical terminology.

Math is a Tool

The Biotechnologist

Math is Beautiful

The Mathematician

To be a skillful laboratory biologist you do not need to "like" math any more than a carpenter needs to "like" a hammer. Most carpenters are probably neither happy nor anxious when they encounter a hammer (unless they have recently smashed their finger with one). Students in the sciences, however, sometimes do have to overcome negative feelings about math. Many people believe that they are not good at math and/or have uncomfortable feelings about math. Sheila Tobias wrote a book about "math anxiety". Tobias points out that in Japan and Taiwan, people believe that hard work leads to good performance in math. In contrast in the United States, people are apt to believe that math ability leads to good performance, that one is either born with this ability or not, and that no amount of hard work can make up for the lack of math ability. Because of these beliefs, Americans may give up on math and try less hard in math classes. In reality, the ability to use math is not a genetic gift but rather is learned with practice. If you are anxious about math, remember that with practice and time people learn to perform the math required in their profession. This book provides a number of practice problems that you can use to assist you in becoming comfortable and confident performing math calculations.

THERE ARE OFTEN MANY PATHS TO THE RIGHT ANSWER

Very often there is more than one strategy to solve a math problem. In some instances this book demonstrates two ways to approach a problem. For example, Chapter 7 shows how to convert between units using both proportions and a unit canceling strategy. Both strategies, when applied correctly, will provide the correct answer. Individuals may prefer one strategy over another. (Of course, in a classroom situation students are encouraged to use strategies as directed by their instructor.) Experienced scientists and technicians often move fluidly from one problem-solving strategy to another, using whatever approach is most efficient for solving a particular problem. Experienced workers also are likely to check their answers by first using one approach to solve the problem and then testing another approach to see if it gives the same answer.

Sometimes it works to use "trial and error". Make up possible answers and see if they work in the context of the problem. There's nothing wrong with trial and error, as long as you have a way to check your solution to the problem.

A FEW TIPS

1. ***Keep track of units and record them!!!!!*** It is tempting to ignore units when performing calculations, but this practice has been the cause of much grief – see for example the story of the missing spacecraft on the next page.

2. ***Keep track of all information.*** Begin with a sheet of paper with plenty of room for each problem. Write down relevant information and record the results of each step.

3. ***Use simple sketches, flowcharts, arrows, or other visual aids to help define problems.***

4. ***Check that each answer makes sense in the context of the problem.*** For example, if you were grocery shopping and calculated that the cost per ounce for salad dressing came to $177, you would probably know something was wrong with the calculation (or that you need to find a better place to shop). Think about your answers to see that they make sense.

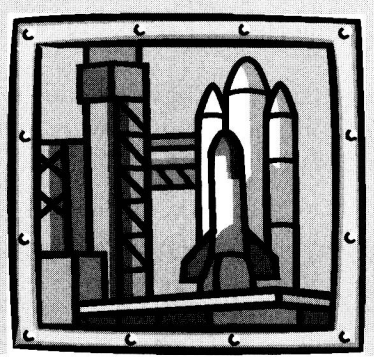
5. ***State the answer clearly; remember the units.***

6. ***Watch for being "off by a power of 10".*** It is common to misplace the decimal point or write the decimal place illegibly. These kinds of errors are easy to make, for example, by miscounting how many zeros are on your calculator's display. Such mistakes can be very serious --after all, if your bank gave you $1 when they were supposed to have given you $100, would you consider it "just a little mistake"? See also "An Infant's Death", below.

SOME TRUE STORIES

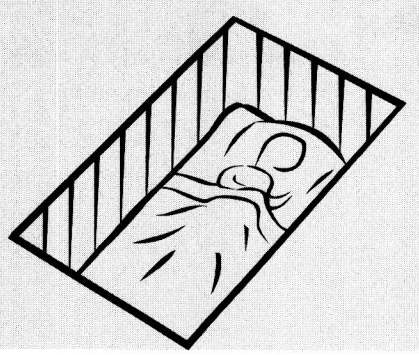
THE STORY OF THE MISSING SPACECRAFT

In 1999, NASA, the U.S. space agency, lost a 125 million dollar robotic spacecraft in a spectacular mishap that could likely have been avoided if scientists had written down the units in their calculations. The errant spacecraft dipped 100 kilometers lower than planned into the Martian atmosphere where it vanished. The problem apparently arose because of miscommunication between two teams working on the orbiter mission. One team was expressing force in metric units while the other team expressed force in units of pounds. Apparently the teams did not write down the units of their calculations and as a result the orbiter went to the wrong place and was lost. According to Marcia S. Smith, space policy analyst of the Congressional Research Service in Washington D.C., "Truly, it is just dumfounding, flabbergasting...that this could possibly happen". Always record and keep track of the units in your calculations. (Reported by R. Cowen in Science News, Volume 156, October 9, p. 229, 1999.)



AN INFANT'S DEATH

It was reported in 1998 that a pharmacist accidentally misread the infant dose of a particular drug as being 500,000 units/kg when it was really 50,000 units/kg. The nurses tending the infant did not recognize the error and administered this dose. The infant died. (Reported in ISMP Medication Safety Alert, Feb. 11, 1998, http://ismp.org/MSAarticles/latent.httml.)



SUGGESTIONS FOR FURTHER READING

"Laboratory Mathematics: Medical and Biological Applications", June and Joe Campbell, 5th edition, Mosby Co., St. Louis, 1997.

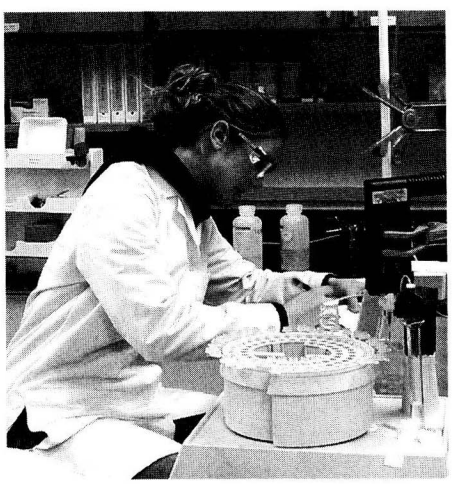
"Basic Mathematics for Beginning Chemistry", Dorothy M. Goldish, 4th edition. Macmillan Publishers, New York, 1990. (A beginning book.)

"Overcoming Math Anxiety", Sheila Tobias, W.W. Norton and Co., New York, 1993. (Does not teach math but rather talks about factors leading to success in math.)

"Lab Ref: A Handbook of Recipes, Reagents, and Other Reference Tools for Use at the Bench", Ed. Jane Roskams and Linda Rogers, Cold Spring Harbor Laboratory Press, New York, 2002. (This is not about math *per se* but it includes a wealth of reagent recipes and useful tables.)

"Lab Math: A Handbook of Measurements, Calculations, and Other Quantitative Skills for Use at the Bench", Dany Spencer Adams, Cold Spring Harbor Laboratory Press, New York, 2003.

"Calculations for Molecular Biology and Biotechnology: A Guide to Mathematics in the Laboratory", Frank H. Stephenson, Academic Press California, 2003. (Covers some specialized topics relating to molecular biology; includes examples of calculations.)



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