

# Understanding **STATISTICS**

in the Behavioral Sciences



SEVENTH EDITION

Robert R. Pagano



# Understanding Statistics in the Behavioral Sciences

EDITION

7

**Robert R. Pagano**

*University of Pittsburgh*

**THOMSON**  
  
**WADSWORTH**

Australia • Canada • Mexico • Singapore • Spain  
United Kingdom • United States

Publisher: Vicki Knight  
Assistant Editor: Jennifer Wilkinson  
Editorial Assistant: Monica Sarmiento  
Technology Project Manager: Darin Derstine  
Marketing Manager: Lori Grebe  
Marketing Assistant: Laurel Anderson  
Advertising Project Manager: Brian Chaffee  
Project Manager, Editorial Production: Paul Wells  
Print/Media Buyer: Kristine Waller  
Permissions Editor: Elizabeth Zuber

Production Service: Graphic World Publishing Services  
Text Designer: E. Kelly Shoemaker  
Copy Editor: Graphic World Publishing Services  
Illustrator: Graphic World Illustration Studio  
Cover Designer: Bill Stanton  
Cover Image: W. Perry Conway/CORBIS  
Cover Printer: Transcontinental Printing/Louisville  
Compositor: Graphic World Inc.  
Printer: Transcontinental Printing/Louisville

COPYRIGHT © 2004 Wadsworth, a division of Thomson Learning, Inc. Thomson Learning™ is a trademark used herein under license.

ALL RIGHTS RESERVED. No part of this work covered by the copyright hereon may be reproduced or used in any form or by any means—graphic, electronic, or mechanical, including but not limited to photocopying, recording, taping, Web distribution, information networks, or information storage and retrieval systems—without the written permission of the publisher.

Printed in Canada  
2 3 4 5 6 7 07 06 05 04

For more information about our products, contact us at:  
**Thomson Learning Academic Resource Center**  
**1-800-423-0563**

For permission to use material from this text,  
contact us by:

**Phone:** 1-800-730-2214 **Fax:** 1-800-730-2215  
**Web:** <http://www.thomsonrights.com>

*ExamView®* and *ExamView Pro®* are registered trademarks of FSCreations, Inc. Windows is a registered trademark of the Microsoft Corporation used herein under license. Macintosh and Power Macintosh are registered trademarks of Apple Computer, Inc. Used herein under license.

COPYRIGHT 2004 Thomson Learning, Inc. All Rights Reserved. Thomson Learning WebTutor™ is a trademark of Thomson Learning, Inc.

Library of Congress Control Number: 2003100345

Student Edition: ISBN 0-534-61767-0

Instructor's Edition: ISBN 0-534-61772-7

**Wadsworth/Thomson Learning**  
**10 Davis Drive**  
**Belmont, CA 94002-3098**  
**USA**

**Asia**  
Thomson Learning  
5 Shenton Way #01-01  
UIC Building  
Singapore 068808

**Australia/New Zealand**  
Thomson Learning  
102 Dodds Street  
Southbank, Victoria 3006  
Australia

**Canada**  
Nelson  
1120 Birchmount Road  
Toronto, Ontario M1K 5G4  
Canada

**Europe/Middle East/Africa**  
Thomson Learning  
High Holborn House  
50/51 Bedford Row  
London WC1R 4LR  
United Kingdom

**Latin America**  
Thomson Learning  
Seneca, 53  
Colonia Polanco  
11560 Mexico D.F.  
Mexico

**Spain/Portugal**  
Paraninfo  
Calle/Magallanes, 25  
28015 Madrid, Spain





## PREFACE

I have been teaching a course in introductory statistics for more than 30 years, first within the Department of Psychology at the University of Washington, and most recently within the Department of Neuroscience at the University of Pittsburgh. This textbook is the mainstay of the course. Most of my students have been psychology majors, but many have also come from biology, business, education, neuroscience, nursing, and other fields. Because most of these students do not have high aptitude for mathematics and are not well grounded in mathematical skills, I have used an informal rather than strictly mathematical approach. This approach assumes only high school algebra for background knowledge. It relies on clarity of presentation, a particularly effective sequencing of the inferential material, detailed verbal description, interesting illustrative examples, and many fully solved practice problems to help students understand the material.

My statistics course has been quite successful. Students are able to grasp the material, even the more complicated topics like “power,” and at the same time, many even enjoy learning it. Student ratings of this course have been quite high. They rate the textbook even higher, saying among other things that it is very clear; they like the touches of humor and state that it helps them to have the material presented in such great detail.

In preparing this seventh edition, I have been guided again by advice and feedback from students and professors. Again, I am very pleased that this feedback has been quite positive and that for most of the textbook the advice has been not to change anything because the text works very well. However, there is one major change, and several more minor changes made in the seventh edition that are worth noting. First, the major change—there is now a free **Companion CD-ROM** that accompanies the textbook. It contains additional fully solved practice problems (approximately two per chapter) for students who would like more guided practice; illustrative examples and practice problems that are solved on the CD using conceptual equations; and chapter-specific computer problem sets that are appropriate for solving using the student edition of SPSS software are included as well. In addition, the CD includes a complete chapter on the Mann–Whitney  $U$  test. The second change is the addition of a new section in

Chapter 15 titled “Power and the Analysis of Variance.” (This is a companion section to the section titled “Power and the  $t$  Test” in Chapter 14). It extends the discussion of power from the sign test, the  $z$  test, and the  $t$  test to the one-way ANOVA. The third change is that in the seventh edition end-of-chapter problems have been color-coded to specify areas within psychology and related fields that the problem is applied. This identification will help instructors assign problems by specific fields and also gives students an appreciation of how broadly statistics applies. Finally, three new “What Is the Truth?” sections have been added: two to Chapter 1 and one to Chapter 10.

## Textbook Rationale

This is an introductory textbook that covers both descriptive and inferential statistics. It is intended for students majoring in the behavioral sciences. For many of these students, statistics is a subject that elicits considerable anxiety and that is avoided for as long as possible. Moreover, I think it is fair to say that when the usual undergraduate course is completed, many students have not understood much of the inferential statistics material. This is partly because the material is inherently difficult and the students themselves are not proficient in mathematics. However, in my opinion, this situation also exists because most textbooks do a poor job of explaining inferential statistics to this group of students. These texts usually err in one or more of the following ways: (1) They are not clearly written; (2) they are not sufficiently detailed; (3) they present the material too mathematically; (4) they present the material at too low a level; (5) they do not give a sufficient number of fully solved problems for the student to practice on; and (6) in inferential statistics, they use an inappropriate sequence of topics, beginning with the sampling distribution of the mean.

In this and the previous six editions, I have tried to correct such deficiencies by using an informal writing style; using a clearly written, detailed, and theoretically oriented presentation that requires only high school algebra for understanding; including many interesting, fully solved practice problems that are located immediately following the relevant expository material; and using a better sequencing of the inferential material.

I believe a key to understanding inferential statistics is the material presented in the beginning inferential chapters and its sequencing. In my opinion, optimal learning of the material occurs by using the sign test as the first inference test encountered by the student and by using the following sequence of topics: random sampling and probability, binomial distribution, introduction to hypothesis testing using the sign test, power, sampling distributions (including their empirical generation), sampling distribution of the mean,  $z$  test for single samples,  $t$  test for single samples, confidence intervals,  $t$  test for correlated and independent groups, introduction to analysis of variance, multiple comparisons, two-way ANOVA, nonparametric tests, and finally, a review of all of inferential statistics.

At the heart of statistical inference lies the concept of “sampling distribution.” The first sampling distribution discussed by most texts is the sampling distribution of the mean. The problem with this approach is that the sampling distribution of the mean cannot be generated from simple probability considerations, which makes it hard for students to understand. This problem is compounded by the fact that most texts do not attempt to generate the sampling distribution of the mean in a concrete way. Rather, they define it theoretically, as a probability distribution that would result if an infinite number of random sam-

ples of size  $N$  were taken from the population and the mean of each sample were calculated. This definition is far too abstract for students, especially when this is their initial contact the *idea* of sampling distributions. *When students fail to grasp the concept of sampling distributions, they fail to grasp the rest of inferential statistics.* What appears to happen is that since students do not understand the material conceptually, they are forced to memorize the equations and to solve problems rote. Thus, students are often able to solve the problems without genuinely understanding what they are doing, all because they fail to comprehend the essence of sampling distributions.

To impart a basic understanding of sampling distributions, I believe it is far better to begin with the sign test (Chapter 10), a simple inference test for which the binomial distribution is the appropriate sampling distribution. The binomial distribution is very easy to understand, and it can be derived from the basic probability rules developed in an earlier chapter (Chapter 8, “Random Sampling and Probability”). It is entirely dependent on simple, logical considerations. Hence, students can easily follow its generation. Moreover, it can also be generated by the same empirical process that is used later in the text for generating the sampling distribution of the mean. It therefore serves as an important bridge to understanding all the sampling distributions discussed later in the textbook. Introducing hypothesis testing with the sign test has other advantages. All of the important concepts involving hypothesis testing can be illustrated; for example, null hypothesis, alternative hypothesis, alpha level, Type I and Type II errors, size of effect, and power. The sign test also provides an illustration of the before-after (repeated measures) design, which is a superior way to begin, as most students are familiar with this type of experiment and the logic of the design is quite easy to follow.

Chapter 11 discusses power. Many texts do not discuss power at all or, if they do, leave it until near the end of the book. Power is a complicated topic. Using the sign test as the vehicle for a power analysis simplifies matters. Understanding power is necessary if one is to grasp the methodology of scientific investigation itself. When students gain insight into power, they can see why we bother discussing Type II errors. Furthermore, they see for the first time why we conclude by “retaining  $H_0$ ” as a reasonable explanation of the data rather than by “accepting  $H_0$  as true” (a most important distinction). In this same vein, students also appreciate the error involved when one concludes that two conditions are equal from data that are not statistically significant. Thus, power is a topic that brings the whole hypothesis testing methodology into sharp focus.

At this state of the exposition, a diligent student can grasp the idea that data analysis basically involves two steps: (1) calculating the appropriate statistic and (2) evaluating the statistic based on its sampling distribution. The time is ripe for a formal discussion of sampling distributions and how they can be generated (Chapter 12). After this, the sampling distribution of the mean is introduced. Rather than depending on an abstract theoretical definition of the sampling distribution of the mean, the text discusses how this sampling distribution can be generated empirically. This gives a much more concrete understanding of the sampling distribution of the mean.

Due to previous experience with one easily understood sampling distribution, the binomial distribution, and using the empirical approach for the sampling distribution of the mean, most conscientious students have a good grasp of what sampling distributions are and why they are essential for inferential statistics. Since the sampling distributions underlying Student’s  $t$  test and the analysis of

variance are also explained in terms of their empirical generation, students can understand the use of these tests rather than just rotely solving problems. With this background, students can comprehend that all of the concepts of hypothesis testing are the same as we go from statistic to statistic. What varies from experiment to experiment is the statistic used and its accompanying sampling distribution. The stage is set for moving through the remaining inference tests.

Chapters 12, 13, 14, and 18 discuss, in a fairly conventional way, the  $z$  test and  $t$  test for single samples, the  $t$  test for correlated and independent groups, and nonparametric statistics. However, these chapters differ from those in other textbooks in the clarity of presentation, the number and interest value of fully solved problems, and the use of empirically derived sampling distributions. In addition, there are differences that are specific to each test. For example, (1) the  $t$  test for correlated groups is introduced directly after the  $t$  test for single samples and is developed as a special case of the  $t$  test for single samples, only this time using difference scores rather than raw scores; (2) the sign test and the  $t$  test for correlated groups are compared to illustrate the difference in power that results from using one or the other; (3) there is a discussion of the factors influencing the power of experiments using Student's  $t$  test; and (4) the correlated and independent groups designs are compared with regard to utility.

Chapters 15 and 17 deal with the analysis of variance. In these chapters, single rather than double subscript notation is deliberately used. The more complex double subscript notation serves to confuse students. In my view, the single subscript notation and resulting single summations work better for the undergraduate major in psychology and related fields because they are simpler, and for this audience, they promote understanding of this reasonably complicated material. In using single subscript notation I have followed in part the notation used by E. Minium, *Statistical Reasoning in Psychology and Education*, 2nd edition, John Wiley & Sons, New York, 1978. I am indebted to Professor Minium for this contribution.

Other features of this textbook are worth noting. Chapter 8, on probability, does not delve deeply into probability theory. This is not necessary because the proper mathematical foundation for all of the inference tests contained in this textbook can be built by the use of basic probability definitions, in conjunction with the addition and multiplication rules, as has been done in Chapter 8. Chapter 16, covering both planned and *post hoc* comparisons, contains two *post hoc* tests, the Tukey HSD test and the Newman-Keuls test. Chapter 17 is a separate chapter on two-way ANOVA for instructors wishing to cover this topic in depth. For instructors with insufficient time for in-depth handling of two-way ANOVA, at the beginning of Chapter 17, I have qualitatively described the two-way ANOVA technique, emphasizing the concepts of main effects and interactions. Chapter 19 is a review chapter that brings together all of the inference tests and provides practice in determining which test to use when analyzing data from different experimental designs and data of different levels of scaling. Students especially like the tree diagram in this chapter for helping them determine the appropriate test. Finally, at various places throughout the text, there are sections titled "What Is the Truth?" These sections show students practical applications of statistics.

Some comments about the descriptive statistics part of this book are in order. The descriptive material is written at a level that (1) serves as a foundation for the inference chapters and (2) enables students to adequately describe the data for its own sake. For the most part, material on descriptive statistics follows a traditional format, because this works well. Chapter 1 is an exception. It dis-

cusses approaches for determining truth and establishes statistics as part of scientific method, which is rather unusual for a statistics textbook.

## Seventh Edition Changes

**New Material** As mentioned earlier, because of positive feedback from users of the sixth edition, seventh edition changes are not extensive. However, there is one major change, as well as many additional more minor ones. These changes include:

- ◆ **A New, Free Companion CD-ROM.** This CD-ROM is integrated with the textbook. It contains additional fully solved practice problems (approximately two per chapter) for students who would like more guided practice. Illustrative examples and practice problems that are solved in the textbook using computational equations are also included on the CD. However, these problems are solved on the CD using conceptual instead of computational equations; they will be useful for students in classes taught by professors who prefer their students to work many problems using conceptual equations instead of, or in addition to, computational ones. The last set of problems contained on the CD are chapter-specific computer problem sets that are appropriate for solving using the student edition of SPSS software. These will be quite useful in classes that include an SPSS computer component. Finally, the CD includes a complete chapter on the Mann–Whitney *U* test for use in classes taught by professors who prefer an in depth treatment of this test to the abbreviated treatment given in Chapter 18 of the textbook.
- ◆ **Color-Coding of End-of-Chapter Problems.** End-of-chapter problems have been color-coded to identify eight areas in psychology and related fields (cognitive psychology, social psychology, developmental psychology, biological psychology, clinical psychology, industrial/organizational psychology, health psychology, education, and other). This coding should be useful in working problems by area and in helping students appreciate the broad application of statistics.
- ◆ **A New Section Titled, “Power and the Analysis of Variance” (in Chapter 15).** This section is a parallel section to “Power of the *t* Test” (in Chapter 14). It extends the coverage of power from the sign test, *z* test, and *t* test to one-way, independent groups ANOVA.
- ◆ **New or Revised End-of Chapter Questions and Problems.** More than 30 new or revised end-of-chapter questions and problems have been added to extend and update this material.
- ◆ **Qualitative Presentation of Two-Way ANOVA Moved to Chapter 17.** To unify the presentation of two-way ANOVA, the qualitative presentation of two-way ANOVA has been moved from the end of the one-way ANOVA chapter to the beginning of Chapter 17, “Introduction to Two-Way Analysis of Variance.”
- ◆ **Three New “What Is The Truth?” sections.** Two new, “What Is The Truth?” sections have been added to Chapter 1, and a third new “What Is The Truth?” section has been added to Chapter 10. They are titled, “Data, Data, What Are the Data?—1,” “Data, Data, What Are the Data?—2” and “Chance or Real Effect?—2,” respectively. The first new section illustrates the point that even though data are presented in a study, the conclusion of the study needs to be appropriate to the data. The second new section also involves data. However, this time the focus is not on, “Are there any data?”



or “Are the data adequate for the truth claims made?” but rather on “How accurate are the data”? The last new section illustrates the point that just because a result is statistically significant, it does not automatically mean that the result is a real effect. In this example, even though statistically significant, the result seems best explained on the basis of chance.

- ♦ **Wording and Formatting Changes.** Minor wording and formatting changes have been made throughout the textbook to improve clarity and interest.

**Ancillary Package** The supplements consist of:

- ♦ A **student’s study guide** that is intended for review and consolidation of the material contained in each chapter of the textbook. Each chapter of the study guide has a chapter outline, a programmed learning concept review, exercises and answers to exercises, true/false questions and answers, and an end-of-chapter self-quiz with answers. Many students have commented on the helpfulness of this study guide. (0-534-61768-9)
- ♦ An **instructor’s manual with test bank** that contains teaching advice, chapter outlines for the textbook material, test questions for each chapter, and answers to selected end-of-chapter problems contained in the textbook. The test questions for each chapter are short answer, multiple-choice, and true/false questions. The answers to the multiple-choice and true/false questions are given in bold type to the left of the question. Because of requests from instructors, I have not included answers to *all* the computational end-of-chapter problems found in the text; instead, I have omitted answers from at least one problem in each chapter. These answers are found at the end of the instructor’s manual. (0-534-61769-7)
- ♦ A free **CD-ROM** that is integrated with the textbook. It contains additional fully solved practice problems (approximately two per chapter) for students who would like more guided practice. Illustrative examples and practice problems that are solved in the textbook using computational equations are also included on the CD. However, these problems are solved on the CD using conceptual instead of computational equations; they will be useful for students in classes taught by professors who prefer their students to work many problems using conceptual equations instead of, or in addition to, computational ones. The last set of problems contained on the CD are chapter-specific computer problem sets that are appropriate for solving using the student edition of SPSS software. These will be quite useful in classes that include an SPSS computer component. Finally, the CD includes a complete chapter on the Mann–Whitney  $U$  test for use in classes taught by professors who prefer an in-depth treatment of this test to the abbreviated treatment given in Chapter 18 of the textbook. (0-534-61773-5)
- ♦ **Software:** The CD-ROM contains computer problems appropriate for solution with the student version of SPSS. I recommend “A Simple Guide to SPSS for Windows, Version 11.0,” by Kirkpatrick and Feeny, to assist the student in navigating through SPSS. It comes with or without the Student Software disk. The manual is available from Wadsworth, alone (0-534-61004-8) or bundled with a disk containing the student version of SPSS. (0-534-04875-7)
- ♦ **ExamView**, a computerized testing package for Windows or Macintosh computers that allows instructors to create, edit, store, and print exams. (0-534-61771-9)

## Acknowledgments

Many individuals have been helpful in the development and production of this edition. First I would like to acknowledge the excellent work of the Wadsworth staff. While all deserve my thanks, three individuals stand out especially. First and foremost is Vicki Knight, my editor. I want to thank her for her very high standards, her availability to me despite a very heavy workload, her developmental skills—particularly regarding the CD-ROM for this edition—and her willingness to go the extra mile to produce a high-quality product. Next, I would like to thank Brian Chaffee, Advertising Project Manager, for the wonderful work he did writing the advertising copy for this edition. The third person who deserves special thanks is Darin Derstine, Senior Technology Project Manager, who was responsible for the technical side of producing the CD-ROM. Darin was a pleasure to work with and produced a CD-ROM that I think is quite attractive and functional. The remaining Wadsworth staff that I would like to thank are as follows: Jennifer Wilkinson, Senior Assistant Editor; Monica Sarmiento, Editorial Assistant; Paul Wells, Senior Production Project Manager; Vernon Boes, Creative Director; Bill Stanton, cover designer; Beth Zuber, Permissions Editor; Lori Grebe, Marketing Manager; and Laurel Anderson, Marketing Assistant.

I am very thankful to Suzanne Kastner, Managing Editor, Graphic World Publishing Services, who made the production of the book go so smoothly.

I wish to thank the following reviewers for their valuable comments regarding past editions:

Bryan Auday, Gordon College	James Ha, University of Washington
Michael Biderman, University of Tennessee at Chattanooga	George P. Knight, Arizona State University
Michael Brown, University of Washington	Deana Liddy, University of Nebraska
Dennis Doverspike, University of Akron	Jae Myung, Ohio State University
Thomas Eissenbert, Virginia Commonwealth University	Nona Phillips, University of Washington
Penny Fidler, California State University, Long Beach	Ladonna Rush, College of Wooster
Michael Gardner, California State University, Northridge	Anna Smith, Troy State University
William Gibson, Northern Arizona University	Paul Smith, Alverno College
Roderick Gillis, University of Miami	Eva Szeli, University of Miami
Tim Goldsmith, University of New Mexico	Mary Tallent-Runnels, Texas Tech University
	Evangeline Wheeler, Towson State University
	Todd Zakrajsek, Southern Oregon State College

I am especially grateful to the reviewers of the seventh edition:

David Bennett, Simmons College	Richard Hagen, Florida State University
James Diefendorff, Louisiana State University	Steve Hall, Embry-Riddle Aeronautical University
Virginia Diehl, Western Illinois University	Le Xuan Hy, Seattle University
Jean Doerr, SUNY Fredonia	Daniel Langmeyer, University of Cincinnati (special thanks)
David Falcone, LaSalle University	Susan Nolan, Seton Hall University
James Ha, University of Washington	Erwin Segal, SUNY Buffalo

Special thanks are due to the following individuals for accuracy checking of the materials:

Eli White, Graduate Student—University of Cincinnati, who read the entire textbook manuscript and worked all problems

Anthony Simmons, CD-ROM developer, who checked the accuracy for the CD-ROM

Caroline Wood, University of Cincinnati, who checked the accuracy for the Study Guide

I am grateful to the Literary Executor of the Late Sir Ronald A. Fisher, F.R.S.; to Dr. Frank Yates, F.R.S.; and to the Longman Group Ltd., London, for permission to reprint Tables III, IV, and VII from their book *Statistical Tables for Biological, Agricultural and Medical Research* (sixth edition, 1974).

The material covered in this textbook, CD-ROM, study guide, and instructor's manual is appropriate for undergraduate students with a major in psychology or related behavioral science discipline. I believe the approach I have followed helps considerably to impart this subject matter with understanding. I am grateful to receive any comments that will improve the quality of these materials.

*Robert R. Pagano*



## BRIEF CONTENTS

### part one OVERVIEW 1

- 1 Statistics and Scientific Method 3

### part two DESCRIPTIVE STATISTICS 21

- 2 Basic Mathematical and Measurement Concepts 23
- 3 Frequency Distributions 38
- 4 Measures of Central Tendency and Variability 66
- 5 The Normal Curve and Standard Scores 86
- 6 Correlation 103
- 7 Linear Regression 134

### part three INFERENCE STATISTICS 159

- 8 Random Sampling and Probability 161
- 9 Binomial Distribution 197
- 10 Introduction to Hypothesis Testing Using the Sign Test 214
- 11 Power 243
- 12 Sampling Distributions, Sampling Distribution of the Mean, the Normal Deviate ( $z$ ) Test 263
- 13 Student's  $t$  Test for Single Samples 293
- 14 Student's  $t$  Test for Correlated and Independent Groups 317
- 15 Introduction to the Analysis of Variance 354
- 16 Multiple Comparisons 381
- 17 Introduction to Two-Way Analysis of Variance 395
- 18 Chi-Square and Other Nonparametric Tests 425
- 19 Review of Inferential Statistics 465





## CONTENTS

### **part one    OVERVIEW    1**

#### **CHAPTER 1    Statistics and Scientific Method    3**

Introduction    3

Methods of Knowing    4

Definitions    6

    An Overall Example: Mode of Presentation and Retention    7

Scientific Research and Statistics    9

Random Sampling    9

Descriptive and Inferential Statistics    10

Using Computers in Statistics    10

Statistics and the “Real World”    11

WHAT IS THE TRUTH? Data, Data, Where Are the Data?    12

WHAT IS THE TRUTH? Authorities Are Nice, But . . .    13

WHAT IS THE TRUTH? Data, Data, What Are the Data?—1    14

WHAT IS THE TRUTH? Data, Data, What Are the Data?—2    15

Summary    17

Important Terms    17

Questions and Problems    17

Web Connection    20

### **part two    DESCRIPTIVE STATISTICS    21**

#### **CHAPTER 2    Basic Mathematical and Measurement Concepts    23**

Study Hints for the Student    23

Mathematical Notation    24

Summation    25

Measurement Scales: Nominal, Ordinal, Interval, and Ratio Scales	27
Nominal Scales	27
Ordinal Scales	28
Interval Scales	29
Ratio Scales	29
Measurement Scales in the Behavioral Sciences	31
Continuous and Discrete Variables	31
Real Limits of a Continuous Variable	32
Significant Figures	33
Rounding	34
Summary	35
Important Terms	35
Questions and Problems	35
Notes	36
Web Connection	37

### **CHAPTER 3    Frequency Distributions    38**

Introduction: Ungrouped Frequency Distributions	38
Grouping Scores	40
Constructing a Frequency Distribution of Grouped Scores	41
Relative Frequency, Cumulative Frequency, and Cumulative Percentage Distributions	45
Percentiles	46
Computation of Percentile Points	47
Percentile Rank	50
Computation of Percentile Rank	50
Graphing Frequency Distributions	53
The Bar Graph	53
The Histogram	55
The Frequency Polygon	56
The Cumulative Percentage Curve	56
Shapes of Frequency Curves	57
Exploratory Data Analysis	58
Stem and Leaf Diagrams	58
WHAT IS THE TRUTH? Stretch the Scale, Change the Tale	60
Summary	62
Important Terms	62
Questions and Problems	62
Web Connection	65

### **CHAPTER 4    Measures of Central Tendency and Variability    66**

Introduction	66
Measures of Central Tendency: Arithmetic Mean, Median, and Mode	67
The Arithmetic Mean	67

The Overall Mean	70
The Median	72
The Mode	74
Measures of Central Tendency and Symmetry	75
Measures of Variability: Range, Standard Deviation, and Variance	76
The Range	76
The Standard Deviation	76
The Variance	82
Summary	82
Important Terms	82
Questions and Problems	82
Notes	85
Web Connection	85

## **CHAPTER 5    The Normal Curve and Standard Scores    86**

Introduction	86
The Normal Curve	87
Area Contained Under the Normal Curve	88
Standard Scores ( $z$ Scores)	88
Characteristics of $z$ Scores	91
Finding Areas Corresponding to Any Raw Score	92
Finding the Raw Score Corresponding to a Given Area	97
Summary	100
Important Terms	100
Questions and Problems	100
Web Connection	102

## **CHAPTER 6    Correlation    103**

Introduction	103
Relationships	104
Linear Relationships	104
Positive and Negative Relationships	107
Perfect and Imperfect Relationships	108
Correlation	111
The Linear Correlation Coefficient Pearson $r$	112
Other Correlation Coefficients	120
Effect of Range on Correlation	124
Effect of Extreme Score	125
Correlation Does Not Imply Causation	125
WHAT IS THE TRUTH? "Good Principal = Good Elementary School," or Does It?	126
Summary	127
Important Terms	128
Questions and Problems	128
Web Connection	133

**CHAPTER 7 Linear Regression 134**

- Introduction 134
- Prediction and Imperfect Relationships 135
- Constructing the Least-Squares Regression Line:
  - Regression of  $Y$  on  $X$  137
  - Regression of  $X$  on  $Y$  143
- Measuring Prediction Errors: The Standard Error of Estimate 146
- Considerations in Using Linear Regression for Prediction 149
- Relation Between Regression Constants and Pearson  $r$  150
- Multiple Regression and Multiple Correlation 151
- Summary 155
- Important Terms 156
- Questions and Problems 156
- Web Connection 158

**part three INFERENCE STATISTICS 159****CHAPTER 8 Random Sampling and Probability 161**

- Introduction 161
- Random Sampling 162
  - Techniques for Random Sampling 164
  - Sampling With or Without Replacement 165
- Probability 166
  - Some Basic Points Concerning Probability Values 167
  - Computing Probability 167
  - The Addition Rule 168
  - The Multiplication Rule 173
  - Multiplication and Addition Rules 183
  - Probability and Normally Distributed Continuous Variables 186
- WHAT IS THE TRUTH? "Not Guilty, I'm a Victim of Coincidence":
  - Gutsy Plea or Truth? 189
- WHAT IS THE TRUTH? Sperm Count Decline—Male or
  - Sampling Inadequacy? 190
- WHAT IS THE TRUTH? A Sample of a Sample 191
- Summary 193
- Important Terms 193
- Questions and Problems 193
- Notes 196
- Web Connection 196

**CHAPTER 9 Binomial Distribution 197**

- Introduction 197
- Definition and Illustration of the Binomial Distribution 197



	Generating the Binomial Distribution from the Binomial Expansion	200
	Using the Binomial Table	202
	Summary	211
	Important Terms	211
	Questions and Problems	211
	Notes	213
	Web Connection	213
<b>CHAPTER 10</b>	<b>Introduction to Hypothesis Testing Using the Sign Test</b>	<b>214</b>
	Introduction	214
	An Experiment: Marijuana and the Treatment of AIDS Patients	215
	Repeated Measures Design	217
	Alternative Hypothesis ( $H_1$ )	218
	Null Hypothesis ( $H_0$ )	218
	Decision Rule ( $\alpha$ Level)	218
	Evaluating the Marijuana Experiment Using the Binomial Distribution	219
	Type I and Type II Errors	220
	Alpha Level and the Decision Process	221
	Evaluating the Tail of the Distribution	223
	One- and Two-Tailed Probability Evaluations	225
	Size of Effect: Significant Versus Important	232
	WHAT IS THE TRUTH? Chance or Real Effect—1?	232
	WHAT IS THE TRUTH? Chance or Real Effect—2?	234
	WHAT IS THE TRUTH? "No Product Is Better Than Our Product"	235
	WHAT IS THE TRUTH? Anecdotal Reports Versus Systematic Research	236
	Summary	238
	Important Terms	239
	Questions and Problems	239
	Notes	242
	Web Connection	242
<b>CHAPTER 11</b>	<b>Power</b>	<b>243</b>
	Introduction	243
	What Is Power?	244
	$P_{\text{null}}$ and $P_{\text{real}}$	244
	$P_{\text{real}}$ : A Measure of the Size and Direction of the Real Effect	245
	Power Analysis of the AIDS Experiment	246
	Effect of $N$ and Size of Real Effect	247
	Power and Beta ( $\beta$ )	251
	Power and Alpha ( $\alpha$ )	252
	Alpha-Beta and Reality	253
	Interpreting Nonsignificant Results	253
	Calculation of Power	254