JAMES McCLAVE | TERRY SINCICH

A FIRST COURSE IN

STATISTICS

TWELFTH EDITION

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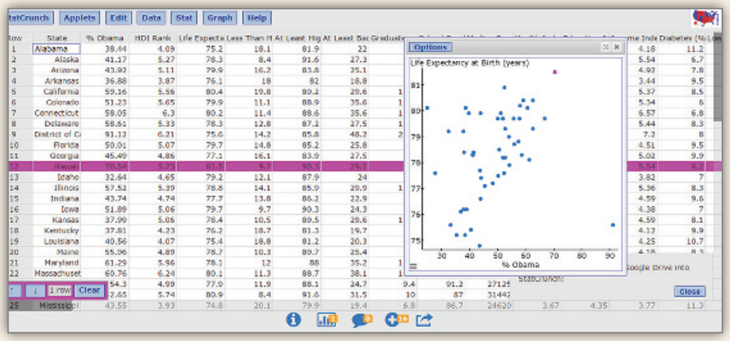

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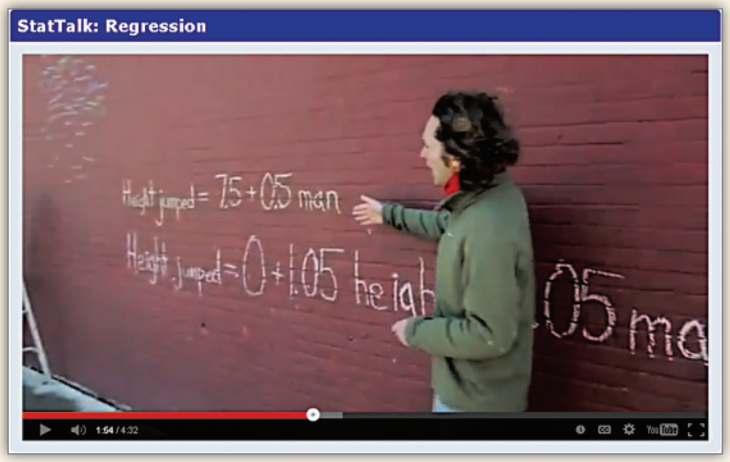

APPLET CORRELATION

Applet	Concept Illustrated	Description	Applet Activity
Sample from a population	Assesses how well a sample represents the population and the role that sample size plays in the process.	Produces random sample from population from specified sample size and population distribution shape. Reports mean, median, and standard deviation; applet creates plot of sample.	**4.4**, 192; **4.6**, 207
Sampling distributions	Compares means and standard deviations of distributions; assesses effect of sample size; illustrates undbiasedness.	Simulates repeatedly choosing samples of a fixed size *n* from a population with specified sample size, number of samples, and shape of population distribution. Applet reports means, medians, and standard deviations; creates plots for both.	**4.7**, 236; **4.8**, 236
Random numbers	Uses a random number generator to determine the experimental units to be included in a sample.	Generates random numbers from a range of integers specified by the user.	**1.1**, 19; **1.2**, 20; **3.6**, 159; **4.1**, 178
Long-run probability demonstrations illustrate the concept that theoretical probabilities are long-run experimental probabilities.			
Simulating probability of rolling a 6	Investigates relationship between theoretical and experimental probabilities of rolling 6 as number of die rolls increases.	Reports and creates frequency histogram for each outcome of each simulated roll of a fair die. Students specify number of rolls; applet calculates and plots proportion of 6s.	**3.1**, 127; **3.3**, 138; **3.4**, 139; **3.5**, 153
Simulating probability of rolling a 3 or 4	Investigates relationship between theoretical and experimental probabilities of rolling 3 or 4 as number of die rolls increases.	Reports outcome of each simulated roll of a fair die; creates frequency histogram for outcomes. Students specify number of rolls; applet calculates and plots proportion of 3s and 4s.	**3.3**, 138; **3.4**, 139
Simulating the probability of heads: fair coin	Investigates relationship between theoretical and experimental probabilities of getting heads as number of fair coin flips increases.	Reports outcome of each fair coin flip and creates a bar graph for outcomes. Students specify number of flips; applet calculates and plots proportion of heads.	**3.2**, 127; **4.2**, 179
Simulating probability of heads: unfair coin ($P(H) = .2$)	Investigates relationship between theoretical and experimental probabilities of getting heads as number of unfair coin flips increases.	Reports outcome of each flip for a coin where heads is less likely to occur than tails and creates a bar graph for outcomes. Students specify number of flips; applet calculates and plots the proportion of heads.	**4.3**, 192
Simulating probability of heads: unfair coin ($P(H) = .8$)	Investigates relationship between theoretical and experimental probabilities of getting heads as number of unfair coin flips increases.	Reports outcome of each flip for a coin where heads is more likely to occur than tails and creates a bar graph for outcomes. Students specify number of flips; applet calculates and plots the proportion of heads.	**4.3**, 192
Simulating the stock market	Theoretical probabilities are long run experimental probabilities.	Simulates stock market fluctuation. Students specify number of days; applet reports whether stock market goes up or down daily and creates a bar graph for outcomes. Calculates and plots proportion of simulated days stock market goes up.	**4.5**, 192
Mean versus median	Investigates how skewedness and outliers affect measures of central tendency.	Students visualize relationship between mean and median by adding and deleting data points; applet automatically updates mean and median.	**2.1**, 61; **2.2**, 61; **2.3**, 61

Applet	Concept Illustrated	Description	Applet Activity
Standard deviation	Investigates how distribution shape and spread affect standard deviation.	Students visualize relationship between mean and standard deviation by adding and deleting data points; applet updates mean and standard deviation.	**2.4,** 68; **2.5,** 69; **2.6,** 69; **2.7,** 91
Confidence intervals for a proportion	Not all confidence intervals contain the population proportion. Investigates the meaning of 95% and 99% confidence.	Simulates selecting 100 random samples from the population and finds the 95% and 99% confidence intervals for each. Students specify population proportion and sample size; applet plots confidence intervals and reports number and proportion containing true proportion.	**5.5,** 279; **5.6,** 280
Confidence intervals for a mean (the impact of confidence level)	Not all confidence intervals contain the population mean. Investigates the meaning of 95% and 99% confidence.	Simulates selecting 100 random samples from population; finds 95% and 99% confidence intervals for each. Students specify sample size, distribution shape, and population mean and standard deviation; applet plots confidence intervals and reports number and proportion containing true mean.	**5.1,** 261; **5.2,** 261
Confidence intervals for a mean (not knowing standard deviation)	Confidence intervals obtained using the sample standard deviation are different from those obtained using the population standard deviation. Investigates effect of not knowing the population standard deviation.	Simulates selecting 100 random samples from the population and finds the 95% z-interval and 95% t-interval for each. Students specify sample size, distribution shape, and population mean and standard deviation; applet plots confidence intervals and reports number and proportion containing true mean.	**5.3,** 271; **5.4,** 271
Hypothesis tests for a proportion	Not all tests of hypotheses lead correctly to either rejecting or failing to reject the null hypothesis. Investigates the relationship between the level of confidence and the probabilities of making Type I and Type II errors.	Simulates selecting 100 random samples from population; calculates and plots z-statistic and P-value for each. Students specify population proportion, sample size, and null and alternative hypotheses; applet reports number and proportion of times null hypothesis is rejected at 0.05 and 0.01 levels.	**6.5,** 343; **6.6,** 344
Hypothesis tests for a mean	Not all tests of hypotheses lead correctly to either rejecting or failing to reject the null hypothesis. Investigates the relationship between the level of confidence and the probabilities of making Type I and Type II errors.	Simulates selecting 100 random samples from population; calculates and plots t statistic and P-value for each. Students specify population distribution shape, mean, and standard deviation; sample size, and null and alternative hypotheses; applet reports number and proportion of times null hypothesis is rejected at both 0.05 and 0.01 levels.	**6.1,** 317; **6.2,** 327; **6.3,** 327; **6.4,** 327
Correlation by eye	Correlation coefficient measures strength of linear relationship between two variables. Teaches user how to assess strength of a linear relationship from a scattergram.	Computes correlation coefficient r for a set of bivariate data plotted on a scattergram. Students add or delete points and guess value of r; applet compares guess to calculated value.	**9.2,** 539
Regression by eye	The least squares regression line has a smaller SSE than any other line that might approximate a set of bivariate data. Teaches students how to approximate the location of a regression line on a scattergram.	Computes least squares regression line for a set of bivariate data plotted on a scattergram. Students add or delete points and guess location of regression line by manipulating a line provided on the scattergram; applet plots least squares line and displays the equations and the SSEs for both lines.	**9.1,** 512

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STATISTICS

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TWELFTH EDITION

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Preface

A First Course in Statistics, 12^{th} edition, is an introductory text designed for one-semester courses that emphasizes inference and sound decision-making through extensive coverage of data collection and analysis. As in earlier editions, the 12th edition text stresses the development of statistical thinking, the assessment of credibility, and value of the inferences made from data, both by those who consume and those who produce them. It assumes a mathematical background of basic algebra.

The text incorporates the following features, developed from the American Statistical Association's (ASA) Guidelines for Assessment and Instruction in Statistics Education (GAISE) Project:

- Emphasize statistical literacy and develop statistical thinking
- Use real data in applications
- Use technology for developing conceptual understanding and analyzing data
- Foster active learning in the classroom
- Stress conceptual understanding rather than mere knowledge of procedures
- Emphasize intuitive concepts of probability

New in the 12th Edition

- **Over 1,000 exercises, with revisions and updates to 30%.** Many new and updated exercises, based on contemporary studies and real data, have been added. Most of these exercises foster and promote critical thinking skills.
- **Updated technology.** All printouts from statistical software (SAS, SPSS, MINITAB, and the TI-83/TI-84 Plus Graphing Calculator) and corresponding instructions for use have been revised to reflect the latest versions of the software.
- **New Statistics in Action Cases.** Almost half of the 9 Statistics in Action cases are new or updated, each based on real data from a recent study.
- **Continued emphasis on Ethics.** Where appropriate, boxes have been added emphasizing the importance of ethical behavior when collecting, analyzing, and interpreting data with statistics.

Content-Specific Changes to This Edition

- **Chapter 1 (Statistics, Data, and Statistical Thinking).** Material on all basic sampling concepts (e.g., random sampling and sample survey designs) has been streamlined and moved to Section 1.5 (Collecting Data: Sampling and Related Issues).
- **Chapter 2 (Methods for Describing Sets of Data).** The section on summation notation has been moved to the appendix (Appendix A). Also, recent examples of misleading graphics have been added to Section 2.10 (Distorting the Truth with Descriptive Statistics).
- **Chapter 4 (Random Variables and Probability Distributions).** Use of technology for computing probabilities of random variables with known probability distributions (e.g., binomial and normal distributions) has been incorporated into the relevant sections of this chapter. This reduces the use of tables of probabilities for these distributions.
- **Chapter 6 (Tests of Hypothesis).** The section on *p*-values in hypothesis testing (Section 6.3) has been moved up to emphasize the importance of their use in real-life studies. Throughout the remainder of the text, conclusions from a test of hypothesis are based on *p*-values.

Hallmark Strengths

We have maintained or strengthened the pedagogical features of *A First Course in Statistics* that make it unique among introductory statistics texts. These features, which assist the student in achieving an overview of statistics and an understanding of its relevance in both the business world and everyday life, are as follows:

- **Use of Examples as a Teaching Device**—Almost all new ideas are introduced and illustrated by data-based applications and examples. We believe that students better understand definitions, generalizations, and theoretical concepts *after* seeing an application. All examples have three components: (1) "Problem", (2) "Solution", and (3) "Look Back" (or "Look Ahead"). This step-by-step process provides students with a defined structure by which to approach problems and enhances their problem-solving skills. The "Look Back" feature often gives helpful hints to solving the problem and/or provides a further reflection or insight into the concept or procedure that is covered.
- **Now Work**—A "Now Work" exercise suggestion follows each example. The Now Work exercise (marked with the icon NW in the exercise sets) is similar in style and concept to the text example. This provides the student with an opportunity to immediately test and confirm their understanding.
- **Statistics in Action**—Each chapter begins with a case study based on an actual contemporary, controversial or high-profile issue. Relevant research questions and data from the study are presented and the proper analysis demonstrated in short "Statistics in Action Revisited" sections throughout the chapter. These motivate students to critically evaluate the findings and think through the statistical issues involved.
- **Applet Exercises**—The text is accompanied by applets (short computer programs) available at www.pearsonhighered.com/mathstatsresources and within MyStatLab. These point-and-click applets allow students to easily run simulations that visually demonstrate some of the more difficult statistical concepts (e.g., sampling distributions and confidence intervals.) Each chapter contains several optional applet exercises in the exercise sets. They are denoted with the following icon: D
- **Real Data-Based Exercises**—The text includes more than 1,000 exercises based on applications in a variety of disciplines and research areas. All the applied exercises employ the use of current real data extracted from a current publications (e.g., newspapers, magazines, current journals, and the Internet). Some students have difficulty learning the mechanics of statistical techniques when all problems are couched in terms of realistic applications. For this reason, all exercise sections are divided into four parts:

  Learning the Mechanics. Designed as straightforward applications of new concepts, these exercises allow students to test their ability to comprehend a mathematical concept or a definition.

  Applying the Concepts—Basic. Based on applications taken from a wide variety of journals, newspapers, and other sources, these short exercises help students begin developing the skills necessary to diagnose and analyze real-world problems.

  Applying the Concepts—Intermediate. Based on more detailed real-world applications, these exercises require students to apply their knowledge of the technique presented in the section.

  Applying the Concepts—Advanced. These more difficult real-data exercises require students to use their critical thinking skills.
- **Critical Thinking Challenges—**Placed at the end of the "Supplementary Exercises" section only, students are asked to apply their critical thinking skills to solve one or two challenging real-life problems. These exercises expose students to real-world problems with solutions that are derived from careful, logical thought and selection of the appropriate statistical analysis tool.

- **Exploring Data with Statistical Computer Software and the Graphing Calculator**—Each statistical analysis method presented is demonstrated using output from three leading Windows-based statistical software packages: SAS, SPSS, and MINITAB. Students are exposed early and often to computer printouts they will encounter in today's hi-tech world.
- **"Using Technology" Tutorials**—MINITAB software tutorials appear at the end of each chapter and include point-and-click instructions (with screen shots). These tutorials are easily located and show students how to best use and maximize MINITAB statistical software. In addition, output and keystroke instructions for the TI-84 Graphing Calculator are presented.
- **Profiles of Statisticians in History (Biography)**—Brief descriptions of famous statisticians and their achievements are presented in side boxes. With these profiles, students will develop an appreciation of the statistician's efforts and the discipline of statistics as a whole.
- **Data and Applets**—The Web site www.pearsonhighered.com/mathstatsresources has files for all the data sets marked with the dataset icon D in the text .These include data sets for text examples, exercises, Statistics in Action and Real-World cases. All data files are saved in three different formats: SAS, MINITAB, and SPSS. This site also contains the applets that are used to illustrate statistical concepts.

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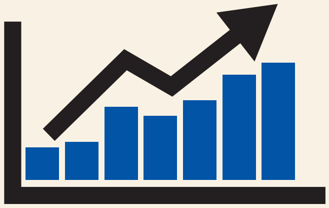

MyStatLab is the world's leading online resource for teaching and learning statistics. MyStatLab helps students and instructors improve results, and provides engaging experiences and personalized learning for each student so learning can happen in any environment. Plus, it offers flexible and time-saving course management features to allow instructors to easily manage their classes while remaining in complete control, regardless of course format.

Personalized Support for Students

- MyStatLab comes with many learning resources–eText, animations, videos, and more–all designed to support your students as they progress through their course.

- The Adaptive Study Plan acts as a personal tutor, updating in real time based on student performance to provide personalized recommendations on what to work on next. With the new Companion Study Plan assignments, instructors can now assign the Study Plan as a prerequisite to a test or quiz, helping to guide students through concepts they need to master.

- Personalized Homework allows instructors to create homework assignments tailored to each student's specific needs, focused on just the topics they have not yet mastered.

Used by nearly 4 million students each year, the MyStatLab and MyMathLab family of products delivers consistent, measurable gains in student learning outcomes, retention, and subsequent course success.

Resources for Success

Student Resources

Student's Solutions Manual, by Nancy Boudreau (Emeritus Associate Professor, Bowling Green State University), includes complete worked-out solutions to all odd-numbered text exercises (ISBN-13: 978-0-13-408101-4, ISBN-10: 0-13-408101-3.

Excel® Manual (download only), by Mark Dummeldinger (University of South Florida). Available for download from www.pearsonhighered.com/mathstatsresources.

Study Cards for Statistics Software. This series of study cards, available for Excel®, MINITAB, JMP®, SPSS, R, StatCrunch®, and TI-83/84 Plus Graphing Calculators, provides students with easy step-by-step guides to the most common statistics software. Visit myPearsonstore.com for more information.

Instructor Resources

Annotated Instructor's Edition contains answers to text exercises. Annotated marginal notes include Teaching Tips, suggested exercises to reinforce the statistical concepts discussed in the text, and short answers to exercises and examples (ISBN-13: 978-0-13-408081-9; ISBN-10: 0-13-408081-5).

Instructor's Solutions Manual (download only), by Nancy Boudreau (Emeritus Associate Professor, Bowling Green State University), includes complete worked-out solutions to all even-numbered text exercises. Careful attention has been paid to ensure that all methods of solution and notation are consistent with those used in the core text.

PowerPoint® Lecture Slides include figures and tables from the textbook. Available for download from Pearson's online catalog at www.pearsonhighered.com/irc and in MyStatLab.

TestGen® (www.pearsoned.com/testgen) enables instructors to build, edit, print, and administer tests using a computerized bank of questions developed to cover all the objectives of the text. TestGen is algorithmically based, allowing instructors to create multiple but equivalent versions of the same question or test with the click of a button. Instructors can also modify test bank questions or add new questions. The software and test bank are available for download from Pearson Education's online catalog at www.pearsonhighered.com/irc and in MyStatLab.

Online Test Bank, a test bank derived from TestGen®, is available for download from Pearson's online catalog at www.pearsonhighered.com/irc and in MyStatLab.

Technology Resources

A companion website (www.pearsonhighered.com/mathstatsresources) holds a number of support materials, including:

- **Data sets** formatted as .csv, .txt, .sas7bdat (SAS), .sav (SPSS), .mtp (minitab), .xls (Excel), and TI files
- **Applets** (short computer programs) that allow students to run simulations that visually demonstrate statistical concepts

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Applications Index

1 Statistics, Data, and Statistical Thinking

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Where We're Going

- Introduce the field of statistics (1.1)
- Demonstrate how statistics applies to real-world problems (1.2)
- Introduce the language of statistics and the key elements to any statistical problem (1.3)
- Differentiate between population and sample data (1.3)
- Differentiate between descriptive and inferential statistics (1.3)
- Identify the different types of data and data collection methods (1.4–1.5)
- Discover how critical thinking through statistics can help improve our quantitative literacy (1.6)

Statistics IN Action Social Media Network Usage—Are You Linked In?

The Pew Research Center, a nonpartisan organization funded by a Philadelphia-based charity, has conducted more than 100 surveys on Internet usage in the United States as part of the Pew Internet & American Life Project (PIALP). In a recent report titled *Social Media Update, 2013*, the PIALP examined adults' (ages 18 and up) attitudes and behavior toward online social media networks. Regarded merely as a fun, online activity for high school and college students just a few years ago, social media now exert tremendous influence over the way people around the world—of all ages—get and share information. The five social media sites investigated in this report include Facebook, Twitter, Instagram, Pinterest, and LinkedIn. The Pew Research Center contacted 1,445 Internet users via landline telephone or cell phone for the survey.

Several of the many survey questions asked are provided here as well as the survey results:

- *Social Networking:*

  When asked if they ever use an online social networking site, adults responded:

Yes	73%
No	27%

- *Facebook Usage:*

  When Facebook users were asked how often they visit the social media site, they responded:

Several times a day	40%
About once a day	24%
3–5 days a week	10%
1–2 days a week	13%
Every few weeks	6%
Less often	7%

- *Twitter Usage:*

  When asked if they ever use Twitter, adults responded:

Yes	18%
No	82%

- *Overall Social Media Usage:*

  When asked about how many of the five social networking sites they use, adults responded:

0	22%
1	36%
2	23%
3	12%
4	5%
5	2%

(Average = 1.48 sites)

In the following "Statistics in Action Revisited" sections, we discuss several key statistical concepts covered in this chapter that are relevant to the Pew Internet & American Life Project survey.

Statistics IN Action Revisited

- Identifying the Population, Sample, and Inference (p. 9)
- Identifying the Data Collection Method and Data Type (p. 16)
- Critically Assessing the Ethics of a Statistical Study (p. 18)

1.1 The Science of Statistics

What does statistics mean to you? Does it bring to mind batting averages, Gallup polls, unemployment figures, or numerical distortions of facts (lying with statistics!)? Or is it simply a college requirement you have to complete? We hope to persuade you that statistics is a meaningful, useful science whose broad scope of applications to business, government, and the physical and social sciences is almost limitless. We also want to show that statistics can lie only when they are misapplied. Finally, we wish to demonstrate the key role statistics plays in critical thinking—whether in the classroom, on the job, or in everyday life. Our objective is to leave you with the impression that the time you spend studying this subject will repay you in many ways.

The *Random House College Dictionary* defines **statistics** as "the science that deals with the collection, classification, analysis, and interpretation of information or data."

Thus, a statistician isn't just someone who calculates batting averages at baseball games or tabulates the results of a Gallup poll. Professional statisticians are trained in *statistical science*. That is, they are trained in collecting information in the form of **data**, evaluating the information, and drawing conclusions from it. Furthermore, statisticians determine what information is relevant in a given problem and whether the conclusions drawn from a study are to be trusted.

Statistics is the science of data. This involves collecting, classifying, summarizing, organizing, analyzing, presenting, and interpreting numerical and categorical information.

In the next section, you'll see several real-life examples of statistical applications that involve making decisions and drawing conclusions.

1.2 Types of Statistical Applications

"Statistics" means "numerical descriptions" to most people. Monthly housing starts, the failure rate of liver transplants, and the proportion of African-Americans who feel brutalized by local police all represent statistical descriptions of large sets of data collected on some phenomenon. (Later, in Section 1.4, we learn that not all data is numerical in nature.) Often the data are selected from some larger set of data whose characteristics we wish to estimate. We call this selection process *sampling*. For example, you might collect the ages of a sample of customers who shop for a particular product online to estimate the average age of *all* customers who shop online for the product. Then you could use your estimate to target the Web site's advertisements to the appropriate age group. Notice that statistics involves two different processes: (1) describing sets of data and (2) drawing conclusions (making estimates, decisions, predictions, etc.) about the sets of data on the basis of sampling. So, the applications of statistics can be divided into two broad areas: **descriptive statistics** and **inferential statistics**.

Descriptive statistics utilizes numerical and graphical methods to look for patterns in a data set, to summarize the information revealed in a data set, and to present that information in a convenient form.

Inferential statistics utilizes sample data to make estimates, decisions, predictions, or other generalizations about a larger set of data.

BIOGRAPHY FLORENCE NIGHTINGALE (1820–1910)

The Passionate Statistician

In Victorian England, the "Lady of the Lamp" had a mission to improve the squalid field hospital conditions of the British army during the Crimean War. Today, most historians consider Florence Nightingale to be the founder of the nursing profession. To convince members of the British Parliament of the need for supplying nursing and medical care to soldiers in the field, Nightingale compiled massive amounts of data from army files. Through a remarkable series of graphs (which included the first pie chart), she demonstrated that most of the deaths in the war either were due to illnesses contracted outside the battlefield or occurred long after battle action from wounds that went untreated. Florence Nightingale's compassion and self-sacrificing nature, coupled with her ability to collect, arrange, and present large amounts of data, led some to call her the Passionate Statistician. ■

Although we'll discuss both descriptive and inferential Statistics in the chapters that follow, the primary theme of the text is **inference**.

Let's begin by examining some studies that illustrate applications of statistics.

Study 1.1 "Best-Selling Girl Scout Cookies" (Source: *www.girlscouts.org*)

Since 1917, the Girl Scouts of America have been selling boxes of cookies. Currently, there are 12 varieties for sale: Thin Mints, Samoas, Lemonades, Tagalongs, Do-si-dos, Trefoils, Savannah Smiles, Thanks-A-Lot, Dulce de Leche, Cranberry Citrus Crisps, Chocolate Chip, and Thank U Berry Much. Each of the approximately 150 million boxes of Girl Scout cookies sold each year is classified by variety. The results are summarized in Figure 1.1. From the graph, you can clearly see that the best-selling variety is Thin Mints (25%), followed by Samoas (19%) and Tagalongs (13%). Since the figure describes the various categories of boxes of Girl Scout cookies sold, the graphic is an example of descriptive statistics.

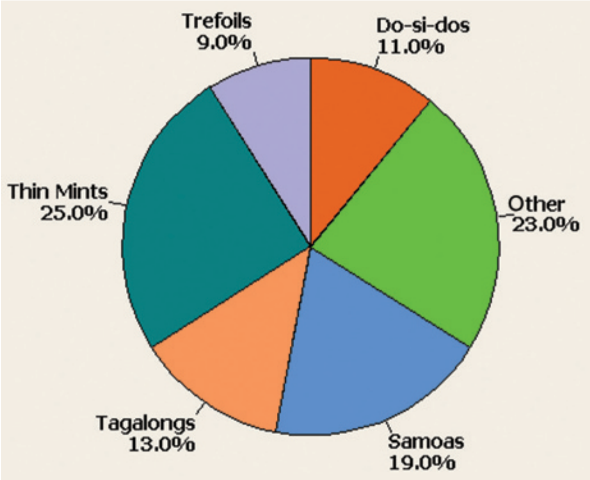

Figure 1.1
MINITAB graph of best-selling Girl Scout cookies (Based on www.girlscouts.org, 2011–12 sales.)

Study 1.2 "Are Action Video Game Players Better than Non-gamers at Complex, Divided Attention Tasks?" (Source: *Human Factors*, Vol. 56, No. 31, May 2014)

Researchers at the Universities of Illinois (Urbana-Champaign) and Central Florida conducted a study to determine whether video game players are better than non-video game players at crossing the street when presented with distractions. Each in a sample of 60 college students was classified as a video game player or a non-gamer. Participants entered a street crossing simulator and were asked to cross a busy street at an unsigned intersection. The simulator was designed to have cars traveling at various high rates of speed in both directions. During the crossing, the students also performed a memory task as a distraction. The researchers found no differences in either the street crossing performance or memory task score of video game players and non-gamers. "These results," say the researchers, "suggest that action video game players [and non-gamers] are equally susceptible to the costs of dividing attention in a complex task." Thus, inferential statistics was applied to arrive at this conclusion.

Study 1.3 "Does Rudeness Really Matter in the Workplace?" (Source: *Academy of Management Journal,* Oct. 2007)

Previous studies have established that rudeness in the workplace can lead to retaliatory and counterproductive behavior. However, there has been little research on how rude behaviors influence a victim's task performance. Consider a study where college students enrolled in a management course were randomly assigned to one of two experimental conditions: rudeness condition (45 students) and control group (53 students). Each student was asked to write down as many uses for a brick as possible in five minutes; this value (total number of uses) was used as a performance measure for each student. For those students in the rudeness condition, the facilitator displayed rudeness by berating the students in general for being irresponsible and unprofessional (due to a late-arriving confederate). No comments were made about the late-arriving confederate for students in the control group. As you might expect, the researchers discovered that the performance levels for students in the rudeness condition were generally lower than the performance levels for students in the control group; thus, they concluded that rudeness in the workplace negatively affects job performance. As in Study 1.2, this study is an example of the use of inferential statistics. The researchers used data collected on 98 college students in a simulated work environment to make an inference about the performance levels of all workers exposed to rudeness on the job.

These studies provide three real-life examples of the uses of statistics. Notice that each involves an analysis of data, either for the purpose of describing the data set (Study 1.1) or for making inferences about a data set (Studies 1.2 and 1.3).

1.3 Fundamental Elements of Statistics

Statistical methods are particularly useful for studying, analyzing, and learning about **populations** of **experimental units**.

> An **experimental** (or **observational**) **unit** is an object (e.g., person, thing, transaction, or event) about which we collect data.

> A **population** is a set of all units (usually people, objects, transactions, or events) that we are interested in studying.

For example, populations may include (1) *all* employed workers in the United States, (2) *all* registered voters in California, (3) *everyone* who is afflicted with AIDS, (4) *all* the cars produced last year by a particular assembly line, (5) the *entire* stock of spare parts available at Southwest Airlines' maintenance facility, (6) *all* sales made at the drive-in window of a McDonald's restaurant during a given year, or (7) the set of *all* accidents occurring on a particular stretch of interstate highway during a holiday period. Notice that the first three population examples (1–3) are sets (groups) of people, the next two (4–5) are sets of objects, the next (6) is a set of transactions, and the last (7) is a set of events. Notice also that *each set includes all the units in the population*.

In studying a population, we focus on one or more characteristics or properties of the units in the population. We call such characteristics **variables**. For example, we may be interested in the variables age, gender, and number of years of education of the people currently unemployed in the United States.

> A **variable** is a characteristic or property of an individual experimental (or observational) unit in the population.

The name *variable* is derived from the fact that any particular characteristic may vary among the units in a population.

In studying a particular variable, it is helpful to be able to obtain a numerical representation for it. Often, however, numerical representations are not readily available, so measurement plays an important supporting role in statistical studies. **Measurement** is the process we use to assign numbers to variables of individual population units. We might, for instance, measure the performance of the president by asking a registered voter to rate it on a scale from 1 to 10. Or we might measure the age of the U.S. workforce simply by asking each worker, "How old are you?" In other cases, measurement involves the use of instruments such as stopwatches, scales, and calipers.

If the population you wish to study is small, it is possible to measure a variable for every unit in the population. For example, if you are measuring the GPA for all incoming first-year students at your university, it is at least feasible to obtain every GPA. When we measure a variable for every unit of a population, it is called a **census** of the population. Typically, however, the populations of interest in most applications are much larger, involving perhaps many thousands, or even an infinite number, of units. Examples of large populations are those following the definition of population above, as well as all graduates of your university or college, all potential buyers of a new iPhone, and all pieces of first-class mail handled by the U.S. Post Office. For such populations, conducting a census would be prohibitively time consuming or costly. A reasonable alternative would be to select and study a *subset* (or portion) of the units in the population.

A **sample** is a subset of the units of a population.

For example, instead of polling all 145 million registered voters in the United States during a presidential election year, a pollster might select and question a sample of just 1,500 voters. (See Figure 1.2.) If he is interested in the variable "presidential preference," he would record (measure) the preference of each vote sampled.

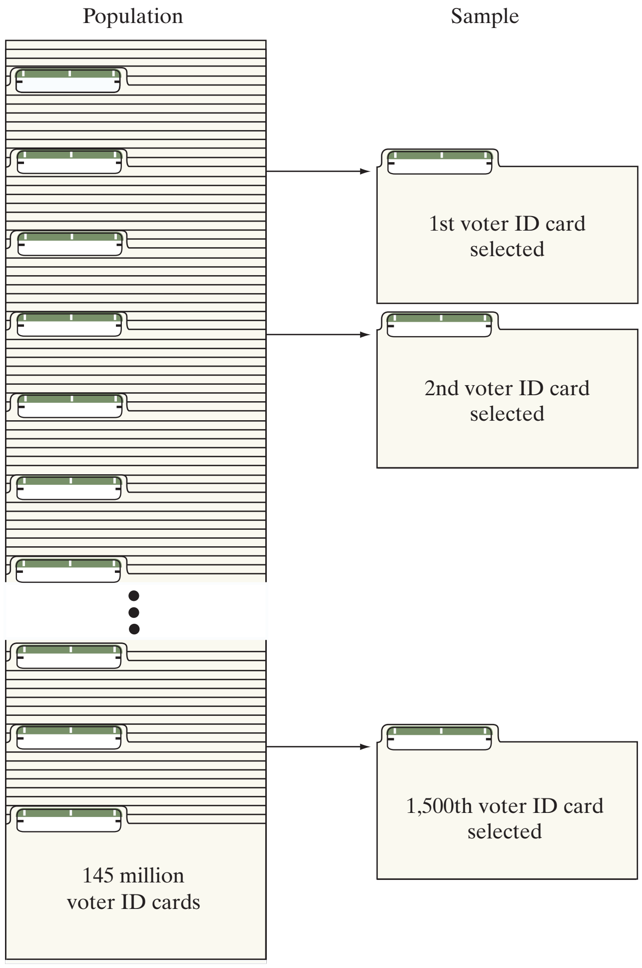

Figure 1.2
A sample of voter registration cards for all registered voters

After the variables of interest for every unit in the sample (or population) are measured, the data are analyzed, either by descriptive or inferential statistical methods. The pollster, for example, may be interested only in *describing* the voting patterns of the sample of 1,500 voters. More likely, however, he will want to use the information in the sample to make inferences about the population of all 145 million voters.

A **statistical inference** is an estimate, prediction, or some other generalization about a population based on information contained in a sample.

That is, *we use the information contained in the smaller sample to learn about the larger population.** Thus, from the sample of 1,500 voters, the pollster may estimate the percentage of all the voters who would vote for each presidential candidate if the election were held on the day the poll was conducted, or he might use the results to predict the outcome on election day.

*The terms *population* and *sample* are often used to refer to the sets of measurements themselves as well as to the units on which the measurements are made. When a single variable of interest is being measured, this usage causes little confusion. But when the terminology is ambiguous, we'll refer to the measurements as *population data sets* and *sample data sets*, respectively.

Example 1.1

Key Elements of a Statistical Problem—Ages of Broadway Ticketbuyers

Problem According to *Variety* (Jan. 10, 2014), the average age of Broadway ticketbuyers is 42.5 years. Suppose a Broadway theatre executive hypothesizes that the average age of ticketbuyers to her theatre's plays is less than 42.5 years. To test her hypothesis, she samples 200 ticketbuyers to her theatre's plays and determines the age of each.

a. Describe the population.
b. Describe the variable of interest.
c. Describe the sample.
d. Describe the inference.

Solution

a. The population is the set of all units of interest to the theatre executive, which is the set of all ticketbuyers to her theatre's plays.
b. The age (in years) of each ticketbuyer is the variable of interest.
c. The sample must be a subset of the population. In this case, it is the 200 ticketbuyers selected by the executive.
d. The inference of interest involves the *generalization* of the information contained in the sample of 200 ticketbuyers to the population of all her theatre's ticketbuyers. In particular, the executive wants to *estimate* the average age of the ticketbuyers to her theatre's plays in order to determine whether it is less than 42.5 years. She might accomplish this by calculating the average age of the sample and using that average to estimate the average age of the population.

Look Back A key to diagnosing a statistical problem is to identify the data set collected (in this example, the ages of the 200 ticketbuyers) as a population or a sample.

■ **Now Work Exercise 1.13**

Example 1.2

Key Elements of a Statistical Problem—Pepsi vs. Coca-Cola

Problem "Cola wars" is the popular term for the intense competition between Coca-Cola and Pepsi displayed in their marketing campaigns, which have featured movie and television stars, rock videos, athletic endorsements, and claims of consumer preference based on taste tests. Suppose, as part of a Pepsi marketing campaign, 1,000 cola consumers are given a blind taste test (i.e., a taste test in which the two brand names are disguised). Each consumer is asked to state a preference for brand A or brand B.

a. Describe the population.
b. Describe the variable of interest.
c. Describe the sample.
d. Describe the inference.

Solution

a. Since we are interested in the responses of cola consumers in a taste test, a cola consumer is the experimental unit. Thus, the population of interest is the collection or set of all cola consumers.
b. The characteristic that Pepsi wants to measure is the consumer's cola preference, as revealed under the conditions of a blind taste test, so *cola preference* is the variable of interest.
c. The sample is the 1,000 cola consumers selected from the population of all cola consumers.
d. The inference of interest is the *generalization* of the cola preferences of the 1,000 sampled consumers to the population of all cola consumers. In particular, the preferences of the consumers in the sample can be used to *estimate* the percentages of cola consumers who prefer each brand.

Look Back In determining whether the study is inferential or descriptive, we assess whether Pepsi is interested in the responses of only the 1,000 sampled customers (descriptive statistics) or in the responses of the entire population of consumers (inferential statistics).

■ Now Work Exercise 1.16b

The preceding definitions and examples identify four of the five elements of an inferential statistical problem: a population, one or more variables of interest, a sample, and an inference. But making the inference is only part of the story; we also need to know its **reliability**—that is, how good the inference is. The only way we can be certain that an inference about a population is correct is to include the entire population in our sample. However, because of *resource constraints* (i.e., insufficient time or money), we usually can't work with whole populations, so we base our inferences on just a portion of the population (a sample). Thus, we introduce an element of *uncertainty* into our inferences. Consequently, whenever possible, it is important to determine and report the reliability of each inference made. Reliability, then, is the fifth element of inferential statistical problems.

The **measure of reliability** that accompanies an inference separates the science of statistics from the art of fortune-telling. A palm reader, like a statistician, may examine a sample (your hand) and make inferences about the population (your life). However, unlike statistical inferences, the palm reader's inferences include no measure of reliability.

Suppose, like the theatre executive in Example 1.1, we are interested in the *error of estimation* (i.e., the difference between the average age of a population of ticketbuyers and the average age of a sample of ticketbuyers). Using statistical methods, we can determine a *bound on the estimation error*. This bound is simply a number that our estimation error (the difference between the average age of the sample and the average age of the population) is not likely to exceed. We'll see in later chapters that this bound is a measure of the uncertainty of our inference. The reliability of statistical inferences is discussed throughout this text. For now, we simply want you to realize that an inference is incomplete without a measure of its reliability.

A **measure of reliability** is a statement (usually quantitative) about the degree of uncertainty associated with a statistical inference.

Let's conclude this section with a summary of the elements of descriptive and of inferential statistical problems and an example to illustrate a measure of reliability.

Four Elements of Descriptive Statistical Problems

1. The population or sample of interest
2. One or more variables (characteristics of the population or sample units) that are to be investigated
3. Tables, graphs, or numerical summary tools
4. Identification of patterns in the data

Five Elements of Inferential Statistical Problems

1. The population of interest
2. One or more variables (characteristics of the population units) that are to be investigated
3. The sample of population units
4. The inference about the population based on information contained in the sample
5. A measure of the reliability of the inference

Example 1.3

Reliability of an Inference—Pepsi vs. Coca-Cola

Problem Refer to Example 1.2, in which the preferences of 1,000 cola consumers were indicated in a taste test. Describe how the reliability of an inference concerning the preferences of all cola consumers in the Pepsi bottler's marketing region could be measured.

Solution When the preferences of 1,000 consumers are used to estimate those of all consumers in a region, the estimate will not exactly mirror the preferences of the population. For example, if the taste test shows that 56% of the 1,000 cola consumers preferred Pepsi, it does not follow (nor is it likely) that exactly 56% of all cola drinkers in the region prefer Pepsi. Nevertheless, we can use sound statistical reasoning (which we'll explore later in the text) to ensure that the sampling procedure will generate estimates that are almost certainly within a specified limit of the true percentage of all cola consumers who prefer Pepsi. For example, such reasoning might assure us that the estimate of the preference for Pepsi is almost certainly within 5% of the preference of the population. The implication is that the actual preference for Pepsi is between 51% [i.e., $(56 - 5)\%$] and 61% [i.e., $(56 + 5)\%$]—that is, $(56 \pm 5)\%$. This interval represents a measure of the reliability of the inference.

Look Ahead The interval 56 ± 5 is called a *confidence interval*, since we are confident that the true percentage of cola consumers who prefer Pepsi in a taste test falls into the range $(51, 61)$. In Chapter 7, we learn how to assess the degree of confidence (e.g., a 90% or 95% level of confidence) in the interval. ■

Statistics IN Action Revisited — Identifying the Population, Sample, and Inference

Consider the 2013 Pew Internet & American Life Project survey on social networking. In particular, consider the survey results on the use of social networking sites like Facebook. The experimental unit for the study is an adult (the person answering the question), and the variable measured is the response ("yes" or "no") to the question.

The Pew Research Center reported that 1,445 adult Internet users participated in the study. Obviously, that number is not all of the adult Internet users in the United States. Consequently, the 1,445 responses represent a sample selected from the much larger population of all adult Internet users.

Earlier surveys found that 55% of adults used an online social networking site in 2006 and 65% in 2008. These are descriptive statistics that provide information on the popularity of social networking in past years. Since 73% of the surveyed adults in 2013 used an online social networking site, the Pew Research Center inferred that usage of social networking sites continues its upward trend, with more and more adults getting online each year. That is, the researchers used the descriptive statistics from the sample to make an inference about the current population of U.S. adults' use of social networking.

1.4 Types of Data

You have learned that statistics is the science of data and that data are obtained by measuring the values of one or more variables on the units in the sample (or population). All data (and hence the variables we measure) can be classified as one of two general types: **quantitative data** and **qualitative data**.

Quantitative data are data that are measured on a naturally occurring numerical scale.* The following are examples of quantitative data:

1. The temperature (in degrees Celsius) at which each piece in a sample of 20 pieces of heat-resistant plastic begins to melt

*Quantitative data can be subclassified as either *interval data* or *ratio data*. For ratio data, the origin (i.e., the value 0) is a meaningful number. But the origin has no meaning with interval data. Consequently, we can add and subtract interval data, but we can't multiply and divide them. Of the four quantitative data sets listed as examples, (1) and (3) are interval data while (2) and (4) are ratio data.