Contents

1	Intr	roduction	1
	1.1	The challenge of teaching introductory statistics	1
	1.2	Fitting demonstrations and examples into a course	1
	1.3	What makes a good example?	3
	1.4	Why is statistics important?	3
	1.5	The best of the best	4
	1.6	Our motivation for writing this book	4

PART I INTRODUCTORY PROBABILITY AND STATISTICS

2	Firs	t weel	k of class	11
	2.1	Guess	sing ages	11
	2.2	Wher	e are the cancers?	13
	2.3	Estim	nating a big number	14
	2.4	What	's in the news?	15
	2.5	Collec	cting data from students	17
3	Des	criptiv	ve statistics	19
	3.1	Displa	aying graphs on the blackboard	19
	3.2	Time	series	19
		3.2.1	World record times for the mile run	20
	3.3	Nume	erical variables, distributions, and histograms	20
		3.3.1	Categorical and continuous variables	20
		3.3.2	Handedness	21
		3.3.3	Soft drink consumption	22
	3.4	Nume	erical summaries	22
		3.4.1	Average soft drink consumption	22
		3.4.2	The average student	24
	3.5	Data	in more than one dimension	24
		3.5.1	Guessing exam scores	25
		3.5.2	Who opposed the Vietnam War?	27
	3.6	The n	normal distribution in one and two dimensions	28
		3.6.1	Heights of men and women	29
		3.6.2	Heights of conscripts	29
		3.6.3	Scores on two exams	29
	3.7	Linea	r transformations and linear combinations	31
		3.7.1	College admissions	31

х	CONTENTS
~	CONTENTS

		3.7.2 Social and economic indexes	31
		3.7.3 Age adjustment	32
	3.8	Logarithmic transformations	32
		3.8.1 Simple examples: amoebas, squares, and cubes	33
		3.8.2 Log-linear transformation: world population	33
		3.8.3 Log-log transformation: metabolic rates	35
4	Stat	tistical graphics	38
	4.1	Guiding principles	39
	4.2	Lecture topics	40
	4.3	Assignments	41
	4.4	1	43
	4.5	One-minute revelation	45
	4.6	Turning tables	46
5	Line	ear regression and correlation	48
	5.1	Fitting linear regressions	48
		5.1.1 Simple examples of least squares	48
		5.1.2 Tall people have higher incomes	49
		5.1.3 Logarithm of world population	51
	5.2	Correlation	53
		5.2.1 Correlations of body measurements	53
		5.2.2 Correlation and causation in observational data	54
	5.3	Regression to the mean	55
		5.3.1 Mini-quizzes	55
		5.3.2 Exam scores, heights, and the general principle	56
6	Dat	a collection	58
	6.1	Sample surveys	58
		6.1.1 Sampling from the telephone book	58
		6.1.2 First digits and Benford's law	62
		6.1.3 Wacky surveys	64
		6.1.4 An election exit poll	65
		6.1.5 Simple examples of bias	66
		6.1.6 How large is your family?	66
	6.2	Class projects in survey sampling	67
		6.2.1 The steps of the project	68
		6.2.2 Topics for student surveys	73
	6.3	How big was the crowd?	76
	6.4	Experiments	78
		6.4.1 An experiment that looks like a survey	78
		6.4.2 Randomizing the order of exam questions	81
		6.4.3 Taste tests	82
		6.4.4 Can they taste the difference?	85
	6.5	Observational studies	85
		6.5.1 The Surgeon General's report on smoking	86

			Large population studies	87
		6.5.3	Coaching for the SAT	88
7	Stat	tistica	l literacy and the news media	90
	7.1	Intro	duction	90
	7.2	Assig	nment based on instructional packets	91
	7.3	Assig	nment where students find their own articles	93
	7.4	Guide	elines for finding and evaluating sources	96
	7.5	Discu	ssion and student reactions	98
	7.6	Exam	ples of course packets	98
		7.6.1	A controlled experiment: Fluids for trauma victims	99
		7.6.2	A sample survey: 1 in 4 youths abused, survey finds	104
		7.6.3	An observational study: Monster in the crib	108
		7.6.4	A model-based analysis: Illegal aliens	112
8	Pro	babili	ty	117
	8.1		tructing probability examples	117
	8.2	Rand	om numbers via dice or handouts	117
			Random digits via dice	117
		8.2.2	Random digits via handouts	117
		8.2.3	Normal distribution	118
		8.2.4	Poisson distribution	118
	8.3		abilities of compound events	118
		8.3.1	Babies	118
		8.3.2	Real vs. fake coin flips	119
			Lotteries	121
	8.4		ability modeling	122
			Lengths of baseball World Series	122
			Voting and coalitions	124
		8.4.3	1	124
	8.5		itional probability	125
			What's the color on the other side of the card?	125
			Lie detectors and false positives	127
	8.6		can load a die but you can't bias a coin flip	128
			Demonstration using wooden dice	129
			Sporting events and quantitative literacy	131
		8.6.3	Physical explanation	132
9	Stat		l inference	134
	9.1	Weigl	hing a "random" sample	134
	9.2	From	probability to inference: totals and averages	135
		9.2.1	00	135
		9.2.2	Real-time gambler's ruin	136
	9.3		dence intervals: examples	137
		9.3.1	Biases in age guessing	137
		9.3.2	Comparing two groups	138

xii CONTENTS

		9.3.3	Land or water?	138
		9.3.4	Poll differentials: a discrete distribution	139
		9.3.5	Golf: can you putt like the pros?	140
	9.4	Confi	dence intervals: theory	140
		9.4.1	Coverage of confidence intervals	140
		9.4.2	Noncoverage of confidence intervals	142
	9.5	Hypo	thesis testing: z, t , and χ^2 tests	142
			Hypothesis tests from confidence intervals	143
			Binomial model: sampling from the phone book	144
			Hypergeometric model: taste testing	145
			Benford's law of first digits	145
			Length of baseball World Series	145
	9.6		le examples of applied inference	146
			How good is your memory?	146
			How common is your name?	147
	9.7		nced concepts of inference	148
			Shooting baskets and statistical power	148
			Do-it-yourself data dredging	148
		9.7.3	Praying for your health	149
10	Mul	tiple	regression and nonlinear models	151
	10.1	Regre	ession of income on height and sex	151
		10.1.1	Inference for regression coefficients	151
		10.1.2	2 Multiple regression	151
		10.1.3	B Regression with interactions	153
		10.1.4	Transformations	154
	10.2	Exam	a scores	155
		10.2.1	Studying the fairness of random exams	155
		10.2.2	2 Measuring the reliability of exam questions	155
	10.3		nlinear model for golf putting	156
			Looking at data	157
			2 Constructing a probability model	157
			Checking the fit of the model to the data	158
	10.4	Pytha	agoras goes linear	160
11	Lyir	ng wit	h statistics	162
	-	-	ples of misleading presentations of numbers	162
			Fabricated or meaningless numbers	162
			2 Misinformation	162
		11.1.3	Ignoring the baseline	164
		11.1.4	Arbitrary comparisons or data dredging	164
	11.2		tion bias	166
		11.2.1	Distinguishing from other sorts of bias	166
		11.2.2	2 Some examples presented as puzzles	168
		11.2.3	Avoiding over-skepticism	168
	11.3	Revie	wing the semester's material	169

	CONTENTS	xiii	
--	----------	------	--

11.3.1 Classroom discussion	169
11.3.2 Assignments: Find the lie or create the lie	171
11.4 1 in 2 marriages end in divorce?	171
11.5 Ethics and statistics	171
11.5.1 Cutting corners in a medical study	171
11.5.2 Searching for statistical significance	172
11.5.3 Controversies about randomized experiments	173
11.5.4 How important is blindness?	173
11.5.5 Use of information in statistical inferences	174

PART II PUTTING IT ALL TOGETHER

12	How	to do it	179
	12.1	Getting started	179
		12.1.1 Multitasking	179
		12.1.2 Advance planning	179
		12.1.3 Fitting an activity to your class	180
		12.1.4 Common mistakes	180
	12.2	In-class activities	183
		12.2.1 Setting up effective demonstrations	183
		12.2.2 Promoting discussion	184
		12.2.3 Getting to know the students	185
		12.2.4 Fostering group work	185
	12.3	Tricks for the large lecture	187
		Using exams to teach statistical concepts	190
	12.5	Projects	190
		12.5.1 Monitoring progress	192
		12.5.2 Organizing independent projects	198
		12.5.3 Topics for projects	201
		12.5.4 Statistical design and analysis	204
	12.6	Resources	205
		12.6.1 What's in a spaghetti box?	206
		12.6.2 Books	207
		12.6.3 Periodicals	207
		12.6.4 Web sites	208
		12.6.5 People	208
13	Stru	aturing an introductory statistics course	209
		Before the semester begins	209
		Finding time for student activities in class	210
		A detailed schedule for a semester-long course	210
		Outline for an alternative schedule of activities	218
14	Teac	ching statistics to social scientists	221
	14.1	Starting with predictions, graphs, and deterministic models	221
	14.2	Teaching style	223

xiv CONTENTS

	14.3 A case study: the sampling distribution of the sample mean14.4 Starting an applied regression course14.5 How is there time to cover all the material?	224 224 226
15	Statistics diaries15.1 Examples of student diaries15.2 Using diaries in statistics classes	$228 \\ 228 \\ 250$
16	 A course in statistical communication and graphics 16.1 Background 16.2 Plan for a 13-week course 	252 252 254
	PART III MORE ADVANCED COURSES	
17	 Decision theory and Bayesian statistics 17.1 Decision analysis 17.1.1 How many quarters are in the jar? 17.1.2 Utility of money 17.1.3 Risk aversion 17.1.4 What is the value of a life? 17.1.5 Probabilistic answers to true–false questions 17.1.6 Homework project: evaluating real-life forecasts 17.1.7 Real decision problems 17.2 Bayesian statistics 17.2.1 Where are the cancers? 17.2.2 Subjective probability intervals and calibration 17.2.3 Drawing parameters out of a hat 17.2.4 Where are the cancers? A simulation 17.2.5 Hierarchical modeling and shrinkage 	$\begin{array}{c} 277\\ 278\\ 278\\ 281\\ 283\\ 284\\ 285\\ 286\\ 287\\ 289\\ 289\\ 289\\ 290\\ 293\\ 293\\ 293\\ 294 \end{array}$
18	 Student activities in survey sampling 18.1 First week of class 18.1.1 News clippings 18.1.2 Question bias 18.1.2 Question bias 18.1.3 Class survey 18.2 Random number generation 18.2.1 What do random numbers look like? 18.2.2 Random numbers from coin flips 18.3 Estimation and confidence intervals 18.4 A visit to Clusterville 18.5 Statistical literacy and discussion topics 18.6 Projects 18.6.1 Analyzing data from a complex survey 18.6.2 Research papers on complex surveys 18.6.3 Sampling and inference in StatCity 	296 296 297 297 299 299 300 300 303 303 303 303 305 305 310 311
	18.6.4 A special topic in sampling	314

CONTENTS XV

19	Pro	blems and projects in probability	315
	19.1	Setting up a probability course as a seminar	315
	19.2	Introductory problems	316
		19.2.1 Probabilities of compound events	317
		19.2.2 Introducing the concept of expectation	318
	19.3	Challenging problems	319
	19.4	Does the Poisson distribution fit real data?	321
		Organizing student projects	322
	19.6	Examples of structured projects	322
		19.6.1 Fluctuations in coin tossing—arcsine laws	323
		19.6.2 Recurrence and transience in Markov chains	325
	19.7	Examples of unstructured projects	327
		19.7.1 Martingales	327
		19.7.2 Generating functions and branching processes	328
		19.7.3 Limit distributions of Markov chains	328
		19.7.4 Permutations	329
	19.8	Research papers as projects	330
20	Dire	ected projects in a mathematical statistics course	332
		Organization of a case study	333
	20.2	Fitting the cases into a course	333
		20.2.1 Covering the cases in lectures	334
		20.2.2 Group work in class	334
		20.2.3 Cases as reports	335
		20.2.4 Independent projects in a seminar course	335
	20.3	A case study: quality control	336
	20.4	A directed project: helicopter design	337
		20.4.1 General instructions	337
		20.4.2 Designing the study and fitting a response surface	339
21	Stat	istical thinking in a data science course	342
	21.1	Goals	343
		21.1.1 Statistical thinking in a computational context	343
		21.1.2 Core paradigms	343
		21.1.3 Learn how to learn new technologies	344
		21.1.4 Connect to real modern problems	344
	21.2	Topics	344
		21.2.1 Language basics	345
		21.2.2 Graphics	345
		21.2.3 Data structures	346
		21.2.4 Programming concepts	346
		21.2.5 Text manipulation	347
		21.2.6 Information technologies	348
		21.2.7 Statistical methods	349
		Projects and student work	350
	21.4	Copy the master	350

xvi CONTENTS

21.5 Spam filtering assignment	354
21.6 Interactive visualization assignment	357
Notes	361
References	375
Author Index	387
Subject Index	392