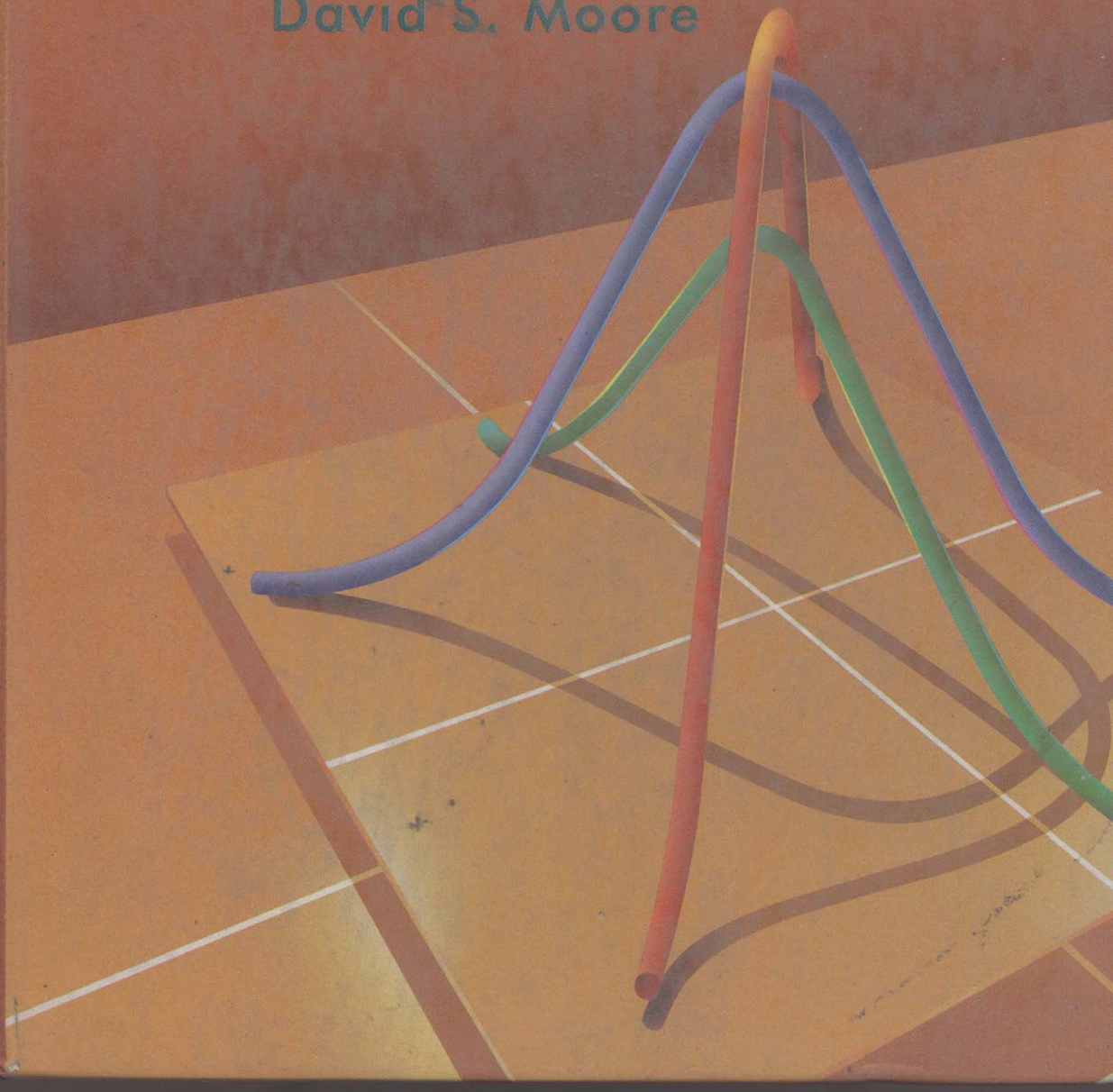
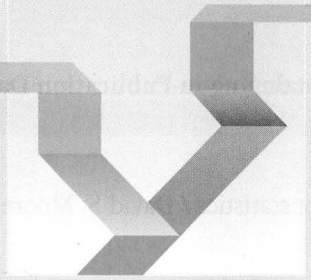
The BASIC PRACTICE of STATISTICS

David S. Moore





THE BASIC PRACTICE OF STATISTICS

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140	12975	13258	13048	45144	72321	81940	00360	02428
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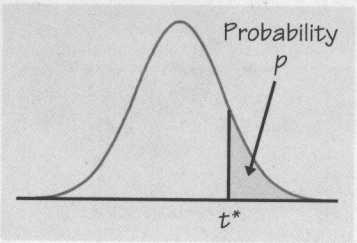

Table entry for p and C is the critical value t^* with probability p lying to its right and probability C lying between $-t^*$ and t^*.

TABLE C t distribution critical values

	Upper tail probability p											
df	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001	.0005
1	1.000	1.376	1.963	3.078	6.314	12.71	15.89	31.82	63.66	127.3	318.3	636.6
2	0.816	1.061	1.386	1.886	2.920	4.303	4.849	6.965	9.925	14.09	22.33	31.60
3	0.765	0.978	1.250	1.638	2.353	3.182	3.482	4.541	5.841	7.453	10.21	12.92
4	0.741	0.941	1.190	1.533	2.132	2.776	2.999	3.747	4.604	5.598	7.173	8.610
5	0.727	0.920	1.156	1.476	2.015	2.571	2.757	3.365	4.032	4.773	5.893	6.869
6	0.718	0.906	1.134	1.440	1.943	2.447	2.612	3.143	3.707	4.317	5.208	5.959
7	0.711	0.896	1.119	1.415	1.895	2.365	2.517	2.998	3.499	4.029	4.785	5.408
8	0.706	0.889	1.108	1.397	1.860	2.306	2.449	2.896	3.355	3.833	4.501	5.041
9	0.703	0.883	1.100	1.383	1.833	2.262	2.398	2.821	3.250	3.690	4.297	4.781
10	0.700	0.879	1.093	1.372	1.812	2.228	2.359	2.764	3.169	3.581	4.144	4.587
11	0.697	0.876	1.088	1.363	1.796	2.201	2.328	2.718	3.106	3.497	4.025	4.437
12	0.695	0.873	1.083	1.356	1.782	2.179	2.303	2.681	3.055	3.428	3.930	4.318
13	0.694	0.870	1.079	1.350	1.771	2.160	2.282	2.650	3.012	3.372	3.852	4.221
14	0.692	0.868	1.076	1.345	1.761	2.145	2.264	2.624	2.977	3.326	3.787	4.140
15	0.691	0.866	1.074	1.341	1.753	2.131	2.249	2.602	2.947	3.286	3.733	4.073
16	0.690	0.865	1.071	1.337	1.746	2.120	2.235	2.583	2.921	3.252	3.686	4.015
17	0.689	0.863	1.069	1.333	1.740	2.110	2.224	2.567	2.898	3.222	3.646	3.965
18	0.688	0.862	1.067	1.330	1.734	2.101	2.214	2.552	2.878	3.197	3.611	3.922
19	0.688	0.861	1.066	1.328	1.729	2.093	2.205	2.539	2.861	3.174	3.579	3.883
20	0.687	0.860	1.064	1.325	1.725	2.086	2.197	2.528	2.845	3.153	3.552	3.850
21	0.686	0.859	1.063	1.323	1.721	2.080	2.189	2.518	2.831	3.135	3.527	3.819
22	0.686	0.858	1.061	1.321	1.717	2.074	2.183	2.508	2.819	3.119	3.505	3.792
23	0.685	0.858	1.060	1.319	1.714	2.069	2.177	2.500	2.807	3.104	3.485	3.768
24	0.685	0.857	1.059	1.318	1.711	2.064	2.172	2.492	2.797	3.091	3.467	3.745
25	0.684	0.856	1.058	1.316	1.708	2.060	2.167	2.485	2.787	3.078	3.450	3.725
26	0.684	0.856	1.058	1.315	1.706	2.056	2.162	2.479	2.779	3.067	3.435	3.707
27	0.684	0.855	1.057	1.314	1.703	2.052	2.158	2.473	2.771	3.057	3.421	3.690
28	0.683	0.855	1.056	1.313	1.701	2.048	2.154	2.467	2.763	3.047	3.408	3.674
29	0.683	0.854	1.055	1.311	1.699	2.045	2.150	2.462	2.756	3.038	3.396	3.659
30	0.683	0.854	1.055	1.310	1.697	2.042	2.147	2.457	2.750	3.030	3.385	3.646
40	0.681	0.851	1.050	1.303	1.684	2.021	2.123	2.423	2.704	2.971	3.307	3.551
50	0.679	0.849	1.047	1.299	1.676	2.009	2.109	2.403	2.678	2.937	3.261	3.496
60	0.679	0.848	1.045	1.296	1.671	2.000	2.099	2.390	2.660	2.915	3.232	3.460
80	0.678	0.846	1.043	1.292	1.664	1.990	2.088	2.374	2.639	2.887	3.195	3.416
100	0.677	0.845	1.042	1.290	1.660	1.984	2.081	2.364	2.626	2.871	3.174	3.390
1000	0.675	0.842	1.037	1.282	1.646	1.962	2.056	2.330	2.581	2.813	3.098	3.300
z^*	0.674	0.841	1.036	1.282	1.645	1.960	2.054	2.326	2.576	2.807	3.091	3.291
	50%	60%	70%	80%	90%	95%	96%	98%	99%	99.5%	99.8%	99.9%
	Confidence level C											

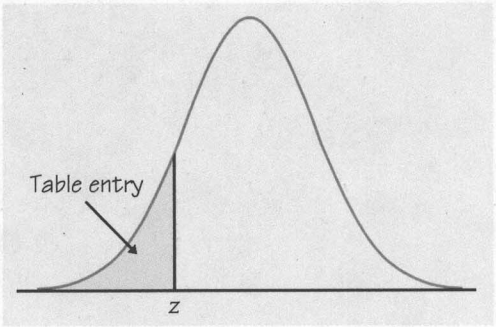

Table entry for z is the area under the standard normal curve to the left of z.

TABLE A Standard normal probabilities

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
−3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
−3.3	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
−3.2	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
−3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
−3.0	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
−2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
−2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
−2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
−2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
−2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
−2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
−2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
−2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
−2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
−2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
−1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
−1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
−1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
−1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
−1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
−1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
−1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
−1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
−1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
−1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
−0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
−0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
−0.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
−0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
−0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
−0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
−0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
−0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
−0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
−0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641

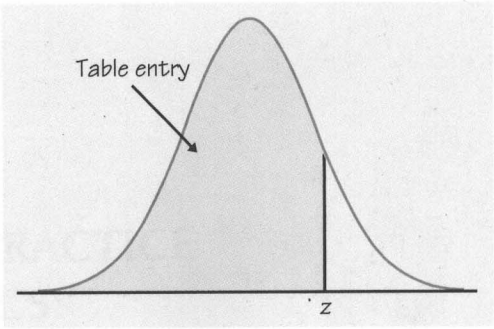

Table entry for z is the area under the standard normal curve to the left of z.

TABLE A Standard normal probabilities (*continued*)

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

THE BASIC PRACTICE OF STATISTICS

PREFACE

The Basic Practice of Statistics is an introduction to statistics for students in two-year and four-year colleges and unversities that emphasizes working with data and statistical ideas. In this preface I describe the book in order to help teachers judge whether it is right for their students.

Guiding principles

The American Statistical Association and the Mathematical Association of America recently formed a joint committee to study the teaching of introductory statistics. Here are their main recommendations:[1]

- Emphasize statistical thinking.
- More data and concepts; less theory, fewer recipes.
- Foster active learning.

I was a member of the ASA/MAA committee, and I agree with their conclusions. Fostering active learning is the business of the teacher (though an emphasis on working with data helps). The first two recommendations are the guiding principles of this text. Although the book is elementary in the level of mathematics required and in the statistical procedures presented, it aims to give students both an understanding of the main ideas of statistics and useful skills for working with data. Examples and exercises, though intended for beginners, use real data and give enough background to allow students to consider the meaning of their calculations. I often ask for conclusions that are more than a number (or "reject H_0"). Some exercises require judgement in addition to right-or-wrong calculations and conclusions. Both students and teachers should recognize that not every part of every exercise has a single correct answer. I hope that teachers will encourage further discussion of results in class.

Chapters 1 and 2 present the methods and unifying ideas of data analysis. Students appreciate the usefulness of data analysis, and the fact that

they can actually do it relieves a bit of their anxiety about statistics. I hope that they will grow accustomed to examining data and will continue to do so even when formal inference to answer a specific question is the ultimate goal. Chapter 3 discusses random sampling and randomized comparative experiments. These are among the most important ideas in statistics, and are often unjustly neglected in beginning instruction. Chapter 4 builds on the ideas of Chapter 3 and the data-analytic tools of Chapter 1 to present the central idea of a sampling distribution and (informally) the language of probability. Chapter 5 is the cornerstone of the rest of the book. It describes the reasoning of statistical inference. The remaining chapters present methods of inference for various settings, with a strong emphasis on practical aspects of using these methods. Chapters 6 and 7 discuss basic one-sample and two-sample procedures. Chapters 8, 9, and 10 (which can be read independently of each other in any order) offer a choice of somewhat more advanced topics.

Technology

Automating calculations increases students' ability to complete problems, reduces their frustration, and helps them concentrate on ideas and problem recognition rather than mechanics. This book requires that students have a ***calculator*** that will do statistical calculations through correlation and simple linear regression. As I write, several makers sell such calculators for less than $18. Because students have calculators, the text doesn't discuss "computing formulas" for the sample standard deviation or least-squares regression line. Exercises assume that students will use a "two-variable statistics" calculator rather than a more rudimentary model. Many scientific calculators are even more capable, offering simulation and some graphics as well as more statistical procedures. Course-wide use of a graphing calculator is somewhat similar to using software, and will probably require specific instruction.

Statistical software has considerable advantages over calculators: easier data entry and editing, much better graphics, more statistical procedures. I encourage the use of software whenever time and facilities permit. This book does not, however, assume that students will use software. Output from four statistical software packages appears in the text, with Minitab most common. Students should be able to interpret output and use it for further work. Because of the great variety of software used for statistics, from spreadsheets to SAS, I have avoided instruction on how to use any one program. A supplementary Minitab handbook is available for teachers who want to introduce Minitab in a way closely tied to the text. Data sets for examples and exercises are available on a data disk, from which they can be read into any statistical software.

Although ***video*** is a poor medium for exposition, actually seeing statistics at work in a variety of settings is a powerful means of changing student attitudes about statistics. I show one of the short on-location documentary segments from the Annenberg/Corporation for Public Broadcasting telecourse *Against All Odds: Inside Statistics* about once a week. Because I was the content developer for this video series, it fits the style and sequence of this book closely. The Instructor's Guide contains suggestions about using video, a list of recommended excerpts, and information on how to obtain *Against All Odds*.

Probability

The difficult issue of how to present probability in a first course on statistical methods deserves separate comment. Experienced teachers recognize that students find probability difficult. Research on learning confirms our experience. I recommend the survey article "Difficulties in learning basic concepts in probability and statistics: implications for research," by Joan Garfield and Andrew Ahlgren.[2] Garfield and Ahlgren document the fragility of probability concepts even among students who can work formal probability problems. They conclude that "teaching a conceptual grasp of probability still appears to be a very difficult task, fraught with ambiguity and illusion." They recommend exploring "how useful ideas of statistical inference can be taught independently of technically correct probability."

Probability is a noble and useful subject. Attempting to present a substantial introduction to probability in a data-oriented statistics course for students who are not mathematically trained, however, is in my opinion unwise. Formal probability does not help these students master the ideas of inference (at least not as much as we teachers imagine), and it depletes reserves of mental energy that might better be applied to essentially statistical ideas.

I have therefore presented very little formal probability in the core of the text. The central idea is that of the sampling distribution of a statistic. Sampling distributions answer a question that leads to the heart of statistical inference, "What would happen if I repeated this random process many times?" Moreover, students can use tools from data analysis to understand distributions. Normal distributions appear already in Chapter 1 as models for the overall pattern of some distributions of data. In Section 1 of Chapter 4, sampling distributions motivate a brief and quite informal introduction to the language of probability. Sections 4.3 and 4.5 look at the sampling distributions of sample proportions and sample means in more detail. Such important probability facts as the central limit theorem and

the law of large numbers appear in this context. A few additional probability ideas, particularly independence, are treated informally when needed. This is the approach I recommend.

Instructors who want more depth in the study of probability distributions will find it in the optional Sections 4.2 and 4.4. Even these sections avoid the formal notation of set theory and general probability. *Introduction to the Practice of Statistics* offers more, and more traditionally presented, probability. I confess that when teaching from that text I omit most of its probability material in favor of additional statistics. Sections 4.1, 4.3, and 4.5 of this book (with the optional Section 4.6 on control charts) contain what I actually teach students without calculus.

What about that other book?

The Basic Practice of Statistics is kin to *Introduction to the Practice of Statistics (IPS).*[3] It shares both its guiding principles and some details (especially exercises) with the larger book. But this is not an abridgement of *IPS.* Much of the material, including all of Chapters 7 to 10, is completely new. I have omitted most of the optional material in *IPS,* as well as a number of topics that were not optional. The result is a shorter book.

I have also endeavored to make this book considerably easier to read. The language, the length of the exposition, the organization of exercises, and the choice of topics have been rethought throughout for a less advanced audience. Each main idea is followed by a short section of exercises for immediate reinforcement. Each chapter review includes a list of specific skills against which students may check their learning. An index of symbols (note that it isn't long—the density of symbols is as low as I could efficiently manage) and an index of procedures are placed ahead of the usual index. There is a removable gatefold insert that includes essential formulas and tables for easy reference and use in testing.

Instructors who appreciate the data-and-ideas approach of *IPS,* but found it hard going for their students, should like this book. Conversely, instructors who wish to present such topics as normal quantile plots, transformations of variables, formal probability, or brief introductions to multiple regression and two-way analysis of variance should consider *IPS.*

Supplements

A full range of supplements is available to help teachers and students use *The Basic Practice of Statistics.* In the *Instructor's Guide* I give an overview and teaching suggestions for each chapter, comments on the use of video, and sample examinations. I also present additional examples for classroom use, with data on the data disk. These helps are followed by complete solutions

(not just answers) for all exercises, prepared by Darryl Nester of Bluffton College. William Notz and Becky Busam of Ohio State University have prepared a *Student Study Guide* and a *Test Bank* for instructors. A set of *Transparency Masters* is available from the publisher. A *Data Disk*, available in both DOS/Windows and Macintosh formats, enables instructors to easily enter the data from examples and exercise sets into their software. Betsy Greenberg of the Unversity of Texas has written a *Minitab Handbook* that gives detailed instruction about the Minitab statistical software linked to the sequence and examples of the text.

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David S. Moore

Notes

1. George Cobb, "Teaching statistics," in L.A. Steen (ed.), *Heeding the Call for Change: Suggestions for Curricular Action,* MAA Notes No. 22, Mathematical Association of America, Washington D.C., 1992, pp. 3–43.
2. Joan Garfield and Andrew Ahlgren, "Difficulties in learning basic concepts in probability and statistics: implications for research," *Journal for Research in Mathematics Education,* 19 (1988), pp. 44–63.
3. David S. Moore and George P. McCabe, *Introduction to the Practice of Statistics,* 2d ed., W. H. Freeman, New York, 1993.

CONTENTS

**Starred sections are optional*