

# CONTENTS

<b>1 RANK TESTS FOR COMPARING TWO TREATMENTS</b>	<b>1</b>
1. Ranks in the comparison of two treatments, 1	
2. The Wilcoxon rank-sum test, 5	
3. Asymptotic null distribution of the Wilcoxon statistic, 13	
4. The treatment of ties, 18	
5. Two-sided alternatives, 23	
6. The Siegel-Tukey and Smirnov tests, 32	
7. Further developments, 40	
Other approximations to the distribution of $W_5$ ; Censored observations; Early termination; Power; Permutation tests.	
8. Problems, 43	
9. References, 52	
<b>2 COMPARING TWO TREATMENTS OR ATTRIBUTES IN A POPULATION MODEL</b>	<b>55</b>
1. Population models, 55	
2. Power of the Wilcoxon rank-sum test, 65	
3. Asymptotic power, 69	
4. Comparison with Student's $t$ -test, 76	
5. Estimating the treatment effect, 81	
6. Confidence procedures, 91	
7. Further developments, 95	
The Behrens-Fisher problem; The Normal Scores test; Increasing the number of levels to improve sensitivity; Small- sample power; Large-sample power and efficiency; Efficiency in the presence of ties; Optimality properties; Additional properties of $\hat{\Delta}$ ; Efficiency of the Siegel-Tukey test; The scale tests of Capon and Klotz; The Savage (or exponential scores) test; Scale tests with unknown location; Power and efficiency of the Smirnov test; Sequential rank tests; The permutation $t$ -test.	
8. Problems, 106	
9. References, 114	

<b>3</b>	<b>BLOCKED COMPARISONS FOR TWO TREATMENTS</b>	<b>120</b>
1.	The sign test for paired comparisons, 120	
2.	The Wilcoxon signed-rank test, 123	
3.	Combining data from several experiments or blocks, 132	
4.	A balanced design for paired comparisons, 141	
5.	Further developments, 143	
	Power of the sign and Wilcoxon tests; Alternative treatment of zeros; Tests against omnibus alternatives; Efficiency and generalizations of the blocked comparisons test $W_5$ .	
6.	Problems, 146	
7.	References, 153	
<b>4</b>	<b>PAIRED COMPARISONS IN A POPULATION MODEL AND THE ONE-SAMPLE PROBLEM</b>	<b>156</b>
1.	Power and uses of the sign test, 156	
2.	Power of the signed-rank Wilcoxon test, 164	
3.	Comparison of sign, Wilcoxon, and $t$ -tests, 171	
4.	Estimation of a location parameter or treatment effect, 175	
5.	Confidence procedures, 181	
6.	Further developments, 185	
	Power and efficiency of the sign test; The absolute Normal Scores test; Power and efficiency of the Wilcoxon and absolute Normal Scores test; Tests of symmetry; A generalized set of confidence points; Bounded-length sequential confidence intervals for $\theta$ ; Robust estimation; Some optimum properties of tests and estimators; Departures from assumption.	
7.	Problems, 191	
8.	References, 199	
<b>5</b>	<b>THE COMPARISON OF MORE THAN TWO TREATMENTS</b>	<b>202</b>
1.	Ranks in the comparison of several treatments, 202	
2.	The Kruskal-Wallis test, 204	
3.	$2 \times t$ Contingency tables, 210	
4.	Population models, 219	
5.	One-sided procedures, 226	
	Comparing several treatments with a control; Testing equality against ordered alternatives.	
6.	Selection and ranking procedures, 238	
	Ranking several treatments; Selecting the best of several treatments.	
7.	Further developments, 247	
	Power and efficiency; Estimation of several differences in location; The estimation of contrasts; Normal Scores and Smirnov tests for the $s$ -sample problem.	

8.	Problems, 250	
9.	References, 257	
<b>6</b>	<b>RANDOMIZED COMPLETE BLOCKS</b>	<b>260</b>
1.	Ranks in randomized complete blocks, 260	
2.	The tests of Friedman, Cochran, and McNemar, 262	
3.	Aligned ranks, 270	
4.	Population models and efficiency, 273	
5.	Further developments, 279	
	More general blocks; One-sided tests and ranking procedures;	
	Estimation of treatment differences and other contrasts;	
	Combination of independent tests.	
6.	Problems, 281	
7.	References, 285	
<b>7</b>	<b>TESTS OF RANDOMNESS AND INDEPENDENCE</b>	<b>287</b>
1.	The hypothesis of randomness, 287	
2.	Testing against trend, 290	
3.	Testing for independence, 297	
4.	$s \times t$ Contingency tables, 303	
5.	Further developments, 311	
	Pitman efficiency of $D$ ; Estimating the regression coefficient $\beta$ ;	
	Tests of randomness based on runs; Other tests of	
	independence; Power and efficiency of tests of independence;	
	Contingency tables.	
6.	Problems, 317	
7.	References, 322	
	<b>APPENDIX</b>	<b>327</b>
1.	Expectation and variance formulas, 327	
2.	Some standard distributions, 339	
	The binomial distribution; The hypergeometric distribution;	
	The normal distribution; The Cauchy, logistic, and	
	double-exponential distributions; The rectangular (uniform)	
	and exponential distributions; The $\chi^2$ -distribution; Order	
	statistics.	
3.	Convergence in probability and in law, 345	
4.	Sampling from a finite population, 352	
5.	U-statistics, 362	
6.	Pitman efficiency, 371	
7.	Some multivariate distributions, 380	
	The multinomial distribution; The multiple hypergeometric	
	distribution; The multivariate normal distribution.	

- 8. Convergence of random vectors, 386
- 9. Problems, 396
- 10. References, 405

**EPILOGUE** **407**

**TABLES** **413**

- A Number of combinations of  $N$  things taken  $n$  at a time, 413
- B Wilcoxon rank-sum distribution, 414
- C Area under the normal curve, 417
- D Square roots, 418
- E Smirnov Exact upper-tail probabilities, 419
- F Smirnov limiting distribution, 421
- G Distribution of sign-test statistics, 422
- H Wilcoxon signed-rank distribution, 424
- I Kruskal-Wallis upper-tail probabilities, 428
- J(a)  $\chi^2$  upper-tail probabilities for  $\nu = 2,3,4,5$  degrees of freedom, 433
- J(b) Critical values  $c$  of  $\chi^2$  with  $\nu = 6(1)40(5)100$  degrees of freedom, 434
- K Upper-tail probabilities of Jonckheere's statistic, 435
- L Amalgamation probabilities for Chacko's test, 436
- M Upper-tail probabilities of Friedman's statistic, 437
- N Distribution of Spearman's statistic, 439

**ACKNOWLEDGMENTS FOR TABLES, 440**

**ANSWERS TO SELECTED PROBLEMS, 441**

**DATA GUIDE (TITLES FOR DATA PRESENTED IN THE TEXT), 451**

**AUTHOR INDEX, 453**

**SUBJECT INDEX, 457**