

# Contents

<b>Presentation of the book</b>	<b>xii</b>
<b>Preface</b>	<b>xiii</b>
<b>Notation and abbreviations</b>	<b>xvii</b>
<b>1 One- and two-sample location problems, tests for symmetry and tests on a single distribution</b>	<b>1</b>
1.1 Introduction	1
1.2 Nonparametric tests	2
1.2.1 Rank tests	2
1.2.2 Permutation tests and combination based tests	3
1.3 Univariate one-sample tests	5
1.3.1 The Kolmogorov goodness-of-fit test	6
1.3.2 A univariate permutation test for symmetry	10
1.4 Multivariate one-sample tests	15
1.4.1 Multivariate rank test for central tendency	15
1.4.2 Multivariate permutation test for symmetry	18
1.5 Univariate two-sample tests	20
1.5.1 The Wilcoxon (Mann–Whitney) test	21
1.5.2 Permutation test on central tendency	27
1.6 Multivariate two-sample tests	29
1.6.1 Multivariate tests based on rank	29
1.6.2 Multivariate permutation test on central tendency	34
References	37
<b>2 Comparing variability and distributions</b>	<b>38</b>
2.1 Introduction	38
2.2 Comparing variability	39
2.2.1 The Ansari–Bradley test	40
2.2.2 The permutation Pan test	43
2.2.3 The permutation O’Brien test	46
2.3 Jointly comparing central tendency and variability	49
2.3.1 The Lepage test	50
2.3.2 The Cucconi test	52

2.4 Comparing distributions	56
2.4.1 The Kolmogorov–Smirnov test	56
2.4.2 The Cramér–von Mises test	59
References	61
<b>3 Comparing more than two samples</b>	<b>65</b>
3.1 Introduction	65
3.2 One-way ANOVA layout	66
3.2.1 The Kruskal–Wallis test	67
3.2.2 Permutation ANOVA in the presence of one factor	73
3.2.3 The Mack–Wolfe test for umbrella alternatives	76
3.2.4 Permutation test for umbrella alternatives	83
3.3 Two-way ANOVA layout	87
3.3.1 The Friedman rank test for unreplicated block design	87
3.3.2 Permutation test for related samples	89
3.3.3 The Page test for ordered alternatives	91
3.3.4 Permutation analysis of variance in the presence of two factors	93
3.4 Pairwise multiple comparisons	95
3.4.1 Rank-based multiple comparisons for the Kruskal–Wallis test	96
3.4.2 Permutation tests for multiple comparisons	98
3.5 Multivariate multisample tests	99
3.5.1 A multivariate multisample rank-based test	99
3.5.2 A multivariate multisample permutation test	103
References	105
<b>4 Paired samples and repeated measures</b>	<b>107</b>
4.1 Introduction	107
4.2 Two-sample problems with paired data	108
4.2.1 The Wilcoxon signed rank test	108
4.2.2 A permutation test for paired samples	114
4.3 Repeated measures tests	116
4.3.1 Friedman rank test for repeated measures	117
4.3.2 A permutation test for repeated measures	120
References	122
<b>5 Tests for categorical data</b>	<b>124</b>
5.1 Introduction	124
5.2 One-sample tests	125
5.2.1 Binomial test on one proportion	125
5.2.2 The McNemar test for paired data (or bivariate responses) with binary variables	128
5.2.3 Multivariate extension of the McNemar test	131

5.3	Two-sample tests on proportions or $2 \times 2$ contingency tables	134
5.3.1	The Fisher exact test	135
5.3.2	A permutation test for comparing two proportions	138
5.4	Tests for $R \times C$ contingency tables	139
5.4.1	The Anderson–Darling permutation test for $R \times C$ contingency tables	140
5.4.2	Permutation test on moments	145
5.4.3	The chi-square permutation test	148
	References	151
<b>6</b>	<b>Testing for correlation and concordance</b>	<b>153</b>
6.1	Introduction	153
6.2	Measuring correlation	154
6.3	Tests for independence	156
6.3.1	The Spearman test	157
6.3.2	The Kendall test	160
6.4	Tests for concordance	166
6.4.1	The Kendall–Babington Smith test	167
6.4.2	A permutation test for concordance	172
	References	174
<b>7</b>	<b>Tests for heterogeneity</b>	<b>176</b>
7.1	Introduction	176
7.2	Statistical heterogeneity	177
7.3	Dominance in heterogeneity	178
7.3.1	Geographical heterogeneity	180
7.3.2	Market segmentation	184
7.4	Two-sided and multisample test	188
7.4.1	Customer satisfaction	189
7.4.2	Heterogeneity as a measure of uncertainty	191
7.4.3	Ethnic heterogeneity	194
7.4.4	Reliability analysis	196
	References	197
<b>Appendix A</b>	<b>Selected critical values for the null distribution of the peak-known Mack–Wolfe statistic</b>	<b>201</b>
<b>Appendix B</b>	<b>Selected critical values for the null distribution of the peak-unknown Mack–Wolfe statistic</b>	<b>203</b>
<b>Appendix C</b>	<b>Selected upper-tail probabilities for the null distribution of the Page <math>L</math> statistic</b>	<b>206</b>
<b>Appendix D</b>	<b>R functions and codes</b>	<b>213</b>
	<b>Index</b>	<b>219</b>