OXFORD

research methods for the BIOSCIENCES

Debbie Holmes, Peter Moody, and Diana Dine

SECOND EDITION

research methods for the biosciences

SECOND EDITION

D. Holmes

P. Moody

D. Dine

常州大学山书馆
藏书章

OXFORD
UNIVERSITY PRESS

OXFORD
UNIVERSITY PRESS
Great Clarendon Street, Oxford OX2 6DP
Oxford University Press is a department of the University of Oxford.
It furthers the University's objective of excellence in research, scholarship,
and education by publishing worldwide in
Oxford New York
Auckland Cape Town Dar es Salaam Hong Kong Karachi
Kuala Lumpur Madrid Melbourne Mexico City Nairobi
New Delhi Shanghai Taipei Toronto
With offices in
Argentina Austria Brazil Chile Czech Republic France Greece
Guatemala Hungary Italy Japan Poland Portugal Singapore
South Korea Switzerland Thailand Turkey Ukraine Vietnam
Oxford is a registered trade mark of Oxford University Press
in the UK and in certain other countries
Published in the United States
by Oxford University Press Inc., New York
© D. Holmes, P. Moody, and D. Dine 2011
The moral rights of the authors have been asserted
Crown Copyright material reproduced with the permission of the
Controller, HMSO (under the terms of the Click Use licence.)
Database right Oxford University Press (maker)
First published Oxford University Press 2006
Second edition published 2011
All rights reserved. No part of this publication may be reproduced,
stored in a retrieval system, or transmitted, in any form or by any means,
without the prior permission in writing of Oxford University Press,
or as expressly permitted by law, or under terms agreed with the appropriate
reprographics rights organization. Enquiries concerning reproduction
outside the scope of the above should be sent to the Rights Department,
Oxford University Press, at the address above
You must not circulate this book in any other binding or cover
and you must impose the same condition on any acquirer
British Library Cataloguing in Publication Data
Data available
Library of Congress Cataloging in Publication Data
Data available
Typeset by Newgen Imaging Systems (P) Ltd., Chennai, India
Printed in Italy
on acid-free paper by
LEGO SpA—Lavis TN
ISBN 978–0–19–954576–6
10 9 8 7 6 5 4 3 2 1

Research Methods for the Biosciences

Preface

Getting the most out of this book

We write this section with some uncertainty since we rarely read a preface in a book and wonder if anyone is going to read what we've written here. Nonetheless, there are several important things we need to explain to you to enable you to get the best out of this book and its Online Resource Centre, so we'd encourage you to take a few moments to read on.

Who should read this book?

This book is primarily written for undergraduates who wish to develop their understanding of designing, carrying out, and reporting research. We anticipate that graduates, although familiar with most of this material, will find this book and its Online Resource Centre to be a useful reference too. We have therefore used examples almost entirely drawn from real undergraduate and some graduate research projects. We are indebted to all our students who have allowed us to use their ideas and data in this book.

Content

The content is designed to take you through all the steps you need to follow when choosing, planning, evaluating and reporting undergraduate research. The content is therefore laid out in a number of sections:

How to choose a suitable topic for undergraduate research (Appendix a)

Section 1: Planning an experiment (Chapters 1 – 4)

Section 2: Handling your data (Chapters 5 – 10)

Section 3: Reporting your results (Chapter 11).

In addition, in the appendices, we have included an explanation of the mathematical processes used in the chapters (Appendix e), a decision web to help you plan your research (Appendix b), and a summary of the information you need to choose the correct statistical test to test hypotheses (Appendix c).

There is a close and essential link between planning research and understanding how statistics fit into this process. We have demonstrated these links

试读结束：需要全本请在线购买： www.ertongbook.com

in Section 1 by cross references to content in Section 2. In Section 2 we have included an overview at the end of each chapter on statistics explaining how this relates to experimental design.

Getting started

You may be coming to this book with very little in the way of training in maths. If you do not know how to calculate this sum $(4\ 3)^2/2$, or if you do not recognize the symbols < or > , then we suggest you first look at Appendix e and the additional examples on the Online Resource Centre.

You may wish to analyse data you have gathered from an experiment carried out in your course. For this we suggest you start with Appendix c. which will then direct you to the correct sections in Chapters 5 to 10.

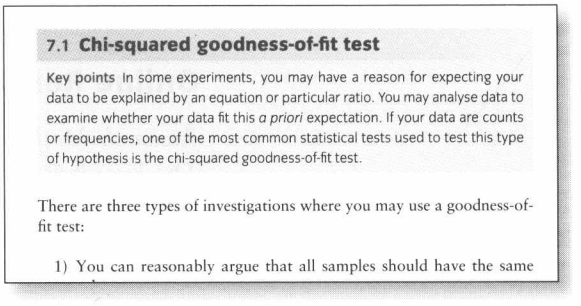
You may wish to prepare a critique of published research. The chapter that considers this is Chapter 2, with cross-referencing to earlier and some later chapters.

If you wish to design a research project and you are familiar with terms such as variable, parametric, aim, hypothesis, etc., then go to Appendix a and Chapter 2. If you are not familiar with these terms still refer to Appendix a, and then continue from Chapter 1.

Learning features

Sign posts

There are a number of ways we have tried to help you quickly find the information you need. We have included chapter ('In a nutshell') and section ('Key points') summaries. At the top of each chapter in Section 2 we have included both an introduction and a guide to choosing the correct statistical test for that chapter. All these chapter specific guides are integrated in Appendix c.



7.1 Chi-squared goodness-of-fit test

Key points In some experiments, you may have a reason for expecting your data to be explained by an equation or particular ratio. You may analyse data to examine whether your data fit this *a priori* expectation. If your data are counts or frequencies, one of the most common statistical tests used to test this type of hypothesis is the chi-squared goodness-of-fit test.

There are three types of investigations where you may use a goodness-of-fit test:

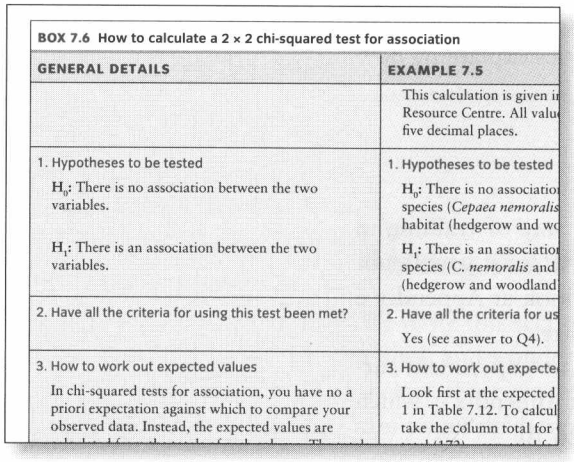
1) You can reasonably argue that all samples should have the same

Key terms

We know that most people will dip in to this book and so we have included a glossary of most terms that you need to be familiar with towards the end. Key terms are shown in **coloured type** the first time they appear; definitions of these key terms then appear in the glossary at the end of the book.

Boxes

In our experience we have found that students best understand the statistics element of this book if they first use a calculator to work out the calculation.



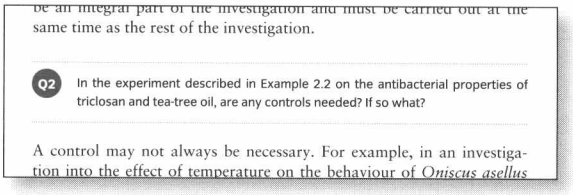
BOX 7.6 How to calculate a 2 × 2 chi-squared test for association

GENERAL DETAILS	EXAMPLE 7.5
	This calculation is given i Resource Centre. All valu five decimal places.
1. Hypotheses to be tested H_0: There is no association between the two variables. H_1: There is an association between the two variables.	1. Hypotheses to be tested H_0: There is no associatio species (*Cepaea nemoralis* habitat (hedgerow and wo H_1: There is an associatio species (*C. nemoralis* and (hedgerow and woodland
2. Have all the criteria for using this test been met?	2. Have all the criteria for us Yes (see answer to Q4).
3. How to work out expected values In chi-squared tests for association, you have no a priori expectation against which to compare your observed data. Instead, the expected values are	3. How to work out expecte Look first at the expected 1 in Table 7.12. To calcul take the column total for

Therefore we have arranged the statistical information in boxes with general details and a worked example for you to follow.

In the calculations we've included in this book we have rounded all values, usually to five decimal places. However, we carried out all the calculations using all decimal places (as you should). This means that some of our sums do not appear to quite add up. Any minor differences in the calculations should be the result of this rounding of values.

In the boxes some the mathematical steps have not been included. We have therefore included the full calculations in the Online Resource Centre. We have also included an explanation of how to use SPSS, Excel, and Minitab to carry out the same calculations in the Online Resource Centre.



be an integral part of the investigation and must be carried out at the same time as the rest of the investigation.

Q2 In the experiment described in Example 2.2 on the antibacterial properties of triclosan and tea-tree oil, are any controls needed? If so what?

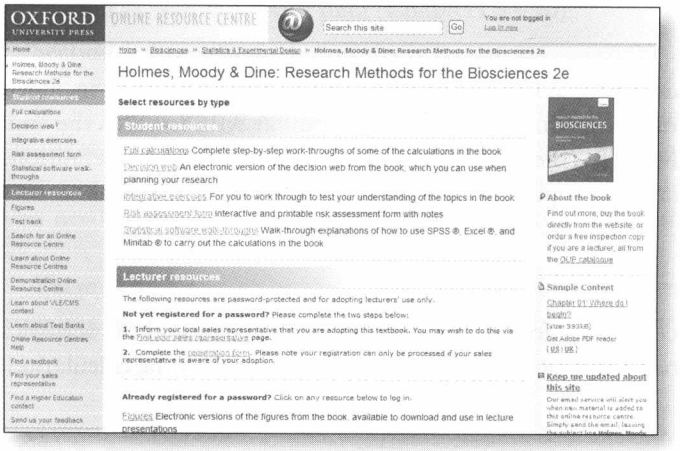
A control may not always be necessary. For example, in an investigation into the effect of temperature on the behaviour of *Oniscus asellus*

Questions

To help you check your understanding of the topics covered by this book we have included a number of questions. The answers are provided at the end of each chapter. More questions are included in the Online Resource Centre.

Online Resource Centre

Research Methods for the Biosciences is more than just this printed book. The *Research Methods for the Biosciences* Online Resource Centre features extensive online materials to help you really get to grips with the skills you need to carry out research work. This can be found at:
www.oxfordtextbooks.co.uk/orc/holmes2e/



The student area of the Online Resource Centre includes:

- full details of all calculations in this book: every step in each calculation is shown so you can see exactly how we reach the answers shown in the book
- walk-through explanations of how to use SPSS, Excel, and Minitab to carry out these calculations
- interactive tasks for you to work through to test your understanding of the topics in this book, and hone your research methods skills.
- an electronic version of the decision web which you can use when planning your research
- an electronic risk assessment which may be used to help you complete this process

You'll see the Online Resource Centre icon throughout the book. This icon tells you that the part of the text you are reading has online materials to accompany it.

The lecturer area of the Online Resource Centre provides additional materials to make the book easier to teach from. These materials include:

- figures from the book, available to download for use in lecture slides
- test bank of questions

Simply go to www.oxfordtextbooks.co.uk/orc/holmes2e/ and register as a user of the book to gain free access to these materials.

And finally ...

Just in case OUP ask us to produce a third edition, we would like to hear about any errors (we hope there are none) and any suggestions you have for improvements. You can contact us by using the 'Send us your feedback' option in the Online Resource Centre.

Boxes outlining the methods for the statistical tests included in this book

Standard deviation and variance

5.1 How to calculate a standard deviation and variance for normally distributed (parametric) data
Parametric and non-parametric data 134

5.2 How to check whether your data are normally distributed (parametric) 140

5.3 How to rank data for non-parametric statistics 142

Chi-squared and *G*-tests

7.1 How to calculate a chi-squared goodness-of-fit test 177

7.2 To check whether your data are normally distributed using a chi-squared goodness-of-fit test 180

7.3 How to calculate a chi-squared test for heterogeneity 185

7.4 How to calculate an $r \times c$ chi-squared test for association 190

7.5 How to calculate a chi-squared goodness-of-fit test when there is one degree of freedom 193

7.6 How to calculate a 2×2 chi-squared test for association 196

7.7 How to calculate a *G* goodness-of-fit test 199

7.8 How to calculate an $r \times c$ *G*-test for association 200

Correlation and regression

8.1 How to carry out Spearman's rank correlation 218

8.2 How to carry out Pearson's product moment correlation 221

8.3 How to carry out a Model I simple linear regression (one *y* value for each *x* value): drawing a regression line 229

8.4 How to carry out a Model I simple linear regression (one *y* value for each *x* value): testing the significance of the association 230

8.5 How to carry out an F_{max} test to check for homogeneous variances before carrying out an ANOVA for linear regressions 235

8.6 How to carry out a one-way parametric ANOVA for a linear regression with equal replicates of y for each value of x 237

8.7 How to carry out a Model II principal axis regression: drawing a regression line 243

8.8 How to carry out a Model II ranged principal axis regression: drawing a regression line 247

z- and *t*-tests

9.1 How to carry out an F-test to check for homogeneous variances before carrying out a z-test for unmatched data 259

9.2 How to carry out a z-test for unmatched data 261

9.3 How to carry out an unequal variance t-test for unmatched data 264

9.4 How to carry out a z- and t-test for matched data 268

Parametric ANOVAs and multiple comparisons

9.5 How to carry out an F_{max} test to check for homogeneous variances, before carrying out an ANOVA 274

9.6 How to carry out a one-way parametric ANOVA with equal replicates 275

9.7 How to carry out Tukey's test after a significant one-way parametric ANOVA with equal replicates 278

9.8 How to carry out a one-way parametric ANOVA with unequal replicates 282

9.9 How to carry out a Tukey–Kramer test after a significant one-way parametric ANOVA with unequal replicates 283

9.10 How to carry out a two-way parametric ANOVA with equal replicates 289

9.11 How to carry out a two-way parametric ANOVA with no replicates 298

9.12 How to carry out a nested ANOVA with one main factor and one nested factor with equal replicates 303

9.13 How to carry out a three-way factorial parametric ANOVA without replicates 309

9.14 How to carry out a three-way factorial parametric ANOVA with replicates: an extension of the method outlined in Box 9.13 313

Mann–Whitney *U* test and Wilcoxon's matched pairs test

10.1 How to carry out a Mann–Whitney U test 324

10.2 How to carry out Wilcoxon's matched pairs test 328

Non-parametric ANOVAs (including the Kruskal–Wallis test) and multiple comparisons

10.3 How to carry out a one-way non-parametric ANOVA (Kruskal–Wallis test) 332

10.4 How to carry out multiple comparisons after a one-way non-parametric ANOVA (Kruskal–Wallis test) 336

10.5A How to carry out a two-way non-parametric ANOVA test: columns 341

10.5B How to carry out a two-way non-parametric ANOVA test: rows 344

10.5C How to carry out a two-way non-parametric ANOVA test: interaction 345

10.6 How to carry out multiple comparisons after a two-way non-parametric ANOVA 349

试读结束：需要全本请在线购买： www.ertongbook.com

Boxes outlining the methods for the statistical tests included in this book

Standard deviation and variance

5.1 How to calculate a standard deviation and variance for normally distributed (parametric) data 134
Parametric and non-parametric data

5.2 How to check whether your data are normally distributed (parametric) 140

5.3 How to rank data for non-parametric statistics 142

Chi-squared and *G*-tests

7.1 How to calculate a chi-squared goodness-of-fit test 177

7.2 To check whether your data are normally distributed using a chi-squared goodness-of-fit test 180

7.3 How to calculate a chi-squared test for heterogeneity 185

7.4 How to calculate an $r \times c$ chi-squared test for association 190

7.5 How to calculate a chi-squared goodness-of-fit test when there is one degree of freedom 193

7.6 How to calculate a 2×2 chi-squared test for association 196

7.7 How to calculate a *G* goodness-of-fit test 199

7.8 How to calculate an $r \times c$ *G*-test for association 200

Correlation and regression

8.1 How to carry out Spearman's rank correlation 218

8.2 How to carry out Pearson's product moment correlation 221

8.3 How to carry out a Model I simple linear regression (one *y* value for each *x* value): drawing a regression line 229

8.4 How to carry out a Model I simple linear regression (one *y* value for each *x* value): testing the significance of the association 230

8.5 How to carry out an F_{max} test to check for homogeneous variances before carrying out an ANOVA for linear regressions 235

Contents

Detailed Contents vii
Boxes outlining the methods for the statistical tests included in this book xvii

Section 1 Planning an experiment

1 **Where do I begin?** 3
2 **Planning your experiment** 19
3 **Questionnaires, focus groups, and interviews** 54
4 **Research, the law, and you** 65

Section 2 Handling your data

5 **What to do with raw data** 111
6 **An introduction to hypothesis testing** 147
7 **Hypothesis testing: do my data fit an expected ratio?** 172
8 **Hypothesis testing: associations and relationships** 209
9 **Hypothesis testing: do my samples come from the same population? Parametric data** 255
10 **Hypothesis testing: do my samples come from the same population? Non-parametric data** 321

Section 3 Reporting your results

11 **Reporting your research** 361

Appendix a. *How to choose a research project* 397
Appendix b. *Planning your experiment* 401
Appendix c. *Which statistical test should I choose?* 409
Appendix d. *Tables of critical values for statistical tests* 416
Appendix e. *Maths and statistics* 434
Glossary 446
References 452
Index 455

Detailed Contents

Section 1 Planning an experiment

1 **Where do I begin?** 3

1.1. **Aims and objectives** 3
1.1.1. The aim 4
1.1.2. The objective 4
i. Clumpers or splitters 5
ii. Only one objective 5
iii. Personal and experimental objectives 6

1.2. **Data, items, and observations** 6

1.3. **Populations** 7

1.4. **Sample** 8
1.4.1. Representative samples 8
1.4.2. How do you obtain a representative sample? 9
i. Random sampling 9
ii. Systematic/periodic sampling 9
iii. Stratified random sampling 9
iv. Homogeneous stands 10

1.5. **Population parameters and sample statistics** 11
1.5.1. Mathematical notation for populations and samples 11
1.5.2. Calculations 11

1.6. **Treatments** 12

1.7. **Variation and variables** 13
1.7.1. Variation 13
1.7.2. Variables 13
1.7.3. Partitioning variation and confounding (non-treatment) variables 14

1.8. **Hypotheses** 15
1.8.1. Null hypotheses 16
1.8.2. Information-theoretic models 17

2 **Planning your experiment** 19

2.1. **Evaluating published research** 20
2.1.1. What are the aim and objective(s)? 20
2.1.2. Strengths of the experimental design 21
2.1.3. Weaknesses of the experimental design 22
i. Faults 22
ii. Limitations 22
iii. Communication 22

a. Fault in the design 22
b. Limitation 23
c. Communication 23

2.2. Have a go! 24

2.2.1. What are my aim and objectives? 25
i. Background information 25
a. The context 25
b. The justification 26
c. The practicalities 26
d. Previous designs 27
ii. Aim and objectives 28
2.2.2. What is the statistical population? 28
2.2.3. Which variables am I investigating? 30
2.2.4. Are there any confounding variables? 31
i. Identifying confounding variables 31
ii. Minimizing the effect of non-treatment variation 32
a. Equalizing the effect 33
b. Randomization 33
iii. Mathematically separate out (partition) the variation in your data 34
2.2.5. Will I need replicates? 34
i. When should you use replicates? 34
a. To increase the reliability of your estimate of the population parameters 34
b. To allow mathematical estimates of non-treatment variation 34
ii. Features of replicates 35
iii. How many replicates? 36
2.2.6. Will I need any controls? 36
2.2.7. How will I analyse my data? 37
i. Which type of hypothesis am I testing? 38
ii. What type of data do I have? 40
iii. How many variables do I wish to test the effect of? 41
iv. How many categories do I have? How many observations in each category? 41
v. Therefore, which statistical test(s) seem appropriate? 42
vi. Finalizing your aim and objectives 44
vii. Writing your hypothesis 44
2.2.8. Do I need to take action to ensure that I comply with UK law? 45
2.2.9. Are there any causes of possible bias? Have I made any assumptions? 46
i. Influencing outcomes and causes of bias 46
ii. Assumptions 46
2.2.10. Will I repeat the investigation? 47
2.2.11. Back to the beginning 48
i. Review your planning 48
ii. Experimental design and methods 48

2.3. Managing research 50

2.3.1. Time management 50
2.3.2. Space management 51
2.3.3. Data management 51
i. Laboratory or field notebooks 51
ii. Electronic records 52

3 **Questionnaires, focus groups, and interviews** 54

3.1. **What is a questionnaire, interview, or focus group?** 55
3.1.1. Questionnaires 55
3.1.2. Focus groups 55
3.1.3. Interviews 55

3.2. **Open and closed questions** 56
3.2.1. Closed questions 56
3.2.2. Open questions 57

3.3. **Phrasing questions** 57

3.4. **Your participants** 59

3.5. **Sample sizes** 59
3.5.1. Closed questions 60
3.5.2. Open questions 63
3.5.3. Achieving the required sample size 64

4 **Research, the law, and you** 65

4.1. **About the law** 66
4.1.1. International law 66
4.1.2. National law 67
i. Common law (case law) 67
ii. Legislation 67
iii. Local law 68
iv. Institutional writers 68
v. Canon law 68
vi. Custom 69
vii. Quasi-legislation 69
viii. Enforcement 69

4.2. **Health and safety** 69
4.2.1. Hazard identification and rating 70
i. The environment 71
ii. Chemicals 71
iii. Biological agents 72
iv. Rating the hazard 73
4.2.2. Activity 73
i. Hazards arising from the activity 74
ii. Scale of exposure 74
iii. Storage and disposal 74
4.2.3. Probability of harm 75
i. Probability of harm 75
ii. Variation among individuals 75
iii. Occupational exposure limits 75
4.2.4. Minimizing the risk 76
i. Prevention 76
ii. Reduction 76
a. Wear personal protection 76
b. Reduce quantities 76
c. Control ventilation 77
d. Organize space 77
e. Take a break 77
f. Inform 77
g. Company 78
h. Be informed 79
iii. Re-evaluate the probability of harm 79
4.2.5. Risk evaluation 79

试读结束：需要全本请在线购买： www.ertongbook.com