FOURTH EDITION

Practical Skills in Biomolecular Sciences

Rob Reed, David Holmes, Jonathan Weyers, Allan Jones

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Practical Skills in Biomolecular Sciences

Fourth edition

Rob Reed
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First published 1998 by Addison Wesley Longman Limited
Second edition published 2003
Third edition published 2007
Fourth edition published 2013

ISBN: 978-1-4082-4552-1

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloguing-in-Publication Data
Practical skills in biomolecular sciences / Rob Reed … [et al.]. - - 4th ed.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-1-4082-4552-1
I. Reed, Robert (Robert H.)
[DNLM: 1. Clinical Laboratory Techniques. 2. Biochemical Phenomena. QY 25]
LC Classification not assigned
572.8- -dc23
2012018698

10 9 8 7 6 5 4 3 2 1
16 15 14 13 12

Typeset in 10/12pt Times by 73
Printed by Ashford Colour Press Ltd, Gosport

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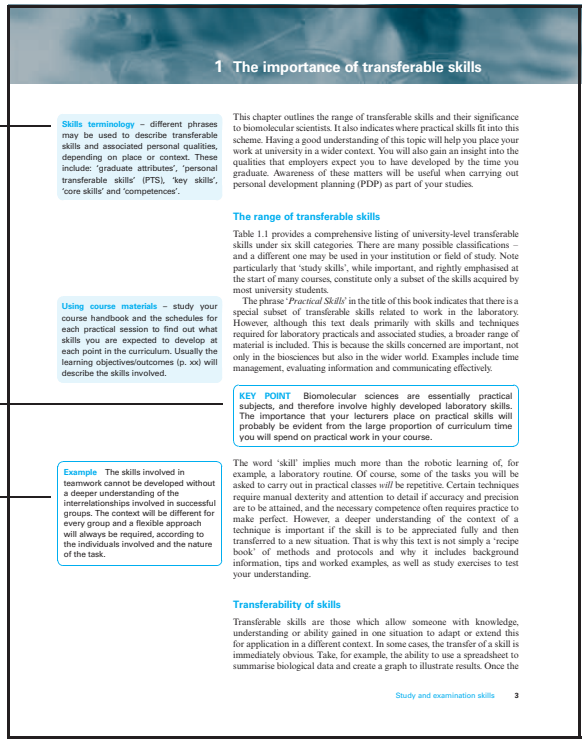
List of boxes

Guided tour

Tips and Hints provide useful hints and practical advice, and are highlighted in the text margin.

Key Points highlight critical features of methodology.

Examples are included in the margin to illustrate important points without interrupting the flow of the main text.



1 The importance of transferable skills

Skills terminology – different phrases may be used to describe transferable skills and associated personal qualities, depending on place or context. These include: 'graduate attributes', 'personal transferable skills' (PTS), 'key skills', 'core skills' and 'competences'.

This chapter outlines the range of transferable skills and their significance to biomolecular scientists. It also indicates where practical skills fit into this scheme. Having a good understanding of this topic will help you place your work at university in a wider context. You will also gain an insight into the qualities that employers expect you to have developed by the time you graduate. Awareness of these matters will be useful when carrying out personal development planning (PDP) as part of your studies.

The range of transferable skills

Table 1.1 provides a comprehensive listing of university-level transferable skills under six skill categories. There are many possible classifications – and a different one may be used in your institution or field of study. Note particularly that 'study skills', while important, and rightly emphasised at the start of many courses, constitute only a subset of the skills acquired by most university students.

The phrase '*Practical Skills*' in the title of this book indicates that there is a special subset of transferable skills related to work in the laboratory. However, although this text deals primarily with skills and techniques required for laboratory practicals and associated studies, a broader range of material is included. This is because the skills concerned are important, not only in the biosciences but also in the wider world. Examples include time management, evaluating information and communicating effectively.

Using course materials – study your course handbook and the schedules for each practical session to find out what skills you are expected to develop at each point in the curriculum. Usually the learning objectives/outcomes (p. xx) will describe the skills involved.

KEY POINT Biomolecular sciences are essentially practical subjects, and therefore involve highly developed laboratory skills. The importance that your lecturers place on practical skills will probably be evident from the large proportion of curriculum time you will spend on practical work in your course.

Example The skills involved in teamwork cannot be developed without a deeper understanding of the interrelationships involved in successful groups. The context will be different for every group and a flexible approach will always be required, according to the individuals involved and the nature of the task.

The word 'skill' implies much more than the robotic learning of, for example, a laboratory routine. Of course, some of the tasks you will be asked to carry out in practical classes *will* be repetitive. Certain techniques require manual dexterity and attention to detail if accuracy and precision are to be attained, and the necessary competence often requires practice to make perfect. However, a deeper understanding of the context of a technique is important if the skill is to be appreciated fully and then transferred to a new situation. That is why this text is not simply a 'recipe book' of methods and protocols and why it includes background information, tips and worked examples, as well as study exercises to test your understanding.

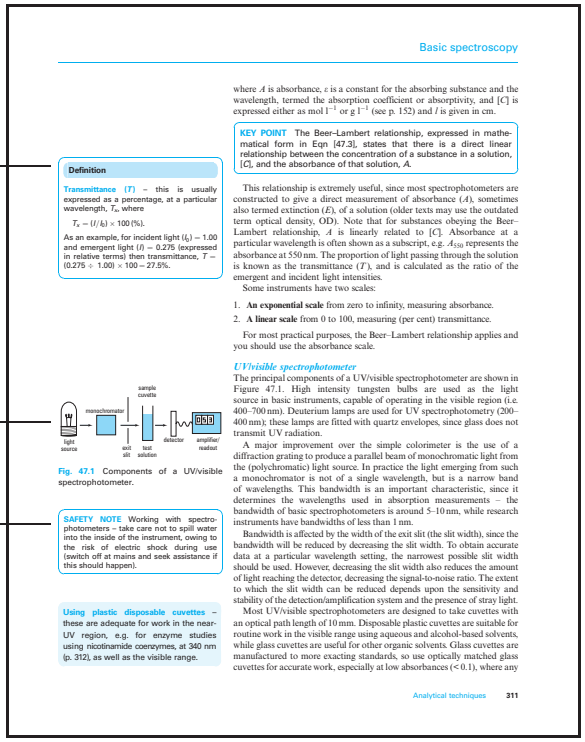
Transferability of skills

Transferable skills are those which allow someone with knowledge, understanding or ability gained in one situation to adapt or extend this for application in a different context. In some cases, the transfer of a skill is immediately obvious. Take, for example, the ability to use a spreadsheet to summarise biological data and create a graph to illustrate results. Once the

Definitions of key terms and concepts are highlighted in the margin.

Figures are used to illustrate key points, techniques and equipment.

Safety Notes highlight specific hazards and appropriate practical steps to minimise risk.



Definition

Transmittance (*T*) – this is usually expressed as a percentage, at a particular wavelength, T_λ, where

$T_\lambda = (I/I_0) \times 100\,(\%)$.

As an example, for incident light (I_0) = 1.00 and emergent light (I) = 0.275 (expressed in relative terms) then transmittance, T = (0.275 ÷ 1.00) × 100 = 27.5%.

where A is absorbance, ε is a constant for the absorbing substance and the wavelength, termed the absorption coefficient or absorptivity, and [C] is expressed either as mol l^{-1} or g l^{-1} (see p. 152) and l is given in cm.

KEY POINT The Beer–Lambert relationship, expressed in mathematical form in Eqn [47.3], states that there is a direct linear relationship between the concentration of a substance in a solution, [C], and the absorbance of that solution, A.

This relationship is extremely useful, since most spectrophotometers are constructed to give a direct measurement of absorbance (A), sometimes also termed extinction (E), of a solution (older texts may use the outdated term optical density, OD). Note that for substances obeying the Beer–Lambert relationship, A is linearly related to [C]. Absorbance at a particular wavelength is often shown as a subscript, e.g. A_{550} represents the absorbance at 550 nm. The proportion of light passing through the solution is known as the transmittance (T), and is calculated as the ratio of the emergent and incident light intensities.

Some instruments have two scales:

1. **An exponential scale** from zero to infinity, measuring absorbance.
2. **A linear scale** from 0 to 100, measuring (per cent) transmittance.

For most practical purposes, the Beer–Lambert relationship applies and you should use the absorbance scale.

UV/visible spectrophotometer

The principal components of a UV/visible spectrophotometer are shown in Figure 47.1. High intensity tungsten bulbs are used as the light source in basic instruments, capable of operating in the visible region (i.e. 400–700 nm). Deuterium lamps are used for UV spectrophotometry (200–400 nm); these lamps are fitted with quartz envelopes, since glass does not transmit UV radiation.

Fig. 47.1 Components of a UV/visible spectrophotometer.

SAFETY NOTE Working with spectrophotometers – take care not to spill water into the inside of the instrument, owing to the risk of electric shock during use (switch off at mains and seek assistance if this should happen).

Using plastic disposable cuvettes – these are adequate for work in the near-UV region, e.g. for enzyme studies using nicotinamide coenzymes, at 340 nm (p. 312), as well as the visible range.

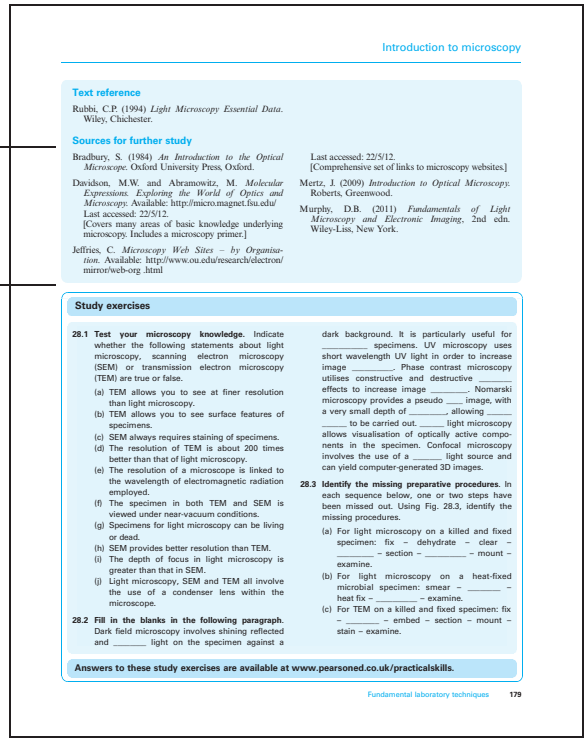
A major improvement over the simple colorimeter is the use of a diffraction grating to produce a parallel beam of monochromatic light from the (polychromatic) light source. In practice the light emerging from such a monochromator is not of a single wavelength, but is a narrow band of wavelengths. This bandwidth is an important characteristic, since it determines the wavelengths used in absorption measurements – the bandwidth of basic spectrophotometers is around 5–10 nm, while research instruments have bandwidths of less than 1 nm.

Bandwidth is affected by the width of the exit slit (the slit width), since the bandwidth will be reduced by decreasing the slit width. To obtain accurate data at a particular wavelength setting, the narrowest possible slit width should be used. However, decreasing the slit width also reduces the amount of light reaching the detector, decreasing the signal-to-noise ratio. The extent to which the slit width can be reduced depends upon the sensitivity and stability of the detection/amplification system and the presence of stray light.

Most UV/visible spectrophotometers are designed to take cuvettes with an optical path length of 10 mm. Disposable plastic cuvettes are suitable for routine work in the visible range using aqueous and alcohol-based solvents, while glass cuvettes are useful for other organic solvents. Glass cuvettes are manufactured to more exacting standards, so use optically matched glass cuvettes for accurate work, especially at low absorbances (< 0.1), where any

Sources for Further Study – every chapter is supported by a section giving printed and electronic sources for further study.

Study exercises are included in every chapter to reinforce learning with problems and practical advice



Introduction to microscopy

Text reference

Rubbi, C.P. (1994) *Light Microscopy Essential Data*. Wiley, Chichester.

Sources for further study

Bradbury, S. (1984) *An Introduction to the Optical Microscope*. Oxford University Press, Oxford.

Davidson, M.W. and Abramowitz, M. *Molecular Expressions. Exploring the World of Optics and Microscopy*. Available: http://micro.magnet.fsu.edu/ Last accessed: 22/5/12. [Covers many areas of basic knowledge underlying microscopy. Includes a microscopy primer.]

Jeffries, C. *Microscopy Web Sites – by Organisation*. Available: http://www.ou.edu/research/electron/mirror/web-org .html Last accessed: 22/5/12. [Comprehensive set of links to microscopy websites.]

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Murphy, D.B. (2011) *Fundamentals of Light Microscopy and Electronic Imaging*, 2nd edn. Wiley-Liss, New York.

Study exercises

28.1 Test your microscopy knowledge. Indicate whether the following statements about light microscopy, scanning electron microscopy (SEM) or transmission electron microscopy (TEM) are true or false.

(a) TEM allows you to see at finer resolution than light microscopy.
(b) TEM allows you to see surface features of specimens.
(c) SEM always requires staining of specimens.
(d) The resolution of TEM is about 200 times better than that of light microscopy.
(e) The resolution of a microscope is linked to the wavelength of electromagnetic radiation employed.
(f) The specimen in both TEM and SEM is viewed under near-vacuum conditions.
(g) Specimens for light microscopy can be living or dead.
(h) SEM provides better resolution than TEM.
(i) The depth of focus in light microscopy is greater than that in SEM.
(j) Light microscopy, SEM and TEM all involve the use of a condenser lens within the microscope.

28.2 Fill in the blanks in the following paragraph. Dark field microscopy involves shining reflected and _____ light on the specimen against a dark background. It is particularly useful for _____ specimens. UV microscopy uses short wavelength UV light in order to increase image _____. Phase contrast microscopy utilises constructive and destructive _____ effects to increase image _____. Nomarski microscopy provides a pseudo ____ image, with a very small depth of _____, allowing _____ _____ to be carried out. _____ light microscopy allows visualisation of optically active components in the specimen. Confocal microscopy involves the use of a _____ light source and can yield computer-generated 3D images.

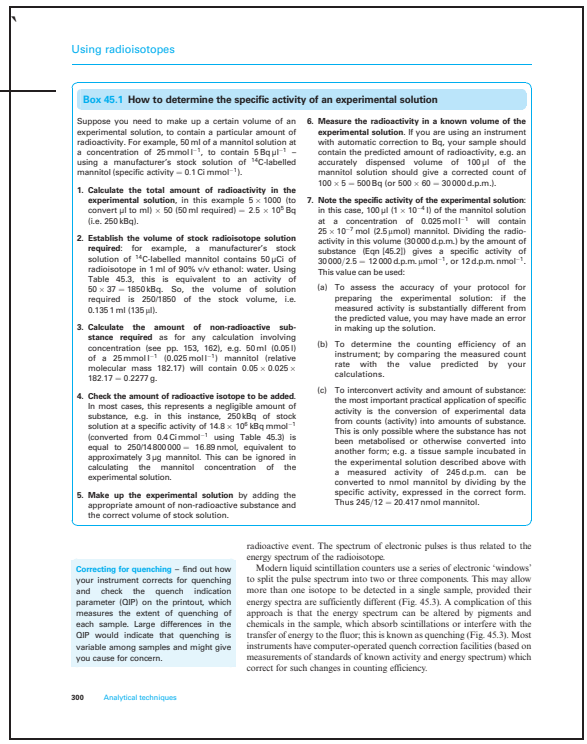
28.3 Identify the missing preparative procedures. In each sequence below, one or two steps have been missed out. Using Fig. 28.3, identify the missing procedures.

(a) For light microscopy on a killed and fixed specimen: fix – dehydrate – clear – _____ – section – _____ – mount – examine.
(b) For light microscopy on a heat-fixed microbial specimen: smear – _____ – heat fix – _____ – examine.
(c) For TEM on a killed and fixed specimen: fix – _____ – embed – section – mount – stain – examine.

Answers to these study exercises are available at www.pearsoned.co.uk/practicalskills.

Fundamental laboratory techniques 179

How to boxes and worked examples set out essential procedures in a step-by-step manner.



Using radioisotopes

Box 45.1 How to determine the specific activity of an experimental solution

Suppose you need to make up a certain volume of an experimental solution, to contain a particular amount of radioactivity. For example, 50 ml of a mannitol solution at a concentration of 25 mmol l^{-1}, to contain 5 Bq μl^{-1} – using a manufacturer's stock solution of ^{14}C-labelled mannitol (specific activity = 0.1 Ci $mmol^{-1}$).

1. **Calculate the total amount of radioactivity in the experimental solution**, in this example 5 × 1000 (to convert µl to ml) × 50 (50 ml required) = 2.5×10^5 Bq (i.e. 250 kBq).
2. **Establish the volume of stock radioisotope solution required**: for example, a manufacturer's stock solution of ^{14}C-labelled mannitol contains 50 µCi of radioisotope in 1 ml of 90% v/v ethanol: water. Using Table 45.3, this is equivalent to an activity of 50 × 37 = 1850 kBq. So, the volume of solution required is 250/1850 of the stock volume, i.e. 0.135 1 ml (135 µl).
3. **Calculate the amount of non-radioactive substance required** as for any calculation involving concentration (see pp. 153, 162), e.g. 50 ml (0.05 l) of a 25 mmol l^{-1} (0.025 mol l^{-1}) mannitol (relative molecular mass 182.17) will contain 0.05 × 0.025 × 182.17 = 0.2277 g.
4. **Check the amount of radioactive isotope to be added.** In most cases, this represents a negligible amount of substance, e.g. in this instance, 250 kBq of stock solution at a specific activity of 14.8 × 10^6 kBq $mmol^{-1}$ (converted from 0.4 Ci $mmol^{-1}$ using Table 45.3) is equal to 250/14 800 000 = 16.89 nmol, equivalent to approximately 3 µg mannitol. This can be ignored in calculating the mannitol concentration of the experimental solution.
5. **Make up the experimental solution** by adding the appropriate amount of non-radioactive substance and the correct volume of stock solution.
6. **Measure the radioactivity in a known volume of the experimental solution**. If you are using an instrument with automatic correction to Bq, your sample should contain the predicted amount of radioactivity, e.g. an accurately dispensed volume of 100 µl of the mannitol solution should give a corrected count of 100 × 5 = 500 Bq (or 500 × 60 = 30 000 d.p.m.).
7. **Note the specific activity of the experimental solution**: in this case, 100 µl (1 × 10^{-4} l) of the mannitol solution at a concentration of 0.025 mol l^{-1} will contain 25 × 10^{-7} mol (2.5 µmol) mannitol. Dividing the radioactivity in this volume (30 000 d.p.m.) by the amount of substance (Eqn [45.2]) gives a specific activity of 30 000/2.5 = 12 000 d.p.m. μmol^{-1}, or 12 d.p.m. $nmol^{-1}$. This value can be used:
   (a) To assess the accuracy of your protocol for preparing the experimental solution: if the measured activity is substantially different from the predicted value, you may have made an error in making up the solution.
   (b) To determine the counting efficiency of an instrument; by comparing the measured count rate with the value predicted by your calculations.
   (c) To interconvert activity and amount of substance: the most important practical application of specific activity is the conversion of experimental data from counts (activity) into amounts of substance. This is only possible where the substance has not been metabolised or otherwise converted into another form; e.g. a tissue sample incubated in the experimental solution described above with a measured activity of 245 d.p.m. can be converted to nmol mannitol by dividing by the specific activity, expressed in the correct form. Thus 245/12 = 20.417 nmol mannitol.

Correcting for quenching – find out how your instrument corrects for quenching and check the quench indication parameter (QIP) on the printout, which measures the extent of quenching of each sample. Large differences in the QIP would indicate that quenching is variable among samples and might give you cause for concern.

radioactive event. The spectrum of electronic pulses is thus related to the energy spectrum of the radioisotope.

Modern liquid scintillation counters use a series of electronic 'windows' to split the pulse spectrum into two or three components. This may allow more than one isotope to be detected in a single sample, provided their energy spectra are sufficiently different (Fig. 45.3). A complication of this approach is that the energy spectrum can be altered by pigments and chemicals in the sample, which absorb scintillations or interfere with the transfer of energy to the fluor; this is known as quenching (Fig. 45.3). Most instruments have computer-operated quench correction facilities (based on measurements of standards of known activity and energy spectrum) which correct for such changes in counting efficiency.

300 Analytical techniques

Preface

> '…there is seen to be a need to re-emphasise the practical nature of the biosciences, through laboratory and fieldwork; and the need for significant levels of numeracy for a subject that is both complex and analytical. …there is an explicit understanding that the biosciences are practical subjects, and cannot be effectively delivered without significant and extensive learning, teaching and experience in a field and/or laboratory environment.'
>
> Foreword, QAAHE Subject Benchmark Statement for Biosciences (QAAHE, 2007)

Practical work forms the cornerstone of scientific knowledge and understanding. Consequently, practical work is an important component of training in the bio-sciences and successful students must develop a number of skills, ranging from those required to observe, measure and record accurately to those associated with operating up-to-date analytical equipment, alongside broader skills involved in teamwork and effective study. In creating this edition, we have maintained the approach of the earlier versions, aiming to support students (and lecturers) in courses where cellular and molecular biosciences form a major component of the syllabus, e.g. biochemistry, biomedical sciences, biotechnology, genetics, microbiology and molecular biology. As before, this support is provided in a concise but user-friendly manner, with key points and definitions, illustrations, worked examples, tips and hints, 'how to' boxes and checklists.

We have used the opportunity of this new edition to update the content and add fresh material on several topics, including new chapters on: bioethics (Chapter 22); stable isotopes (Chapter 44); together with expanded coverage of microbiology (Chapters 35–41). Additional material has been added in other chapters to cover a range of topics, including: graduate attributes, tutorials, peer assessment, active revision (for example, memorisation techniques), bibliographic software and academic writing, including the use of reasoned argument. Overall, the new edition has seven additional chapters. There are also many new figures, plus additional margin tips, key points, examples and definitions. Safety issues are emphasised through the use of 'safety notes'.

Some areas move faster than others and, in particular, those chapters dealing with online resources have seen many changes. An important new addition to this edition is practical advice and guidance on the use of Microsoft *Office 2010* software, including *Word*, *Excel* and *PowerPoint*. Boxes giving details of approaches based on *Office 2003* that appeared in the previous edition will be available through the book's website at www.pearsoned.co.uk/practicalskills. This online resource will include all study exercises and their answers, as well as text references and sources for further study – with 'live' web links, where applicable. We have also updated all references, added many new sources and have checked the availability of all online sources.

We would like to take this opportunity to thank our wives and families for their continued support, and to recognise the following colleagues and friends who have provided assistance, comment and food for thought at various points during the production of all editions: James Abbott, Margaret Adamson, Chris Baldwin, Gary Black, Geoff Bosson, Eldridge Buultjens, Richard Campbell, Bob Cherry, Steve Cummings, Mirela Cuculescu, John Dean, Jackie Eager, Brian Eddy, Neil Fleming, Howard Griffiths, Alan Grant, Rod Herbert, Steve Hitchin, Helen Hooper, Jane Illés, Andy Johnston, Alan Jones, Ian Kill, Rhonda Knox, Lisa Lee-Jones, Phil Manning, Pete Maskrey, Fiona McKie-Bell, Steve Millam, Kirsty Millar, Stephen Moore, Rachel Morris, Lorna Moxham, Bob Newby, Fiona O'Donnell, John Raven, Steve Reed, Pete Rowell, David Sillars, Liz Smith, Peter Sprent, Bill Tomlinson, Ruth Valentine, Lorraine Walsh, Dave Wealleans, Mark White, Will Whitfield, Ian Winship, Bob Young and Hilary-Kay Young. We would also like to thank the staff of Pearson Education for their friendly support over the years, and would wish to acknowledge Pauline Gillett, Owen Knight, Rufus Curnow, Patrick Bond, Simon Lake and Alex Seabrook for their encouragement and commitment to the *Practical Skills* series. Our thanks are also extended to Sarah Beanland, Sue Gard and Mary Lince for their excellent work during the preparation of the new edition. As with the previous editions, we would be grateful to hear of any errors you might notice, so that these can be put right at the earliest opportunity.

ROB REED (r.reed@cqu.edu.au)
DAVID HOLMES (david.holmes@northumbria.ac.uk)
JONATHAN WEYERS (j.d.b.weyers@dundee.ac.uk)
ALLAN JONES (allan.jones9@btinternet.com)

List of abbreviations

A	absorbance (e.g. A_{260} = absorbance at 260 nm)
AC	affinity chromatography
ACDP	Advisory Committee on Dangerous Pathogens
ADP	adenosine diphosphate
ANOVA	analysis of variance
ATP	adenosine triphosphate
BSA	bovine serum albumin
CCCP	carbonylcyanide *m*-chlorophenylhydrazine
CE	capillary electrophoresis
CFU	colony-forming unit
CGE	capillary gel electrophoresis
COSHH	Control of Substances Hazardous to Health
CTP	cytosine triphosphate
CZE	capillary zone electrophoresis
ddNTP	dideoxyribonucleotide triphosphate
DMSO	dimethyl sulfoxide
DNA	deoxyribonucleic acid
d.p.m.	disintegrations per minute
dsDNA	double stranded DNA
dNTP	deoxyribonucleoside triphosphate
ECD	electron capture detector
EDTA	ethylenediaminetetraacetic acid
EI	electron impact ionisation
EIA	enzyme immunoassay
ELISA	enzyme-linked immunosorbent assay
EMR	electromagnetic radiation
EOF	electro-osmotic flow
ESR	electron spin resonance
F	Faraday constant
FIA	fluorescence immunoassay
FID	flame ionisation detector
FPLC	fast protein liquid chromatography
FT	Fourier transformation
g	acceleration due to gravity
GC	gas chromatography
GPC	gel permeation chromatography
HEPES	*N*-[2-hydroxyethyl]piperazine-*N*′-[ethanesulphonic acid]
HIC	hydrophobic interaction chromatography
HPLC	high performance liquid chromatography
IEC	ion-exchange chromatography
IEF	isoelectric focusing
Ig	immunoglobulin
IMAC	immobilised metal affinity chromatography
IR	infrared (radiation)
IRGA	infrared gas analyser
IRMA	immunoradiometric assay
IRMS	isotope ratio mass spectroscopy
ISE	ion selective electrode
K_m	Michaelis constant
K_w	ionisation constant of water
LDH	lactate dehydrogenase
LSD	least significant difference
MEKC	micellar electrokinetic chromatography
MPN	most probable number
M_r	relative molecular mass
MRI	magnetic resonance imaging
MS	mass spectrometry
NAD^+	nicotinamide adenine dinucleotide (oxidised form)
NADH	nicotinamide adenine dinucleotide (reduced form)
$NADP^+$	nicotinamide adenine dinucleotide phosphate (oxidised form)
NADPH	nicotinamide adenine dinucleotide phosphate (reduced form)
NH	null hypothesis
NMR	nuclear magnetic resonance
PAGE	polyacrylamide gel electrophoresis
PAR	photosynthetically active radiation
PCR	polymerase chain reaction
PDP	personal development planning
PEG	polyethylene glycol
PFD	photon flux density
PFU	plaque-forming unit
PGFE	pulsed field gel electrophoresis
pH	$-\log_{10}$ proton concentration (activity), in mol l^{-1}
PI	photosynthetic irradiance
PPFD	photosynthetic photon flux density
PPi	pyrophosphate (inorganic)
PVA	polyvinyl alcohol
PY-MS	pyrolysis-mass spectroscopy
R	universal gas constant
RCF	relative centrifugal field
R_F	relative frontal mobility
RIA	radioimmunoassay
RID	radioimmunodiffusion
RNA	ribonucleic acid
RP-HPLC	reverse phase high performance liquid chromatography

List of abbreviations

r.p.m.	revolutions per minute
RT	reverse transcriptase
SDS	sodium dodecyl sulfate
SE	standard error (of the sample mean)
SEM	scanning electron microscopy
SI	Système International d'Unités
ssRNA	single stranded RNA
STP	standard temperature and pressure
TCA	trichloroacetic acid
TCD	thermal conductivity detector
TEM	transmission electron microscopy
TEMED	*N,N,N′,N′*-tetramethylethylenediamine
TLC	thin layer chromatography
TRIS	tris(hydroxymethyl)aminomethane
TTP	thymidine triphosphate
UNG	uracil-*N*-glycosylase
URL	uniform resource locator
UV	ultraviolet (radiation)
V_{max}	maximum velocity
z	net charge on an ion

Acknowledgements

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Figures

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Tables

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For the student

This book aims to provide guidance and support over the broad range of your undergraduate course, including laboratory classes, project work, lectures, tutorials, seminars and examinations, as outlined below.

Chapters 1–8 cover general skills

These include a number of transferable skills that you will develop during your course, for example: self-evaluation; time management; teamwork; preparing for exams; creating a CV. They also provide guidance on how to study effectively and how to approach examinations and other assessments.

Chapters 9–20 deal with IT, library resources and communication

These chapters will help you get the most out of the resources and information available in your library, and on the World Wide Web, as well as providing helpful guidance on the use of software packages for data analysis, preparing assignments, essays and laboratory reports, alongside support in relation to oral, visual and written forms of communication. The ability to evaluate information is an increasingly important skill in contemporary society, and practical guidance is provided here, as well as more specific advice, e.g. on bioinformatics resources available *via* the Internet.

Chapters 21–68 cover a wide range of specific practical skills required in biomolecular sciences

These are based on the authors' experience of the questions students often ask in practical classes, and the support that is needed in order to get the most out of particular exercises. The text includes tips, hints, definitions, worked examples and 'how to' boxes that set out the key procedures in a step-by-step manner, with appropriate comments on safe working practice. The material ranges from basic laboratory procedures, such as preparing solutions, through specimen collection, identification and manipulation to the more advanced practical procedures that you might use during a final year project, e.g. radioisotope work and more advanced analytical methods.

Chapters 69–74 explain data analysis and presentation

This will be an important component of your course and you will find that these chapters guide you through the skills and techniques required, ranging from the presentation of results as graphs or tables through to the application of statistical tests. Worked examples are used to reinforce the numerical aspects wherever possible.

Study exercises

We added these following comments from students and staff at UK universities, who felt that they would provide a useful opportunity to practise some of the skills covered in the book and a check on the understanding of the material. We hope that the exercises will be useful both to learners and to their tutors: some of the exercises are based on material contained within the corresponding chapter, while others provide opportunities to develop understanding in a particular topic area beyond the basic materials. In general, the more straightforward exercises have been placed first, with more advanced problems at the end of each section.

Most of the exercises and problems assume that students are working on their own, using the information supplied; however, tutors might wish to provide alternative starting material (e.g. a set of data from a practical class). We have also assumed that students will have access to a scientific calculator and, sometimes, to a networked PC with typical 'office' programs (especially word processor and spread-sheet), plus Internet access *via* a modem and browser. Where a library is mentioned, this is assumed to include access to standard reference works and a selection of scientific journals.

We recommend that students work together for some exercises – this is a valuable means of learning and, where there is no single correct answer to a problem, teamwork provides a mechanism for checking and discussing different approaches. Answers are provided on the book's website at www.pearsoned.co.uk/practicalskills. For numerical problems, the working out is shown with the final answer, while, for non-numerical exercises, 'answers' are provided in the form of tips, general guidance or illustrative examples, etc.

We hope that you will find this book and its companion website a helpful guide throughout your course, and beyond.

Study and examination skills

1 The importance of transferable skills

Skills terminology – different phrases may be used to describe transferable skills and associated personal qualities, depending on place or context. These include: 'graduate attributes', 'personal transferable skills' (PTS), 'key skills', 'core skills' and 'competences'.

This chapter outlines the range of transferable skills and their significance to biomolecular scientists. It also indicates where practical skills fit into this scheme. Having a good understanding of this topic will help you place your work at university in a wider context. You will also gain an insight into the qualities that employers expect you to have developed by the time you graduate. Awareness of these matters will be useful when carrying out personal development planning (PDP) as part of your studies.

The range of transferable skills

Table 1.1 provides a comprehensive listing of university-level transferable skills under six skill categories. There are many possible classifications – and a different one may be used in your institution or field of study. Note particularly that 'study skills', while important, and rightly emphasised at the start of many courses, constitute only a subset of the skills acquired by most university students.

Using course materials – study your course handbook and the schedules for each practical session to find out what skills you are expected to develop at each point in the curriculum. Usually the learning objectives/outcomes (p. 30) will describe the skills involved.

The phrase '*Practical Skills*' in the title of this book indicates that there is a special subset of transferable skills related to work in the laboratory. However, although this text deals primarily with skills and techniques required for laboratory practicals and associated studies, a broader range of material is included. This is because the skills concerned are important, not only in the biosciences but also in the wider world. Examples include time management, evaluating information and communicating effectively.

KEY POINT Biomolecular sciences are essentially practical subjects, and therefore involve highly developed laboratory skills. The importance that your lecturers place on practical skills will probably be evident from the large proportion of curriculum time you will spend on practical work in your course.

Example The skills involved in teamwork cannot be developed without a deeper understanding of the interrelationships involved in successful groups. The context will be different for every group and a flexible approach will always be required, according to the individuals involved and the nature of the task.

The word 'skill' implies much more than the robotic learning of, for example, a laboratory routine. Of course, some of the tasks you will be asked to carry out in practical classes *will* be repetitive. Certain techniques require manual dexterity and attention to detail if accuracy and precision are to be attained, and the necessary competence often requires practice to make perfect. However, a deeper understanding of the context of a technique is important if the skill is to be appreciated fully and then transferred to a new situation. That is why this text is not simply a 'recipe book' of methods and protocols and why it includes background information, tips and worked examples, as well as study exercises to test your understanding.

Transferability of skills

Transferable skills are those which allow someone with knowledge, understanding or ability gained in one situation to adapt or extend this for application in a different context. In some cases, the transfer of a skill is immediately obvious. Take, for example, the ability to use a spreadsheet to summarise biological data and create a graph to illustrate results. Once the

Table 1.1 Transferable skills identified as important in the biosciences. The list is based on several sources, including the most recent UK Quality Assurance Agency for Higher Education Subject Benchmark Statement for the Biosciences and for Biomedical Sciences. Particularly relevant chapters are shown for the skills covered by this book (numbers in **bold coloured** text indicate a deeper, or more extensive, treatment)

Skill category	Examples of skills and competences	Relevant chapters in this textbook
Generic skills for bioscientists	Having an appreciation of the complexity and diversity of life and life processes	12, 30, 35–40, 56–59
	Reading and evaluating biological literature with a full and critical understanding	4, 9, **10**
	Capacity to communicate a clear and accurate account of a biological topic, both verbally and in writing	**15**, **16**, **17**, **18–20**
	Applying critical and analytical skills to evaluate evidence regarding theories and hypotheses	10, **32**
	Using a variety of methods for studying the biosciences	35–68
	Having the ability to think independently, set personal tasks and solve problems	32, 34, 72
Intellectual skills	Recognising and applying biological theories, concepts and principles	10, 32
	Analysing, synthesising and summarising information critically	10, 20, 70–74
	Obtaining evidence to formulate and test hypotheses; applying knowledge to address familiar and unfamiliar problems	30–34, 74
	Recognising and explaining moral, ethical and legal issues in biological research	**22**, 23, 35, 36, 40
Experimental (practical) and observational skills	Carrying out basic laboratory techniques and understanding the principles that underlie them	**21**, 22–31, 42–47, 55, 64
	Working in the laboratory safely, responsibly and legally, with due attention to ethical aspects	**21**, 23, 34–41
	Designing, planning, conducting and reporting on biological investigations and data arising from them	15, 16, 19, **32**, 34
	Obtaining, recording, collating and analysing biological data	30–34, 42–54, 69–74
	Carrying out basic techniques relevant to core subjects in biomedical science (biochemistry, molecular genetics, immunology, microbiology)	21–29, 30–41, 42–54, 64–68
Numeracy, communication and IT skills	Understanding and using data in several forms (e.g. numerical, textual, verbal and graphical)	4, 10, 70–74
	Communicating in written, verbal, graphical and visual forms	**15**, **16**, **17**, 18–20, **70**, **71**, 72
	Citing and referencing the work of others in an appropriate manner	**9**, 10, 20
	Obtaining data, including the concepts behind sampling and sampling errors, calibration and types of error	29, 30–34, **42**, 72–74
	Processing, interpreting and presenting data, and applying appropriate statistical methods for summarising and analysing data	12, 70–72, **73**, **74**
	Solving problems with calculators and computers, including the use of tools such as spreadsheets	11, **12**, 13, 21, **72**
	Using computer technology to communicate and as a source of biological information	**11**, **12**, 13, **14**
Interpersonal and teamwork skills	Working individually or in teams as appropriate; identifying individual and group goals and acting responsibly and appropriately to achieve them	**3**
	Recognising and respecting the views and opinions of others	3
	Evaluating your own performance and that of others	3, 8
	Appreciating the interdisciplinary nature of contemporary biosciences	1, 20
Self-management and professional development skills	Working independently, managing time and organising activities	2, 32, 34
	Identifying and working towards targets for personal, academic and career development	1, **8**
	Developing an adaptable and effective approach to study and work (including revision and exam technique)	2, 4, 5, 6, **7**

key concepts and commands are learned (Chapter 13), they can be applied to many instances outside the biosciences where this type of output is used. This is not only true for similar data sets, but also in unrelated situations, such as making up a financial balance sheet and creating a pie chart to show sources of expenditure. Similarly, knowing the requirements for good graph drawing and tabulation (Chapters 70 and 71), perhaps practised by hand in earlier work, might help you use spreadsheet commands to make the output suit your needs.

Other cases may be less clear but equally valid. For example, towards the end of your undergraduate studies you may be involved in designing experiments as part of your project work. This task will draw on several skills gained at earlier stages in your course, such as preparing solutions (Chapters 24–27), deciding about numbers of replicates and experimental layout (Chapters 32 and 34) and perhaps carrying out some particular method of observation, measurement or analysis (Chapters 42–68). How and when might you transfer this complex set of skills? In the workplace, it is unlikely that you would be asked to repeat the same process, but in critically evaluating a problem or in planning a complex project for a new employer, you will need to use many of the time management, organisational and analytical skills developed when designing and carrying out experiments. The same applies to information retrieval and evaluation and writing essays and dissertations, when transferred to the task of analysing or writing a business report.

Opportunities to develop and practise skills in your private or social life – you could, for example, practise spreadsheet skills by organising personal or club finances using Microsoft *Excel*, or teamwork skills within any university clubs or societies you may join (see Chapter 7).

Personal development planning

Many universities have schemes for personal development planning (PDP), which may go under slightly different names such as progress file or professional development plan. You will usually be expected to create a portfolio of evidence on your progress, then reflect on this, and subsequently set yourself plans for the future, including targets and action points. Analysis of your transferable skills profile will probably form part of your PDP (Box 1.1). Other aspects commonly included are:

- **your aspirations, goals, interests and motivations;**
- **your learning style or preference** (see p. 25);
- **your assessment transcript or academic profile information** (e.g. record of grades in your modules);
- **your developing CV** (see p. 45).

Taking part in PDP can help focus your thoughts about your university studies and future career. This is important, as many biosciences degrees do not lead only to a single, specific occupation. The PDP process will introduce you to some new terms and will help you to describe your personality and abilities. This will be useful when constructing your CV and when applying for jobs.

Types of PDP portfolio and their benefits – some PDP schemes are centred on academic and learning skills, while others are more focused on career planning. Some are carried out independently and others in tandem with a personal tutor or advisory system. Some PDP schemes involve creating an online portfolio, while others are primarily paper-based. Each method has specific goals and advantages, but whichever way your scheme operates, maximum benefit will be gained from being fully involved with the process.

Definition

Employability – the 'combination of in-depth subject knowledge, work awareness, subject-specific, generic and career management skills, and personal attributes and attitudes that enable a student to secure suitable employment and perform excellently throughout a career spanning a range of employers and occupations.' *(Higher Education Academy Centre for Bioscience* definition of employability for bioscientists)

Graduate attributes and employability

The skills emphasised in biology courses (Table 1.1) are sometimes considered alongside a university-wide framework of graduate attributes that are intended to summarise the qualities and skills that an employer might expect in those with qualifications from your institution. The

Box 1.1 How to carry out a simple skills audit

1. **Create a list of appropriate skills.** As noted on p. 3, there are many systems for categorising skills. If your university publishes a specific skill set, e.g. as part of its framework for personal development planning (PDP) or graduate attributes, then you should use that. If not, you could adapt the listing in Table 1.2 or consult a text like McMillan and Weyers (2009). Your list should relate to you personally, your intended career and any specific skills associated with your intended qualification.
2. **Lay out your list in table format.** You will need to create a table using a word processor or spreadsheet program. Your table should have four columns, as shown in Table 1.2.
3. **Rate your skills.** This may be challenging for many students as it is difficult to be objective and tough to gauge employer expectations. A confident student may rate a certain skill strongly, while a self-critical person may consider the same level of skill to be deficient. However, this does not matter too much as you will effectively be comparing yourself at different stages in your learning, rather than judging yourself against an outside standard. The suggested method is to use a scale of 1 to 10, with low values indicating that the skill 'needs lots of development' and high values indicating that, *for the time being*, your competence is 'well above average'.
4. **Note actions.** This especially applies to skills with low scores in the previous column – and you may wish to prioritise certain ones. You will need to think about ways in which you could improve, and this may require some research on your part. Is there a book you could read? Is there a training workshop you could attend? Could an extracurricular activity help you to develop? Should you sign up to speak to a skills advisor? It is important that you recognise that the solution to any deficiencies you perceive lies in your own hands. At university, no one will do the work for you.
5. **Add comments and progress notes.** Here is where you can add any comments to amplify or assist with the action points. The addition of progress notes implies that you will revisit the list from time to time. If your university PDP system allows you to add the list to a portfolio, then do this.

Inevitably, your skills audit will become out of date after a period. It will still be useful, however, to look back at it so that you can see how you have progressed. This will give a sense of achievement and self-awareness that could be valuable when speaking to careers advisors and potential employers. You may wish to set up a new list at intervals, perhaps at the start of each academic year.

Table 1.2 One possible way of creating a personal skills audit. The second row provides guidance about the content of each column. The third row provides an example of possible content.

Skill	Rating at [date] with notes	Proposed actions	Comments and notes on progress
You should be quite specific. It may be a good idea to subdivide complex skills like 'communication'	Provide a realistic evaluation of your competence in the skill at a specific point in time	This column will note what you intend to do to try to improve the skill. You might tick these off as completed	This column will summarise your progress. You may wish to add a revised rating
Giving spoken presentations	4/10 [3 March 2011] Wasn't satisfied with presentation to tutorial group – nervous, a little disorganised and ppt too 'wordy'	1. Read Ch 14 in Practical Skills in Biology ✓ 2. Learn how to use advanced features of PowerPoint ✓ 3. Ask more questions in tutorials ✓	Gave second presentation to tutorial group; went well, although quite nervous at start. Slides much better. Make sure not to rush the introduction next time. 7/10

associated notion of 'graduateness' summarises the effect of degree-level experience and learning on an individual. This in turn is connected with the concept of 'employability' which encompasses those skills and qualities required to gain and maintain employment. An understanding of these terms is important for every student, as this not only leads to a better understanding of the value of certain activities and assessments,

but also provides a specialised vocabulary and gives insights about personal and career development.

At the end of your course, which may seem some time away, you will aim to get a job and start on your chosen career path. You will need to sell yourself to your future employer, firstly in your application form and curriculum vitae (Chapter 8), and perhaps later at interview. Companies rarely employ bioscience graduates simply because they know how to carry out a particular lab routine or because they can recall specific facts about their chosen degree subject. Instead, they will be looking for a range of graduate level skills and attributes. Typically, for example, they will seek employees who can demonstrate the ability to work in a team, to speak effectively and write clearly about their work. All of these skills and attributes can be developed at different stages during your university studies.

KEY POINT Factual knowledge is important in degrees with a strong vocational element, but understanding how to find and evaluate information is usually rated more highly by employers than the ability to memorise facts.

Most likely, your future employer(s) will seek someone with an organised yet flexible mind, capable of demonstrating a logical approach to problems – someone who has a range of skills and who can transfer these skills to new situations. Many competing applicants will probably have similar qualifications. If you want the job, you will have to show that your additional skills place you above the other candidates.

Text references

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Sources for further study

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Study exercises

1.1 Evaluate your skills. Examine the list of skill topics shown in Table 1.1 (p. 4). Now create a new table with two columns, like the one shown opposite. The first half of this table should indicate *five* skills you feel confident about and show where you demonstrated the skill (for example, 'working in a team' and 'in a first year group project in molecular biology'). The second half of the table should show *five* skills you do not feel confident about, or that you recognise need development (e.g. 'communicating in verbal form'). List these and then list ways in which you think the course material for your current modules will provide opportunities to develop these skills, or what activities you might take to improve them (e.g. 'forming a study group with colleagues').

Skills I feel confident about	Where demonstrated
1.	
2.	
3.	
4.	
5.	
Skills that I could develop	Opportunities for development
6.	
7.	
8.	
9.	
10.	

1.2 Find skills resources. For at least one of the skills in the second half of Table 1.1, check your university's library database to see if there are any texts on that subject. Alternatively, carry out a search for relevant websites (there are many); decide which are useful and 'bookmark' them for future use (Chapter 11).

1.3 Analyse your goals and aspirations. Spend a little time thinking about what you hope to gain from university. See if your friends have the same aspirations. Think about and/or discuss how these goals can be achieved, while keeping the necessary balance between university work, paid employment and your social life.

Answers to these study exercises are available at www.pearsoned.co.uk/practicalskills.

2 Managing your time

Definition

Time management – a system for controlling and using time as efficiently and as effectively as possible.

One of the most important activities that you can do is to organise your personal and working time effectively. There is a lot to do at university and a common complaint is that there isn't enough time to accomplish everything. In fact, research shows that most people use up a lot of their time without realising it through ineffective study or activities such as extended coffee breaks. Developing your time management skills will help you achieve more in work, rest and play, but it is important to remember that putting time management techniques into practice is an individual matter, requiring a level of self-discipline not unlike that required for dieting. A new system won't always work perfectly straight away, but through time you can develop a system that is effective for you. An inability to organise your time effectively, of course, results in feelings of failure, frustration, guilt and being out of control in your life.

Setting your goals

The first step is to identify clearly what you want to achieve, both in work and in your personal life. We all have a general idea of what we are aiming for, but to be effective, your goals must be clearly identified and priorities allocated. Clear, concise objectives can provide you with a framework in which to make these choices. Try using the 'SMART' approach, in which objectives should be:

- **Specific** – clear and unambiguous, including what, when, where, how and why.
- **Measurable** – having quantified targets and benefits to provide an understanding of progress.
- **Achievable** – being attainable within your resources.
- **Realistic** – being within your abilities and expectations.
- **Timed** – stating the time period for completion.

Example The objective 'to spend an extra hour each week on directed study in microbiology next term' fulfils the SMART criteria, in contrast to a general intention 'to study more'.

Having identified your goals, you can now move on to answer four very important questions:

1. **Where does your time go?**
2. **Where should your time go?**
3. **What are your time-wasting activities?**
4. **What strategies can help you?**

Advantages of time management – these include:

- a feeling of much greater control over your activities;
- avoidance of stress;
- improved productivity – achieve more in a shorter period;
- improved performance – work to higher standards because you are in charge;
- increase in time available for non-work matters – work hard, but play hard too.

Analysing your current activities

The key to successful development of time management is a realistic knowledge of how you currently spend your time. Start by keeping a detailed time log for a typical week (Fig. 2.1), but you will need to be truthful in this process. Once you have completed the log, consider the following questions:

- **How many hours do I work in total and how many hours do I use for relaxation?**
- **What range of activities do I do?**