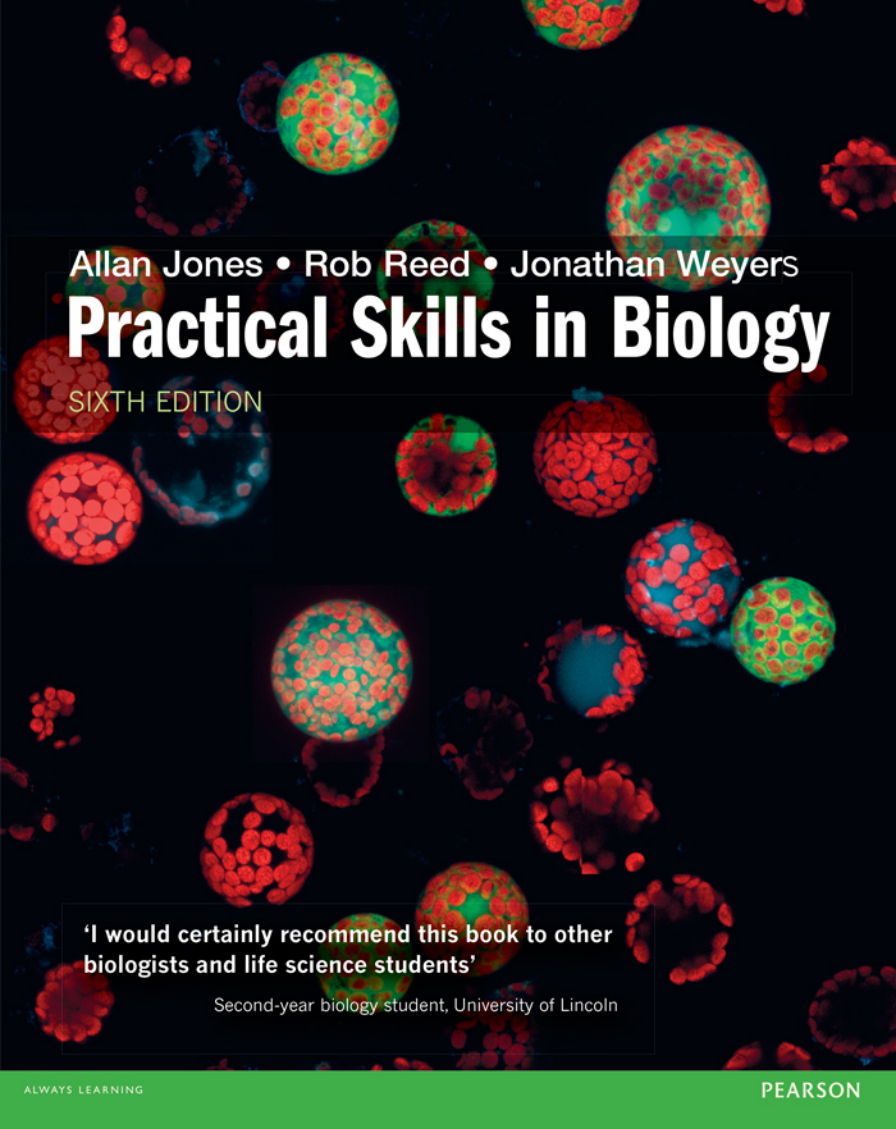

Allan Jones • Rob Reed • Jonathan Weyers

Practical Skills in Biology

SIXTH EDITION

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Second-year biology student, University of Lincoln

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Practical Skills in Biology

Sixth Edition

Allan Jones
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List of boxes

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Preface to the sixth edition

The biosciences exist in an environment of current hypotheses rather than certainty, where natural variation occurs and can confuse empirical data. Knowledge of research design and the appropriate use of statistical analysis to enable a valid interpretation of experimental results is required. The biosciences are essentially practical and experimental subjects. Students are required to undertake appropriate practical education throughout their programme, which is progressive in nature and designed to supplement other academic learning.

> *Draft Subject Benchmark Statement for Biosciences* (2015) Quality Assurance Agency for Higher Education. Available: http://www.qaa.ac.uk/en/Publications/Documents/SBS-Biosciences-consultation-15.pdf. Last accessed 18/07/15.

All knowledge and theory in biology have originated from observation and experiment. As a result, laboratory and field work are important components of undergraduate training, and successful students develop a number of practical 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 the sixth edition of *Practical Skills in Biology,* we have maintained the approach of the previous editions, with the aim of supporting students (and lecturers) over a wide range of practical topics. As before, this is provided in a concise but user-friendly manner, with key points and definitions, illustrations and worked examples, tips and hints, 'How to' boxes and checklists and 'Safety note' boxes where appropriate.

This new edition consolidates the changes made for the fifth edition, which included additional material covering environmental investigations, chemical analysis, photosynthesis and respiration, stable isotopes and electrophoresis. We have completely revised and updated the text references and sources for further study, and incorporated over 50 new tips, figures, tables and boxes. Throughout the book we have changed the guidance regarding Microsoft *Office* software to apply in a generic sense rather than to any specific version. This may mean that readers may need to adjust commands if these are not appropriate. Guidance on specific commands and their syntax can usually be found using the software's help facility. Boxes giving details of approaches based on *Office 2003* and *Office 2007* that appeared in previous additions will be made available via the book's online resource at www.pearsoned.co.uk/practicalskills. This website continues to host the answers to the study exercises as well as text references and sources for further study – with live web links where applicable.

We should 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 six editions: Richard A'Brook, Margaret Adamson, Gail Alexander, Steve Atkins, Janet Aucock, Chris Baldwin, Abdellah Barekate, Gary Black, Geoff Bosson, Olivia Bragg, Sally Brown, Eldridge Buultjens, Richard Campbell, Cathy Caudwell, Bob Cherry, Mirela Cuculescu, John Dean, Charlie Dixon, Jackie Eager, Brian Eddy, Charmain Elder, Neil Fleming, Jennifer Gallacher, Karen Gowlett-Holmes, Alan Grant, Margaret Gruver, Mhairi Haggerty, Bryan Harrison, Rod Herbert, Dave Holmes, Helen Hooper, David Hopkins, Steve Hubbard, Jane Illés, Hugh Ingram, Wendy James, Andy Johnston, Alan Jones, Lorraine Kay, Ian Kill, Rhonda Knox, Lisa Lee-Jones, Phil Manning, Pete Maskrey, Fiona McKie-Bell, Steve Millam, Kirsty Millar, Stephen Moore, Rachel Morris, Fiona O'Donnell, Roy Oliver, Neil Paterson, John Raven, Steve Reed, Pete Rowell, David Sillars, J. Andrew C. Smith, Philip Smith, Susan Smith, Peter Sprent, Rob Sunley, Bill Tomlinson, Ruth Valentine, Lorraine Walsh, Dave Wealleans, Will Whitfield, Ian Winship, Bob Young and Hilary-Kay Young.

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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 examinations; creating a CV. They also provide guidance on how to study effectively and how to approach examinations and assessments.

Chapters 9-19 deal with IT, learning resources and communicating information

These chapters will help you get the most out of the resources and information available in your library, and on the Web, as well as providing helpful guidance on the use of software packages for data analysis, preparing assignments, essays and laboratory reports, etc. The ability to evaluate information is an increasingly important skill in contemporary society, and practical advice is provided here.

Chapters 20-70 cover a wide range of specific practical skills required in biology

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.

Chapters 71-76 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 and problems

We added these as a new feature in the third edition, following comments from students and staff at UK universities, who felt that it 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 continue be useful both to learners and to their tutors.

Most of the problems assume 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 spreadsheet), 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, we provide 'answers' in the form of tips, general guidance or illustrative examples, etc.

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

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Figures

Figure 40.2 adapted from *New Flora of the British Isles*, 2nd edn, Cambridge University Press (Stace, C.A. 1997) Cambridge University Press, Cambridge; Figure 54.1 from www.ukgbc.org/site/document/download/?document_id=556, http://jncc.defra.gov.uk/, Joint Nature Conservation Committee; Figure 56.2 from *Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys*, 2nd edn, ftp://ftp-fc.sc.egov.usda.gov/NSSC/Soil_Taxonomy/tax.pdf, US Government Printing Office, Washington. USA; Figure 58.1 from *Methods for Physical and Chemical Analysis of Fresh Waters*, 2nd edn, Blackwell Scientific (Golterman, H.L., Clymo, R.S. and Ohnstad, M.A.M. 1978) No 8, Wiley-Blackwell; Figure 58.3 adapted from *Methods for Physical and Chemical Analysis of Fresh Waters*, 1st edn, Blackwell Scientific, Oxford (Golterman, H.L.,Clymo, R.S. and Ohnstad, M.A.M. 1978) Wiley-Blackwell; Figure 66.2 from http://ppsystems.com/co2-gas-analyzers/, www.ppsystems.com, PP Systems; Figure 67.1 from http://www.fisher.co.uk/index.php/en/component/searchenhanced/, www.fisher.co.uk, Fisher Scientific UK Ltd, Thermo Fisher Scientific.

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Table 54.1 after *National Vegetation Classification: Users' Handbook*, Joint Nature Conservation Committee (Rodwell, J.C. 2006) Joint Nature Conservation Committee; Tables 54.3 and 54.4 from Age specific survivorship and reproduction in *Phlox drummondii*, *The American Naturalist*, 113, pp. 881–903 (Leverlich, W.J. and Levin, D.A. 1979), University of Chicago Press; Table 58.2 from *The Biology of Seaweeds*, University of California Press (Luning, K.J. Editors: C.S. Lobban and .J. Wynne 1981) pp. 326–55, University of California Press; Table 58.2 from *The Biology of Seaweeds* by Lobban, Christopher S.; Wynne, Michael J. Reproduced with permission of Blackwell Scientific via Copyright Clearance Center.

Text

Box 5.1 adapted from A Guide to Learning Preferences, vark-learn.com, Version 7.1 (2011) held by Neil D. Fleming, Christchurch, New Zealand.

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(Key: b-bottom; c-centre; l-left; r-right; t-top)

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List of abbreviations

A	absorbance
A_r	relative atomic mass
ACDP	Advisory Committee on Dangerous Pathogens
ADP	adenosine diphosphate
ANOVA	analysis of variance
ATP	adenosine triphosphate
ASA	American Standards Association
BOD	biological (or biochemical) oxygen demand
BSA	bovine serum albumin
CD	compact disc
CE	capillary electrophoresis
CFU	colony-forming unit
CGE	capillary gel electrophoresis
CIEF	capillary isoelectric focusing
COD	chemical oxygen demand
COSHH	Control of Substances Hazardous to Health
CoV	coefficient of variance
CZE	capillary zone electrophoresis
DCMU	3-(3′,4′-dichlorphenyl)-1,1-dimethylurea
DCPIP	2,6-dichlorophenol-indophenol
DEFT	direct epifluorescence technique
d.f.	degrees of freedom
DIN	Deutsches Institut fur Normung
DMO	5,5-dimethyl-2,4-oxazolidinedione
DNA	deoxyribonucleic acid
DNP	dinitrophenol
DO	dissolved oxygen
d.p.m.	disintegrations per minute
DTT	dithiothreitol
EC	electron capture
EDTA	ethylenediaminetetraacetic acid
EI	electron impact ionisation
EIA	enzyme immunoassay
ELISA	enzyme-linked immunosorbent assay
EM	electron microscopy
EMI	extended matching items
EMR	electromagnetic radiation
ESR	electron spin resonance
F	Faraday constant
FAA	formalin acetic acid
FTP	file transfer protocol
g	acceleration due to gravity
GA	graduate attributes
GC	gas chromatography
GFP	green fluorescent protein
GMO	genetically modified organism
GPS	global positioning system
HCG	human chorionic gonadotrophin
HEPA	high-efficiency particulate air
HEPES	*N*-[2-hydroxyethyl]piperazine-*N*′-[2-ethanesulphonic acid]
HPLC	high-performance liquid chromatography
HRP	horseradish peroxidise
IAPSO	International Association for Physical Sciences of the Ocean
IEF	isoelectric focusing
Ig	immunoglobulin
IPTG	isothiopropylgalactoside
IR	infrared (radiation)
IRGA	infrared gas analyser
IRMA	immunoradiometric assay
IRMS	isotope ratio mass spectrometry
ISO	International Organization for Standardization
*K*m	Michaelis constant
*K*w	ionisation constant of water
LAN	local area network
LM	light microscopy
LOI	loss on ignition
LSD	least significant difference
M	molar (mol l^{-1})
MCQ	multiple-choice question
MECC	micellar electrokinetic capillary chromatography
MEL	maximum exposure limits
MMR	measles-mumps-rubella
MPN	most probable number
MRI	magnetic resonance imaging
M_r	relative molecular mass
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
NPQ	non-photochemical quenching
NTU	national turbidity unit
OC	organic carbon
OD	optical density
OES	occupational exposure standards
OM	organic matter
PAGE	polyacrylamide gel electrophoresis
PAM	pulse-amplified modulated
PAR	photosynthetically active radiation
PBL	problem-based learning
PCR	polymerase chain reaction
PDP	personal development planning

PEG	polyethylene glycol
PFD	photon flux density
PFU	plaque-forming unit
pH	$-\log_{10}$ proton concentration (activity), in mol m^{-1}
PI	photosynthetic irradiance
pK_a	$\log_{10}$ acid dissociation constant
PM	particulate materials
PMF	proton-motive force
PPFD	photosynthetic photon flux density
PQ	photosynthetic quotient
PS II	photosystem II
PTS	personal transferable skills
QIP	quench indication parameter
R	universal gas constant
RCF	relative centrifugal field
rDNA	recombinant deoxyribonucleic acid
R_F	relative frontal mobility
RIA	radioimmunoassay
RID	radioimmunodiffusion
RNA	ribonucleic acid
RP-HPLC	reverse phase high-performance liquid chromatography
r.p.m.	revolutions per minute
SAQ	short-answer question
SD	standard deviation
SDS	sodium dodecyl sulphate
SE	standard error (of the sample mean)
SEM	scanning electron microscopy
SI	Systeme Internationale d'Unités
SLR	single lens reflex
SPM	selectively permeable membrane
STP	standard temperature and pressure
T	absolute temperature (in kelvin)
TCA	tricarboxylic acid
TEM	transmission electron microscopy
TEMED	tetramethylethylenediamine
TLC	thin-layer chromatography
TMB	tetramethylbenzidine
TPMD	tetramethylphenylenediamine
TPP^+	tetraphenylphosphonium
TRIS	tris(hydroxymethyl)aminomethane *or* 2-amino-2-hydroxymethyl-1,3-propanediol
TS	transverse section
TTL	through the lens
URL	uniform resource locator
USB	Universal Serial Bus
UV	ultraviolet (radiation)
V_{max}	maximum velocity
WWW	World Wide Web
XGAL	5-bromo-4-chloro-3-indolyl-β-D-galactoside (62)

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Study and examination skills

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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 biologists. It also indicates where practical skills fit into this scheme. Having a good understanding of this topic will help you place your studies 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 help 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 outline the skills involved.

The phrase '*Practical Skills*' in the title of this book indicates that there is a special area of transferable skills related to work in the laboratory or field. However, although this text deals primarily with skills and techniques required for laboratory practicals, fieldwork 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 Biology is essentially a practical subject, and therefore involves highly developed laboratory and field 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 fully 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 why it includes background information, tips and worked examples, as well as study exercises to test your understanding.

Transferability of skills

'Transferability' implies that someone with knowledge, understanding or ability gained in one situation can 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 key concepts and commands are learned (Chapter 13), they can be applied to

Table 1.1 Transferable skills identified as important in the biosciences. The list is based on the UK Quality Assurance Agency for Higher Education *Subject Benchmark Statement for the Biosciences* (QAA, 2007). Particularly relevant chapters are shown for the skills covered by this book (numbers in **bold** blue text indicate a deeper, or more extensive, treatment)

Skill category	Examples of skills and competences	Relevant chapters in this textbook
Generic skills for biologists	Having an appreciation of the complexity and diversity of life and life processes	36–8; **39**; 40–1; 61–2
	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	**14–16**; 17–19
	Applying critical and analytical skills to evaluate evidence regarding theories and hypotheses in biology	10; **33**
	Using a variety of methods for studying biology	36–70
	Having the ability to think independently, set personal tasks and solve problems	33; 35; **74**
Intellectual skills	Recognising and applying biological theories, concepts and principles	10; 33
	Analysing, synthesising and summarising information critically	10; 71–6
	Obtaining evidence to formulate and test hypotheses; applying knowledge to address familiar and unfamiliar problems	27–32; **33**; 34–5
	Recognising and explaining moral, ethical and legal issues in biological research	**21**; 22; 31; 36; 40
Experimental (practical) and observational skills	Carrying out basic laboratory and field techniques and understanding the principles that underlie them	**20**; 22–31; 34; 40–1; 43–5
	Working in lab or field safely, responsibly and legally, with due attention to ethical aspects	20–1; **22**; 31; 35–6; 38; 42
	Designing, planning, conducting and reporting on biological investigations and data arising from them	15; 18; 31; **33**; 35; 52
	Obtaining, recording, collating and analysing data in the field and laboratory	27; 29; **31**; 32–3; 36–41; **51**; **52**; 53–8; **71**; 72–6
Numeracy, communication and IT skills	Understanding and using data in several forms (e.g. numerical, textual, verbal and graphical)	4; 10; 29; 71–4
	Communicating in written, verbal, graphical and visual forms	**14**, **15**, **16**; 17–19; **72**; **73**; 74
	Citing and referencing the work of others in an appropriate manner	**9**
	Obtaining data, including the concepts behind sampling and sampling errors, calibration and types of error	29; **32**; 33; **34**; **53**; 71; 74; **75**; 76
	Processing, interpreting and presenting data, and applying appropriate statistical methods for summarising and analysing data	71–4; **75**; **76**
	Solving problems with calculators and computers, including the use of tools such as spreadsheets	11; **12**; **20**; **74**
	Using computer technology to communicate and as a source of information in biology	**11**; 12; **13**
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 biology	1; 19
Self-management and professional development skills	Working independently, managing time and organising activities	**2**; 31; 33; 35
	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)	**5**; **6**; **7**

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 72 and 73), 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 23–26), deciding about numbers of replicates and experimental layout (Chapters 32 and 33) and perhaps carrying out some particular method of observation, measurement or analysis (Chapters 42–70). 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 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. 23);
- **your assessment transcript or academic profile information** (e.g. record of grades in your modules);
- **your developing CV** (see p. 45).

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. They may be carried out independently or possibly in tandem with a personal tutor or advisory system. Certain 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 fully involving yourself in the process.

Taking part in PDP can help you to focus your thoughts about your university studies and future career. This is important in biology, because most biological sciences degrees do not lead only to a 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.

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.' (Anon, 2015: Higher Education Academy Centre for Bioscience, *Define Employability in the Context of Teaching Bioscience*).

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 associated notion of 'graduateness' summarises the effect of degree-level

Box 1.1 How to carry out a personal 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 PDP or graduate attributes (GA), then you should use that. If not, you could adapt the listing in Table 1.1 or consult a text such as McMillan and Weyers (2013). 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, you feel 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 adviser? 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 so you can see how you have progressed. This will give a sense of achievement and self-awareness that could be valuable when speaking to academic tutors or careers advisers 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 [3rd March 2012] Wasn't satisfied with presentation to tutorial group – nervous, a little disorganised and ppt too 'wordy'	1. Read Ch 15 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

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 notions 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 can be 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 and personal attributes place you above the other candidates.

Text references

Anon. *Define employability in the context of teaching bioscience*. Available at http://www.bioscience.heacademy.ac.uk/ftp/events/empforum/definition.pdf Last accessed 12/02/15. [Part of the HE Academy Centre for Bioscience website.]

McMillan, K.M. and Weyers, J.D.B. (2013) *The Study Skills Book,* 3rd edn. Pearson Education, Harlow.

QAA (2007) *Subject benchmark statement – Biosciences 2007.* Available: http://www.qaa.ac.uk/academicinfrastructure/benchmark/statements/biosciences07.asp Last accessed 12/02/15. [Part of the Quality Assurance Agency Academic Infrastructure.]

Sources for further study

Drew, S. and Bingham, R. (2010) *The Guide to Learning and Study Skills.* Gower Publishing Ltd, Aldershot.

Race, P. (2007) *How to Get a Good Degree: Making the Most of Your Time at University*, 2nd edn. Open University Press, Buckingham.

STUDY EXERCISES

1.1 Evaluate your skills. Examine the list of skill topics shown in Table 1.1. Now create a new table with two columns, like the one on the right-hand side. The first half of this table should indicate *five* skills you feel confident about in column 1 and show where you demonstrated this skill in column 2 (for example, 'working in a team' and 'in a first year group project on marine biology'). The second half of the table should show *five* skills you do not feel confident about, or you recognise need development (e.g. communicating in verbal form). List these in column 1 and in column 2 list ways in which you think the course material and activities in your current modules will provide you with the opportunity to develop these skills.

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

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.	

1.3 Analyse your goals and aspirations. Spend a little time thinking 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.

Advantages of time management – these include:

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

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'.

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 is just not 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 will not always work perfectly straight away, but through time you can evolve 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.

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?**

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?**