SCHOOL OF BIOLOGICAL SCIENCES

INTERMEDIATE SKILLS MANUAL

A manual for all students taking Intermediate units of study in the School of Biological Sciences
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PREFACE

The Intermediate Skills Manual has been prepared as part of the Generic Skills Program in the School of Biological Sciences, which has the aim of developing the generic skills needed by Biology students and graduates.

In several places throughout this manual you will be advised to consult reference books or Websites for further information. These sites include those prepared in conjunction with this manual, sites prepared by the School of Biological Sciences Teaching Development Unit, and sites from sources outside the School that cover certain areas particularly well. There is a Generic Skills site linked to the eLearning (Blackboard) sites for your Intermediate subjects. This is one source of additional information and also includes answers to some of the questions and exercises in this manual.

The Faculty of Science Generic Attributes statement is on the next page and gives a general guide to the sorts of skills and attributes all graduates should possess when they complete their degree. You should be developing all of these skills throughout your studies. A number of these areas are directly addressed in this manual, specifically those relating to research and inquiry, information literacy and communication, and practical skills, such as data handling and hypothesis testing. You should refer to the relevant sections for assistance when preparing assignments, reports and presentations. Intellectual, ethical, social and professional attributes will be constantly addressed through your course assignment work, participation in classwork and daily interactions with your colleagues and teachers.

In 2004, the College of Sciences and Technology developed a Website that provides a mechanism for you to track your skills development during your time at university, so that you can easily use this information when you apply for a job. The site is at http://www.lifelonglearning.science.usyd.edu.au/. All students are strongly advised to use this site throughout your degree.

The Generic Skills Coordinator for the School of Biological Sciences is Dr Elizabeth May. You can send any comments or suggestions relating to this manual, or any general questions you might have about generic skills and attributes, by email to: elizabeth.may@sydney.edu.au
FACULTY OF SCIENCE

GRADUATE ATTRIBUTES STATEMENT

Research and Inquiry. Graduates of the Faculty of Science will be able to create new knowledge and understanding through the process of research and inquiry.

A1. Apply scientific knowledge and critical thinking to identify, define and analyse problems, create solutions, evaluate opinions, innovate and improve current practices.

A2. Gather, evaluate and deploy information relevant to a scientific problem.

A3. Design and conduct investigations, or the equivalent, and analyse and interpret the resulting data.

A4. Critically examine the truth and validity in scientific argument and discourse, and evaluate the relative importance of ideas.

A5. Disseminate new knowledge and engage in debate around scientific issues.

A6. Value the importance of continual growth in knowledge and skills, and recognise the rapid and sometimes major changes in scientific knowledge and technology.

Information Literacy. Graduates of the Faculty of Science will be able to use information effectively in a range of contexts.

B1. Use a range of searching tools (such as catalogues and databases) effectively and efficiently to find information.

B2. Access a range of information sources in the science disciplines, for example books, reports, research articles, patents and company standards.

B3. Critically evaluate the reliability and relevance of information in a scientific context.

B4. Consider the economic, legal, social, ethical and cultural issues in the gathering and use of information.

B5. Use information technology to gather, process, and disseminate scientific information.

Communication. Graduates of the Faculty of Science will recognise and value communication as a tool for negotiating and creating new understanding, interacting with others, and furthering their own learning.

C1. Explain and present ideas to different groups of people in plain English.

C2. Write and speak effectively in a range of contexts and for a variety of different audiences and purposes.

C3. Use symbolic and non-verbal communication, such as pictures, icons and symbols as well as body language and facial expressions, effectively.
C4. Present and interpret data or other scientific information using graphs, tables, figures and symbols.

C5. Work as a member of a team, and take individual responsibility within the group for developing and achieving group goals.

C6. Take a leadership role in successfully influencing the activities of a group towards a common goal.

C7. Actively seek, identify, and collaborate with others in a professional and social context.

**Ethical, Social and Professional Understanding.** *Graduates of the Faculty of Science will hold personal values and beliefs consistent with their role as responsible members of local, national, international and professional communities.*

D1. Demonstrate an understanding of the significance and scope of ethical principles, both as a professional scientist and in the broader social context, and a commitment to apply these principles when making decisions.

D2. Appreciate the importance of sustainability and the impact of science within the broader economic, environmental and socio-cultural context.

D3. Demonstrate empathy with, and sensitivity towards, another's situation, feelings and motivation.

**Personal and Intellectual Autonomy.** *Graduates of the Faculty of Science will be able to work independently and sustainably, in a way that is informed by openness, curiosity and a desire to meet new challenges.*

E1. Evaluate personal performance and development, recognise gaps in knowledge and acquire new knowledge independently.

E2. Demonstrate flexibility in adapting to new situations and dealing with uncertainty.

E3. Reflect on personal experiences, and consider their effect on personal actions and professional practice.

E4. Set achievable and realistic goals and monitor and evaluate progress towards these goals.

E5. Demonstrate openness and curiosity when applying scientific understanding in a wider context.
COMMUNICATION SKILLS

The University of Sydney has a strong commitment to the fostering of effective communication skills in students and graduates. One of the primary attributes of a science graduate should be the ability to communicate effectively with persons both within and outside their scientific field. Communication comprises both oral and written forms and includes poster presentations, essays, practical reports, production of Web pages, seminar presentations, and, ultimately, journal manuscripts and conference presentations. In first year Biology, the focus was on laboratory report writing and you were given the opportunity to improve your reports by submitting a draft report. You may have been required to give oral presentations of your posters in certain units of study. The on-line learning module Writing a Report in Biology is still available for reference on Blackboard for your Intermediate units of study.

Increasingly, the emphasis in employment is on the skills demonstrated by an applicant, as well as their knowledge and experience. Your University degree will be taken as an indicator not only that you possess a certain body of knowledge but also that you are capable of carrying out all the expected tasks of a working scientist. Employers will assume that you are capable of independent work in the office, laboratory and field environment; that you can apply scientific principles and management skills to a research task; that you can organize your work; and that you can be involved in management of cooperative tasks. In particular, an employer will assume and, more often than not, look for evidence that a University science graduate can write, and write well. We therefore allocate part of your biology curriculum to developing communication skills.

Of course, by second year, many students feel that they already ‘know how to write’. However, the majority of academic staff do not necessarily share this view. It is the role of the academic staff to assist you not only to develop your writing skills but also to develop your ability to assess your achievement in this area and diagnose areas where you need further help. Many of us recognize that we, too, are in the lifelong process of honing our own skills throughout our careers. What we provide in these notes are some directives and guidelines to help you further develop the skills you require as a Science student and graduate. For some of you, they will provide remedial help in areas where you have had less experience.
SCIENTIFIC WRITING

"After all, what are the chief differentiae between man and the brute creation but that he clothes himself, that he cooks his food, that he uses articulate speech? Let us cherish and improve all these distinctions."  Sir Arthur Quiller-Couch, On the art of writing.

The requirements for writing a report were provided to you in First Year and you should be fairly proficient in that style of scientific writing by now. In Intermediate courses you will need to further develop your writing skills and take time to develop an appropriate scientific style of communication. Brief notes on writing a practical report, an essay and a literature review are given below and in specific sections of this manual. The following section on Scientific Writing is more related to the effective use of English and gives details on general scientific writing style, scientific conventions and grammar.

Using the English language to communicate scientific findings does not come easily to most people. Choosing the correct words and using correct grammar are skills now rarely taught in schools, so many University students are at some disadvantage. The following notes are designed to encourage you to think more carefully about how effectively you write and to give you an introduction to the format and conventions required for different types of written scientific works. There are a number of questions, written in italics, throughout the text. You should answer these as you work through the notes. Answers to certain questions are available at the Generic Skills Website: http://sydney.edu.au/science/biology/learning/generic_skills/

1. INTRODUCTION

Good research is meaningless unless you can communicate your findings in a clear and interesting fashion. The days in which scientific papers were works of great literature is past but we can still strive to make our writing informative and worth reading. Woods (1989) wrote ‘The purpose of any writing other than lecture notes or pieces that start with “Dear Diary” is to influence your reader. If you are writing great fiction you may move your reader to tears. This can also happen with scientific writing, but generally you do not want to make your reader weep.’ (We hope this does not happen when we mark your essays!)

The importance of good writing cannot be over-emphasized. In many cases the written word is the only means by which scientists communicate and it is the main way in which students communicate with, and are assessed by, their teachers. The quotations below are several published thoughts by University lecturers:

‘...for a student to succeed in a science course, and to become an adequate scientific practitioner, [he/she] must have better expression skills than are necessary for almost any other course or vocation. Vagueness, ambiguity and inability to express clearly and succinctly are intolerable in a scientist.’  (Towns, 1990)
‘Offer me a choice: two [University] entrants of the same IQ (if such a measure can, for a moment, be accepted as valid). Both have natural curiosity about science,¹ and sensible ambition. One has inadequate chemistry but good literacy skills, the other the converse. Which do I feel has the greater chance, given strong motivation, of succeeding in a science degree and beyond? Well, I shall take the literate one. Those who disagree with me are quite welcome to the other.’ (Towns, 1990)

‘The fundamental purpose of scientific discourse is not the mere presentation of information and thought, but rather its actual communication. It does not matter how pleased an author might be to have converted all the right data into sentences and paragraphs; it matters only whether a large majority of the reading audience accurately perceives what the author had in mind.’ (Gopen and Swan, 1990)

And from Sir Arthur Quiller-Couch, a professor of literature at Cambridge University, circa 1916:

“You have been told, I daresay often enough, that the business of writing demands two – the author and the reader. Add to this what is equally obvious, that the obligation of courtesy rests first with the author, who invites the séance, and commonly charges for it. What follows, but that in speaking or writing we have an obligation to put ourselves into the hearer’s or reader’s place? It is his comfort, his convenience, we have to consult. To express ourselves is a very small part of the business and almost unimportant as compared with impressing ourselves: the aim of the whole process is to persuade. (On the Art of Writing, p 163)

Whether you are writing an essay, literature review or the discussion in a practical report, you will have the task of presenting a logical series of facts and reasoned argument to your reader. Your sentences and paragraphs should be in a logical order so that the reader can easily follow your argument and reach the same conclusion you have. Each paragraph should be able to stand on its own and be internally cohesive. A long piece of writing can be made more readable if you use subheadings to organize the prose into sections. Be cautious about writing the first phrase that comes into your head and get into the habit of writing several drafts of any report or essay.

You want your reader to understand what you are writing, to maintain respect for you and not to become annoyed with you. This can be done if you write simply, succinctly and without grammatical errors. Correct spelling is also a great help!

**A note on computer spellcheckers**

Correcting a final draft of a piece of writing is not something that can be left to the efforts of the spellchecker in your word processing program. They are useful for a first scan of your work but they are not infallible and will miss many errors, for example:

- if you have used *there* instead of *their*, the spellchecker will not recognize it as a mistake as the words are correctly spelt;

¹ Refer to page 20 for discussion of the ‘Oxford comma’.
- if you have typed the instead of then, the Spellchecker will ignore it as the is correctly spelt.

Remember to select an English/Australian dictionary in your word processing program, especially if you use Autocorrect, so that American spellings are not accepted in your work. (Note that some computer ‘Australian-English’ dictionaries accept American spelling. The words center, hemoglobin, anemia, and color are NOT English.) See Appendix 1 for a cautionary tale about Spellcheckers.

N.B. If you use computers on campus or you are connected to the University of Sydney server from your home computer you can access the Complete Oxford English Dictionary at http://www.oed.com.ezproxy2.library.usyd.edu.au/. You will need to login with your Unikey or library borrower’s number.

A note on computer grammarcheckers
Hmm! Several years ago I would have suggested that you not waste your time with them. However, they have improved recently and are useful for picking up repeated words, non-sentences, multiple spaces between words and my favourite, the correct usage of ‘that’ and ‘which’. (See entry under 3.2 Common errors of word usage.)

2. TYPES OF SCIENTIFIC LITERATURE
‘Keeping up with the literature’ is a common obsession of successful scientists. That ominous phrase ‘the literature’ generally refers to the published journal and review papers on a particular subject.

2.1 Journal papers and practical reports
A journal paper reports the results of original research. As an undergraduate you will be required to write reports on laboratory and fieldwork; these correspond in purpose and style to journal papers. You have received instruction on how to write a laboratory report in First Year and there are further instructions on report writing later in this manual. See also pages 63 - 68 of Lindsay (1984).

2.2 Literature reviews and essays
A review paper presents the previously published facts and theories in a particular field but is more than a mere catalogue of previous literature. A good review is a critical summary or synthesis of the current knowledge in that field. It should highlight areas in which further research should be carried out and should stimulate readers to carry out this research. It should point out any deficiencies or inaccuracies in previous research. The author of a review is free to use his own interpretation and opinion, e.g. ‘I believe Brown (1980) is mistaken because ...’. Such interpretations must be supported by sound reasoning (note the word ‘because’) and normally result from years of experience in the field.
Communication

As an undergraduate you will write essays or literature reviews, which correspond to review papers. You do not have the experience of the average review author but it should still be possible to inject some originality into your review, rather than just presenting a catalogue of facts. You can reassess the conclusions of the original authors in the light of more recent knowledge and compare and contrast the results and conclusions of different authors.

3. WORDS

3.1 Save trees! (and eschew terminological obfuscation!)

‘Use words with precision and economy to construct sentences that are exact, clear and as simple as the subject permits.’

CBE Style Manual.

Many students have a tendency to write in a flowery fashion and use many more words than are really necessary in order to tell their reader what they want to say. The previous sentence, for example, could be written: Many students use flowery language and more words than necessary to say what they want. There are no extra marks for writing long-winded, convoluted sentences, or using seven-syllable words. In scientific writing only your ability to communicate clearly is on trial. Compare the following lists of wordy and concise statements:

<table>
<thead>
<tr>
<th>Wordy</th>
<th>Concise</th>
</tr>
</thead>
<tbody>
<tr>
<td>... if conditions are such that...</td>
<td>... if...</td>
</tr>
<tr>
<td>... in order to...</td>
<td>... to...</td>
</tr>
<tr>
<td>... there can be little doubt that this is</td>
<td>... this probably is...</td>
</tr>
<tr>
<td>... plants exhibited good growth...</td>
<td>... plants grew well...</td>
</tr>
<tr>
<td>... bright green in colour...</td>
<td>... bright green...</td>
</tr>
<tr>
<td>... by means of...</td>
<td>... by/with...</td>
</tr>
<tr>
<td>... created the possibility...</td>
<td>... made possible...</td>
</tr>
<tr>
<td>... due to the fact that...</td>
<td>... because...</td>
</tr>
<tr>
<td>... fewer in number...</td>
<td>... fewer...</td>
</tr>
<tr>
<td>... for the reason that...</td>
<td>... because, since...</td>
</tr>
<tr>
<td>... in all cases...</td>
<td>... always...</td>
</tr>
<tr>
<td>... in view of the fact that...</td>
<td>... since, because...</td>
</tr>
<tr>
<td>... it is often the case that...</td>
<td>... often...</td>
</tr>
<tr>
<td>... it is possible that the cause is...</td>
<td>... the cause may be...</td>
</tr>
<tr>
<td>... it would appear that...</td>
<td>... apparently...</td>
</tr>
</tbody>
</table>
In the early twentieth century, W. H. Fowler was commissioned by Oxford University Press to write a book on English usage. He and his brother Frank had previously produced *The Concise Oxford Dictionary* and *The King’s English*. Following his brother’s death, W.H. Fowler proposed to his publisher that he write an ‘idiom dictionary’, for the ‘half-educated Englishman of literary proclivities who ... has idioms floating in his head in a jumbled state and knows it.’ The project was eventually accepted and the book was published in 1926 as *The Oxford Guide to Modern English Usage*. It is still regarded as the final word on grammar and word usage. Fowler formulated five simple rules as a starting point for good writing; more recent authors have modified these rules and they can be summarized as follows:

1. **Prefer the familiar word to the unfamiliar word**  
   (*e.g.* ‘linkage’ rather than ‘concatenation’)

2. **Prefer the concrete word to the abstract word**  
   (*e.g.* ‘Investigate’ rather than ‘Make an investigation into’)  
   (verb)                                              (noun)

3. **Prefer the active voice to the passive voice**  
   (*e.g.* ‘Our experiments show’ rather than ‘It has been shown by our experiments’)

4. **Prefer the single word to the round-about phrase**  
   (*e.g.* ‘because’ rather than ‘due to the fact that’)

5. **Prefer the short word to the long word**  
   (*e.g.* ‘orient’ rather than ‘orientate’)

The rules are in order of merit and 2. and 3. make a similar point. Fowler’s final rule was to prefer the Saxon word to the Romance; however, recent authorities suggest that strict adherence to this rule would beggar the richness of the English language. Quiller-Couch (1916) was critical of the Saxon Rule, as well as 5. in the list above, describing both as “precepts you would have to modify by so long a string of exceptions that I do not commend them to you”. He is all for number 2., however, exclaiming “How vile a thing...is the abstract noun! It wraps a man’s thoughts round like cotton wool.”

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2 His lectures were, of course, directed only to “Gentlemen”, as no woman had yet been admitted to the hallowed halls of Cambridge in 1916. His lecture on *Jargon* is worth reading for those who wish to write concise prose. Imagine my excitement to learn that the full text of his collection of lectures, *On the Art of Writing*, can be read online at [http://hdl.handle.net/2027/uc1.32106001648978](http://hdl.handle.net/2027/uc1.32106001648978).
Question 1. Rewrite the following sentences using as few words as possible.

(a) It is generally thought that the most common reason for the difference in experimental results in biological experiments can be said to be due to the large amount of variability between individuals of any population that is being studied.

(b) The question of whether or not students should be expected to pay tuition fees continues to be under debate.

(c) Use a great deal of care to ensure that your fingers do not come into contact with the bunsen flame.

The references provided (end of section 8) contain many more examples but the message is the same: your first thought or written sentence will usually be more wordy than necessary, so read critically and remove non-essential words and phrases.

3.2 Common errors of word usage

Good communication in science requires exactness. The following words are often confused. Learn the differences between them (or suffer the wrath of your lecturers and demonstrators!). Consult the glossary (section 9) for the meanings of grammatical terms.

Affect and effect

These two words have very different meanings and are regularly misused.

Affect is a verb. e.g. Stomatal closing affects the temperature of a leaf.

Effect is (in most cases) a noun. e.g. Stomatal closing has a significant effect on leaf temperature.

There is one case in which effect is used as a verb: when it means ‘to cause or bring about’, as in to effect a change. If you have trouble with the distinction between these two words refer to any of the references on usage. (Any student guilty of their misuse will be severely penalized and held up for general censure.)

Alternate and alternative

Alternate = ‘occur or arrange by turns’. e.g. TV programmes during the non-ratings period alternate between awful and terrible.

Alternative implies that a choice is possible. e.g. The alternative to watching these appalling programmes is to hire DVDs.

Consist of and comprise

Consist(s) takes the preposition of but comprise(s) does not. e.g. A virus consists of a core of nucleic acid and a protein coat; Your Intermediate classwork comprises lectures, practicals and tutorials.

(Use comprise only when ALL of the components are listed - if they are not, then use include. e.g. in the statement Your Intermediate classwork includes lectures and practicals, comprise would be incorrect.)
However
This word has a very specific meaning and is too often used when but will suffice. There is an extended explanation of its correct usage at the Generic Skills Grammatical Tip of the Week site.

It’s and Its
It’s is the contraction of it is or it has. Its is the possessive pronoun and has no apostrophe.

e.g. ‘It’s a long way to the top’; The garden snail gets its helical shape through the process of torsion.

Similarly the possessive pronouns hers, ours and yours have no apostrophe.

Less and fewer
Take note our illiterate politicians!

Less = ‘a smaller amount of’ and takes a singular noun.

e.g. There is less work available during a recession.

Fewer = ‘a smaller number of’ and takes a plural noun.

e.g. There are fewer jobs available during a recession.

From Column 8 ‘An ex-teacher of Turramurra sympathizes with her former colleagues’ problems but wishes they would be a bit more careful with their advertising stickers. ‘Less teachers, pupils suffer’ was what she read on a Commodore window at Fairfield. ‘Fewer, please,’ she pleads.’

Problematic plurals
The word data is plural. e.g. Data are tabulated in Fig. 1. The singular is datum and is rarely used.

* Bacterium is singular. e.g. The bacterium E. coli is the microbiologist’s white rat. The plural is bacteria. e.g. Bacteria are killed by various antibiotics.

* Medium is singular. e.g. The bacteria were cultured in a nutrient medium. The plural is media. e.g. Several different media were used to culture different strains of bacteria.

* Phenomenon is singular. e.g. An interesting phenomenon. The plural is phenomena. e.g. These phenomena are odd.

* Criterion is singular, meaning ‘standard by which something is judged.’ e.g. One criterion for success is...
The plural is criteria. e.g. The criteria for awarding the prize are ... (Note the form of the verb ‘to be’ in each case.)

* The plural of taxon is two or more taxa.

* The plural of genus is two or more genera.
* The plural of **phylum** is two or more **phyla**.

* **There is** and **There are** are frequently misused. **There is** or **There’s** can only precede a singular entity. *e.g.* **There’s several reasons** ... **incorrect!** This should be written **There are several reasons** ...

(Note: ‘**There’s too many of you**’ (Temple scene, *Jesus Christ Superstar*) is **incorrect!**) No-one in the Australian media knows the distinction between these two forms, especially advertisers. Listen carefully the next time you turn on the television or the radio and be appalled!

**Shall and will, should and would**

**Shall** and **should** express obligation. **Will** and **would** express determination or resolve. 
*e.g.* **He should be more careful.** **You would say that!**

(Legend has it that a Scotsman once drowned because he cried ‘I will drown and no-one shall save me’ and the Englishmen on the bank took him at his word!)

Many pages in formal usage texts are devoted to the distinction between the use of **shall** in the first person and **will** in the second and third person to express simple futurity (1 and 2) or as an auxiliary (3 and 4).
*e.g.* 1. **I shall go.** 2. **You/he/she will go.** 3. I **should like to thank you.** 4. **He would like to come.**

In common practice it is now acceptable to use **will/would** for all persons and using **shall** and **should** is considered archaic by some authorities. The first person **should** must still be used for formal writing, especially in formal correspondence. (Remember this if you write to the Queen’s private secretary.) (On no account may you address any letter to the Queen personally.) (Debrett’s Correct Form)

**That and which**

Use **that** at the beginning of a defining (restrictive) clause. (See glossary)
*e.g.* **Each student should write a list of the references that they used in their essay.**

The clause **that they used in their essay** defines a particular set of references. It is **not** separated from the main clause by commas.

Use **which** for a non-defining (non-restrictive) clause. (See glossary)
*e.g.* **Students should refer to a large number of references, which are found in the library.**

The clause **which are found in the library** simply provides further information about references in general. It is separated from the main clause by commas.

(To anyone who has a copy of Burchfield’s revised edition of Fowler’s Modern English Usage, which allows the use of **which** in a defining clause, I would recommend burning it at once.)
Note that **who** replaces **that** and **which** when you are referring to particular people. The rule about placing a comma before a non-defining clause remains the same (refer to the doctor example in the glossary.)

**There, their and they’re**

Compare the following:

‘**There** is a house in New Orleans ...’

Their house is in New Orleans.

They’re (they are) living in a house in New Orleans.

**Various, varying and variable**

**Various** means ‘of several kinds’. **Varying** and **variable** imply changing from one kind to another.

*e.g.* Nets of varying mesh size are used to collect different sized organisms from plankton implies that a net is capable of changing its mesh size, and is incorrect.

**Words and phrases to avoid**

being; though; furthermore; in addition; Firstly, Secondly, Thirdly at the beginning of a series of sentences. A well-structured piece of prose does not need these navigational terms. (I have read some student writing in which every sentence in certain paragraphs begins with furthermore.)

**Adding word endings – to double or not to double?**

To work out whether words such as offer, occur, refer, level, *etc.* take a double letter when you add a word ending, say the word out loud. If the emphasis is on the second syllable, double the last letter of the stem word. If the emphasis is on the first syllable, do not double the last letter. Hence: occurred, offered, referred, labeled.

(Note: There is no double ‘r’ in ‘reference’ because the emphasis is on ‘ref-‘, not ‘-er’. There is a double ‘r’ in ‘referral’ because the emphasis is on the ‘-er’)

**Read on**

This is not an exhaustive list, merely some of the very worst offenders. Fowler (1965), Gowers (1986), Partridge (1973) and the *The Oxford Miniguide to English Usage* include extensive lists of similarly confused words and they make fascinating reading. If you are in any doubt at all about the correct usage of words you are using then look them up in any (or all) of these references. Check the Generic Skills Website for further advice and links to English usage sites.
3.3 Scientific conventions and nomenclature

Use of italics

Specific names of organisms are written using a capital letter for the genus name (*Homo*) and a small letter for the species epithet (*sapiens*). Italics are used for specific names in printed works, but in handwritten reports the entire specific name should be underlined (don’t bother trying to hand-write italics!). Do not underline or italicize any other taxonomic names (such as class and family names).

*e.g.* The fat-tailed dunnart, *Sminthopsis crassicaudata*, is a member of the Family Dasyuridae.

Or: The fat-tailed dunnart, *Sminthopsis crassicaudata*, is a member of the Family Dasyuridae.

The second time the same species name is used in the one document, you can abbreviate the genus name, UNLESS it occurs at the beginning of a sentence (as abbreviations should NEVER be used at the beginning of a sentence). Beware the automated insertion of a capital letter after a fullstop if you are using Word. Proofread your work! Ensure that species names are also italicized in your reference list!

Further usage rules for generic and specific names:

* **DO NOT** use a definite article (the) or indefinite article (a) in front of a species or genus name. *e.g.* “*Schistosoma* is an unusual trematode, as it is gonochoristic”. **DO NOT** write “The *Macropus rufus*.”

* **DO NOT** make plurals of specific or generic names.

* **DO NOT** use apostrophes with specific or generic names: Write “The limbs of *Balanus*”; NOT “*Balanus’s* (or *Balanus’*) limbs”.

* Verbs relating to species names should be in the singular, *e.g.* “*Macropus rufus* is Australia’s largest extant marsupial.” **NOT** “*Macropus rufus* are ...”. And write the full genus name at the start of a sentence!

Italics (or underlining) are also used for foreign words, especially Latin terms such as *in vivo*, *in vitro*, *a priori*, *exemplia gratia* (*e.g.*), *id est* (*i.e.*), *etc.*

Taxon names and common names

All generic and specific names should be underlined or italicised, including those in your reference list. No other taxon names should be underlined or italicized. All names of taxa above the rank of genus should start with a capital letter. However, if the name of a taxon is used as a common name (which will have a different ending to the taxon name) then it starts with a lower case letter.

*e.g.* The Family Dasyuridae includes quolls.

Quolls and *Antechinus spp.* are dasyurids.

Experience shows that dasyurid teeth are very sharp.
The endings of taxon names are standardized, although the standards are different for zoological, botanical and bacteriological taxa. In the Zoological Code, superfamily names end in -oidea, family names in -idae, and subfamily names in -inae. 

*e.g.* The Superfamily Vombatoidea includes the Families Vombatidae and Phascolarctidae. Phylum, class and order names have various endings, although many end in -a.

In the Botanical Code, class names end in -ida, order names end in -ales, and family names end in -aceae.

Some journals require the common names of species to be written with a capital letter (*e.g.* the Koala) but there is no absolute convention for this. If you use the convention of writing a capital letter for common names, be consistent throughout the work. Remember this convention applies only in reference to one species: you can write the Red Kangaroo, but NOT Kangaroos, as there are many species of kangaroos.

**Abbreviations**

If you wish to use an abbreviation for a chemical or generic name, write the full name the first time it appears in the text. *e.g.* Glyceraldehyde 3-phosphate is converted to 1,3-diphosphoglycerate (1,3-DPG). Henceforth in the same manuscript you can simply refer to 1,3-DPG (unless it is at the beginning of a sentence). The second time you refer to the fat-tailed dunnart you can use *S. crassicaudata*. Never abbreviate the species part of a scientific name (*e.g.* you must always write *crassicaudata* in full).

*Do not* use an abbreviation at the beginning of a sentence. Avoid using abbreviations in a summary or abstract, unless the same expression is to be used several times within the summary itself. You should also avoid using contractions such as don’t, can’t, wasn’t, etc. in scientific works.

**Numbers and numerals**

Always write the full word for single digit numbers (*e.g.* five, not 5). For double-digit numbers, write the numerals (*e.g.* 35, 287).

---

**4. SENTENCES**

The Oxford English Dictionary defines a sentence as ‘a series of words in connected speech or writing, forming the grammatically complete expression of a single thought.’ A sentence must contain a **subject** and a **verb that directly relates** to the subject. More formally this definition is expressed as a **subject** and a **predicate**, where predicate refers to what is said about the subject.

**Subordinate clauses - or how to write a non-sentence**

A **common error** is to mistake a subordinate clause (containing a verb) for a complete sentence. A subordinate clause (preceded by words such as that, which, who, if, although) provides extra information about the main clause and **cannot** exist on its own as a complete sentence. (See the glossary for further information on clauses.)
e.g. The birds that migrate to southern Europe, where the climate is milder. is not a sentence. It does contain verbs but neither of them directly relates to the subject of the sentence - The birds. Compare the true sentence The birds migrate to southern Europe, where the climate is milder. in which the verb migrate directly relates to the subject.

A good way to check that you have written a true sentence is to read it without the subordinate clauses and check whether it makes sense. In the first example above, the clause that migrate to southern Europe defines the birds and the clause where the climate is milder gives more information about southern Europe. If you leave out these clauses it reads The birds, and this is clearly not a sentence. In the second example, the shortened sentence reads The birds migrate to southern Europe, and this is a true sentence.

Though and although precede a subordinate clause and that clause alone does not constitute a sentence. e.g. Though it looked like rain. is a non-sentence.

Question 2. (a) Which of the following are true sentences?
(b) Rewrite any ‘non-sentences’ to make them true sentences.
(i) The forest ecosystem that is currently under threat from logging, vandalism and the impact of feral cats and foxes.
(ii) The sheep rumen contains large populations of protists, fungi and bacteria, which break down cellulose.
(iii) Although the experimental conditions were optimal.

Keep your subordinate clauses close to the subject. A classic example of misplaced clauses is: Rugby is a game played by men with funny shaped balls. And this was written in a New Zealand train timetable: The carriages are comfortable, fully carpeted and are equipped with wool-covered seats featuring large panoramic windows. Similar confusion can be created by ordering adjectives in the wrong way: owners of a koala sanctuary asked readers of Column 8 to send them ‘used women’s stockings’ to tie up their sapling eucalypts. The editor agreed to print the request provided the wording was changed to ‘women’s used stockings’.

The present participle - or how to write a non-sentence
The following examples illustrate a common student error - that of using the present participle (that’s the verb form that ends in ‘ing’) in place of the present or past tense.

e.g. The blue whale being the largest mammal on Earth. (should read The blue whale is the largest mammal on Earth.)

My advice is if you have used (or have the slightest inclination to use) a verb ending in ‘ing’ in your writing then BEWARE. Take some time to ensure that the sentence makes grammatical sense. ASK ME if in doubt! Let’s refer back to the definition of a sentence, as containing a subject and verb that directly relates to the subject: being the largest mammal on Earth is a subordinate clause and the word being does not relate directly to the subject (The blue whale).
Verb agreement - or how to write a nonsensical sentence

Do not write sentences that are so long that the reader loses track of the main point. Split any such sentence into smaller ones. Keep the subject and verb close together, as this will help you to avoid errors of tense and of verbs not agreeing with their subject.

**Question 3.** What is wrong with the following sentence? Rewrite it (using more than one sentence) to make it grammatically correct.

*The lion, which lives in Africa where it is greatly feared by the natives and which feeds on kudu, eland, gnus, wildebeeste, zebras and a wide variety of other animals, which are usually stalked and killed by the lionesses, are savage.*

5. PUNCTUATION

“But I know how to use punctuation!” I hear you cry. To use that immortal line from the movie *Betrayal*, I would reply: “Are you sure?” Here are a few brief and very introductory pointers on correct punctuation. Refer to any of the suggested references on usage [in particular pages 152 - 175 of Gowers (1986) or pages 587 - 592 of Fowler (1965)] for more detail. Used wisely, punctuation makes your prose readable. However, do not fall into the trap of using punctuation as an excuse for poorly structured sentences.

**Stops**

Stops are used to break up your prose. In order of increasing strength they are the comma, semicolon, colon and full stop.

**Comma (,)**

‘The correct use of the comma - if there is such a thing as “correct” use - can only be acquired by common sense, observation and taste.’ (Gowers, 1986). This immediately poses a problem for the average undergraduate student, who may not possess any of these qualities. A good rule is to use a comma only if your meaning would be unclear without one. Another useful technique is to read your work aloud and use a comma where you pause for breath. If any sentence you write contains more than four commas, reword it or break it up into smaller sentences.

A **common error** is to use a comma where a firmer stop (fullstop, colon or semicolon) is required, thus running several sentences together so they read as nonsense.

*e.g.* **The words significant difference refer to the results of statistical tests, you should therefore use them discriminately. Incorrect!** Use a conjunction (and or so, deleting therefore) or separate the two parts by a semicolon or fullstop.

If you use commas to insert parenthetical phrases, be careful to correctly place **both** commas.

*e.g.* **It is useful when recording references, to write each one on a record card. Incorrect!** (Place a comma after **useful** or omit all commas.)
Authors have different preferences for placing a comma after the second last item in a list and there is no absolute rule for this. *e.g.* Little girls *are made of sugar, spice and all things nice* vs Little girls *are made of sugar, spice, and all things nice*. The comma preceding the last item in a list is called ‘the Oxford comma’. I would recommend not using the comma unless it is necessary to clarify groupings.

*e.g.* Annelids were classically divided into three groups: polychaetes, clitellates, containing the leeches and earthworms, and the group comprising pogonophorans and vestimentiferans. (Also consider how useful the Oxford comma would have been to the author who dedicated her book ‘to my parents, Ayn Rand and God’.)

**Do not** use commas to parenthesize a defining (restrictive) clause. (See glossary)

*e.g.* Students, *who are lazy*, will obtain poor results. **Incorrect!**

(This sentence says all students are lazy. Without the commas [correct] the sentence would describe what happens to certain students [the lazy ones] only.)

**Do not** use commas to separate two main clauses, each of which could stand alone as a complete sentence. *e.g.* We *went to the beach and played volleyball*. (No comma after *beach*.) (Note that when joining two main clauses the subject need not be repeated - see glossary)

**Semicolon (;)**

Use a semicolon:

(i) to divide a sentence, when the two parts are too closely related to be separated by a full stop.

*e.g.* Biological evolution may be slight or substantial; it embraces everything from slight changes in the proportion of different alleles within a population (such as those determining blood types) to the successive alterations that led from the earliest protoorganism to snails, bees, giraffes, and dandelions. (Futuyma, 1987).

(ii) to separate members of a list when the members are long, or contain their own commas.

*e.g.* The major tenets of the evolutionary synthesis, then, were that populations contain genetic variation that arises by random (*i.e.* not adaptively directed) mutation and recombination; that populations evolve by changes in gene frequency brought about by random genetic drift, gene flow, and especially natural selection; that most adaptive genetic variants have individually slight phenotypic changes so that phenotypic changes are gradual (although some alleles with discrete effects may be advantageous, as in certain colour polymorphisms); that diversification comes about by speciation, which ordinarily entails the gradual evolution of reproductive isolation among populations; and that these processes, continued for sufficiently long, give rise to changes of such great magnitude as to warrant the designation of higher taxonomic levels (genera, families, and so forth). (Futuyma, 1987)
Colon ( : )

Use a colon:
(i) to separate two parts of a sentence that are in antithesis.
   *e.g.* “Fair is foul: foul is fair.”

(ii) to introduce an explanation or a list.
   *e.g.* The oxidation of organic carbon has a special metabolic function for the heterotroph: it provides energy for growth. (It would be correct to insert a colon after *were* in the first line of example (ii) under Semicolon.)

Full stop ( . )

Use a full stop at the end of a sentence and at the end of abbreviations where the final letter is not the final letter of the full word, *e.g.* Capt. - Captain; *e.g.* - *exemplia gratia*. Compare Dr - Doctor; and wt - weight. An exception to this rule is for abbreviations of SI units, which do not require a full stop (*e.g.* kg - kilogram)

Quotation marks ( “...” or ‘...’ )

Double or single? Here pragmatism can prevail, and Fowler recommends that you use single quotation marks for a quotation and only use double when a quotation is enclosed in a quotation. Use double quotation marks for spoken text.

Parentheses (Brackets or paired dashes)

Use brackets or paired dashes to insert an illustration, explanation or additional piece of information into a sentence that is logically and grammatically complete without it. Make sure you correctly pair (or close) your brackets or dashes. *e.g.* His distinctive contribution was to show that ‘fixed air’ - namely CO$_2$ - is taken up by photosynthesis. (See also the second example under Semicolon.)

(N.B. If you enclose a complete sentence in brackets, place the fullstop inside the closing bracket.) (Use a different bracket type if you enclose a second set of brackets inside the first [as in this example].)

NOTE that parentheses create a pause in a sentence so you do not need to surround the words enclosed in brackets by commas as well!

**Question 4:** Changes in punctuation can markedly alter the meaning of a sentence. To illustrate this, write as many different versions of the following sentence as you can, by changing the punctuation *only*.

*What is this thing called Love?*

There are at least ten possibilities. *(Selected answers available at the Generic Skills Website. Send any more you come up with to Elizabeth.)*
Apostrophe

Apostrophe s (’s) denotes possession, not plurality! Use s’ if the subject that is doing the possessing is plural. *e.g.* the student’s book (one student), the students’ books (more than one student). (Note that the students’ book would be correct if one book were jointly owned by several students.) (Column 8 in the Sydney Morning Herald occasionally records readers’ examples of misplaced apostrophes [and other misuses of the English language]). The most common error is to use an apostrophe to denote a simple plural entity, *e.g.* The student’s were protesting in the Main Quad. is incorrect.

Do not use an apostrophe before the s for the plural of acronyms, *e.g.* CDs (not CD’s), PCs (not PC’s).

6. PARAGRAPHS

A paragraph is essentially a unit of thought, not of length (Fowler, 1965). Each paragraph should be homogeneous in content and should treat the content in logical and sequential order. There is no general rule about the length of a paragraph and it should be a matter of common sense (that terrible phrase again!). Avoid writing lots of very short paragraphs or excessively long paragraphs. Sensible paragraphing gives your reader a rest and indicates that you are going on to the next point.

A paragraph should be able to stand alone and be understandable independent of the preceding paragraph so do not start a paragraph with Its ..., These ..., They ... or any other pronoun that is defined in the preceding paragraph.

A good way to check that your prose flows logically is to summarize the point of each paragraph with a single sentence or phrase. Check whether the flow is logical, with ideas moving easily from one to another, as you read through the summary. If you follow the principle that a paragraph is homogeneous in content, it should be easy to summarize the guts of it in a phrase or sentence.

7. REFERENCE CITATION

The information you write in any piece of scientific work could come from one of several sources: your own mind or experience; a written source such as a journal paper or textbook; or the words or experience of a colleague, tutor or lecturer. If you include any facts or ideas obtained from any place other than your own head or analysis of your own data, you MUST indicate the original source.

**Written works**

The name-and-year system (or Harvard system) of citation is most commonly used in biological journals and you will be required to use this system in all your written work. Some journals use a numbering system but this is normally due to space limitations and is not acceptable for assignment or thesis work.
Choose a logical point within your sentence to write in brackets the surname of the author(s) and the year of publication of the journal or book. Placing a comma between the author and year is optional (but should be consistent within any one manuscript).

*e.g.* Anaerobic fungi extensively colonise plant material in rumen digesta (Bauchop, 1979).

**Citations and punctuation**

If the author’s name forms part of the sentence, write the year in brackets. **NOTE** that any punctuation mark is placed after the closing bracket. This rule also applies to any other stop in the sentence (comma, semicolon or colon).

*e.g.* The role of brown adipose tissue in the increased heat production of cold-acclimated rats was clearly demonstrated by the blood flow studies of Foster and Frydman (1979).

**Two authors**

Write both names separated by and (or &).

*e.g.* Thermogenesis in cold-exposed placental mammals involves heat generated by muscle and brown adipose tissue (Foster and Frydman, 1979).

**Three or more authors**

Write the first author, followed by *et al.*, which stands for *et alia* (= and others).

*e.g.* The synergistic action of three enzymes is necessary for sufficient breakdown of cellulose in the termite, *Macrotermes mulleri* (Rowland *et al.*, 1988).

(Note that *et al.* (i) is italicized (or underlined) because it is Latin; and (ii) ends with a full stop because the last letter of the abbreviation is not the same as the last letter of the full word.)

* Do NOT include a page number in a reference citation. A page number is only required for direct quotations, which, you recall, should be avoided).

* The full reference for every citation (including surnames and initials of all authors) should appear in your reference list (called References, References Cited, or Literature Cited but NEVER Bibliography). Note carefully how each reference is written in the reference lists in your course manuals and in the scientific papers you read.

* If you cite articles written in foreign languages you must indicate, in your reference list, whether you are citing the original article, a translation or an abstract.

**DO NOT USE FOOTNOTES** to list references. And do not use *ibid.* - you must write the reference citation each time you use the reference.

* In instances where you have cited several different publications by the same author in the same year: these are cited in the text as (Smith, 1980a), (Smith, 1980b), *etc.* and are listed in the order a, b, *etc.* in your reference list.
Unseen references
You should avoid citing references that you have not read. If it is really unavoidable (e.g. if the original paper cannot be found or is in a foreign language) then you must cite both the original work and the reference in which you found the cited material.

e.g. The French strain of the parasite Trioxys pallidus was not effective in reducing numbers of the walnut aphid (van den Bosch & Messenger, 1971, in Dixon, 1977).

This example indicates that you read the reference by Dixon (1977), in which the author cited the reference by van den Bosch & Messenger (1971). The complete details of both references should appear in your reference list. Be warned that more than two such citations in any submitted work will be viewed with grave suspicion!

Direct quotations
Direct quotations should also be avoided. If you cannot paraphrase an author’s work and feel that only a direct quotation will do the job, you should enclose the quoted section in single quotation marks (unless you are quoting speech, in which case you use double quotation marks). Place any comma or full stop inside the closing quotation mark but place any colon (:) or semicolon (;) outside the closing quotation mark. Include the page number in the reference citation (ONLY for direct quotations). If you omit a section of the original quotation, indicate this with three full stops (ellipsis marks) and if you insert your own words to clarify anything within the quotation, indicate this by square brackets. Be careful that you do not change the author’s meaning when you do this.

e.g. ‘[One] case for regarding the ... Mollusca as being derived from the turbellarian-rhynchocoel phyla ... hinges on the conclusion that metameric segmentation ... does not occur in primitive molluscs.’ (Russell-Hunter, 1979, p 618)

Verbal references
If you use information that another person told you, cite the initials and surname of the person, followed by pers. comm. (for ‘personal communication’). This is often used in journal papers to include unpublished results passed on to the author from another person.

e.g. Preliminary experiments have shown the insecticide to have no significant effect on genetic mutants of Drosophila (W. N. Bingle, pers. comm.).

Plagiarism
If you use the words or work of another person without citation or proper quotation you are guilty of plagiarism and at University this amounts to a charge of academic misconduct. A charge of academic misconduct can result in exclusion of a student from the University for up to two years. The charge of plagiarism and academic misconduct extends to use of another student’s work.
8. REFERENCE LIST

The full reference for every citation (including surnames and initials of ALL authors) should appear in your reference list (called References, References Cited, or Literature Cited but NEVER Bibliography). Note carefully how each reference is written in the reference lists in your course manuals and in the scientific papers you read.

List references in alphabetical order according to first author. Do not re-arrange the order of authors within a reference. (The order usually indicates the relative contribution of each author to the work.) Each reference must give the reader all the information required to find the original paper or monograph. When you use any reference, even if you make only a few brief notes from it, record the full reference at the same time. It is extremely irritating to have to relocate the journal just to find out such details as the page numbers. Writing each reference onto a file card is a convenient method of keeping track and it is then a simple matter to order the appropriate cards alphabetically to compile your reference list. (Alternatively use a reference database program such as Endnote.)

Titles of journals are normally abbreviated and there is an international convention for this. The accepted abbreviation is usually printed as a header on the first page or every page of the paper. If in doubt, write the full journal name. Abbreviations for the names of common journals are listed in the World List of Scientific Periodicals and Sources for the Biosis Data Base, which are available in Fisher and Badham libraries.

Examples of references and their text citations

<table>
<thead>
<tr>
<th>TYPE OF PUBLICATION</th>
<th>EXAMPLE</th>
</tr>
</thead>
</table>
Publishers vary in the conventions required for typesetting and punctuating references, e.g. presence or absence of bracketing, commas, fullstops after author initials, italicising, bold type, underlining, etc. Provided all the required information is present and you are consistent within the one work, you may go with your own preference for punctuating references in essays and assignments. Compare the reference lists in a variety of publications to see the range of conventions. Placing brackets around the year and placing the year immediately after the author(s) does make it easier to read.

**So, how do you translate the information in a title page or journal page into a correct reference listing?**

For a **monograph**, the date is the year of copyright, which is usually printed on the page after the title page. If there is more than one edition of the book, include the edition number in the title and make sure the date you cite is the correct copyright date for that edition. For a **paper or chapter in a book**, make sure you record the author(s) of the paper or chapter, the first and last page numbers, and the full title, editors and publication details of the book. For a **journal article**, the abbreviated journal title, volume number and page numbers are usually written in a header or footer on each page. (If not, record all this information when you photocopy the article!)
Publication details

If the place of publication or location of a University is not well known, include either the city, state or country as necessary, e.g. (Prentice Hall: Englewood Cliffs, New Jersey); (Bond University: Queensland, Australia). Do not include Co., Pty Ltd, Inc., & Sons, etc. in the name of a publisher. Note that U.S.A., U.K. or Aust. are not sufficient to indicate the place of publication! Do not confuse the place of publication with the city where the publication was typeset and printed: they usually differ. Some publishers may have several towns or cities listed on the title page; the place of publication is the first town or city listed and the address of that office is usually printed on the next page.

References (cited in text above)


Useful student references

Pocket guides to English


General writing style and word usage


Scientific writing


9. GLOSSARY OF GRAMMATICAL TERMS

**Noun:** a ‘naming’ word - a word that labels a person, place, thing or idea.
e.g. table, gait, conscience, Paul, Sydney.

**Pronoun:** replaces a noun previously used or indefinite.
e.g. he, her, it, anyone, something.

**Adjective:** gives further information about (describes) a noun.
e.g. Oh, you sexy thing!
A group of words (phrase) can sometimes act as an adjective (adjectival phrase).
e.g. The girl with the black velvet band ...

**Verb:** a ‘doing’ word - a word that tells about an action or a state of being.
e.g. jump, be, carry, learn.
A verb usually has a subject (the thing that does the action). Verbs may or may not have a
direct object (the thing that receives the action).
Verbs that take a direct object are called transitive verbs.
e.g. I killed the flies.
Verbs that do not take a direct object are called intransitive verbs.
e.g. I must learn some grammar; I can kill flies.
Some verbs take a direct and an indirect object. The indirect object names the person or
thing to whom/which an action is done.
e.g. I gave the textbook to my sister. (the textbook is direct; to my sister is indirect)

**Adverb:** gives further information about (describes) a verb.
e.g. They ran quickly.
A group of words (phrase) can sometimes act as an adverb (adverbial phrase).
e.g. Her room at college was a complete mess.
(adjectival phrase) (adverbial phrase)

**Preposition:** gives information about position or movement.
e.g. on, over, in, there, to, with.
**Sentence:** a group of words that contains a subject and a verb that directly relates to that subject. A sentence may consist of a single clause (simple sentence) or two or more clauses (compound or complex sentence).

*example (simple)*
The cricket ball shattered the window.

*example (compound)*
We went to Adelaide and visited the Barossa Valley.

*example (complex)*
We travelled through Victoria, which was dry and dusty.

**Clause:** a group of words that contains a verb, the subject of the verb and often the object of the verb.

*example*
The insecticide killed the flies ...

(subject)  (verb)  (object)

Two clauses in the one sentence can be joined by a coordinating conjunction (*e.g.* and, but, neither, nor, yet). In this case the two clauses are of equal importance.

*example*
The insecticide killed the flies and retarded metamorphosis of the pupae.

(main clause)  (main clause)

(It is not necessary to repeat the subject. However, if the sentence were separated into two sentences, then the subject [or its pronoun] should appear in the second sentence.)

When a clause is preceded by a subordinate conjunction (*e.g.* that, which, who, since, because, when, if) it becomes a subordinate clause. A subordinate clause cannot exist on its own as a sentence!

*example*
When applied in sufficient concentration, the insecticide killed the flies.

(subordinate clause)  (main clause)

A defining (restrictive) clause defines a noun and limits the possible reference of the noun. It is never separated from the noun by a comma!

*example*
The flies that were not killed by the insecticide were naturally resistant.

(The defining clause defines a particular set of flies - those that were not killed by the insecticide.)

A non-defining (non-restrictive) clause simply gives more information about a noun, without limiting its possible reference. It is always separated from the main clause by commas.

*example*
The flies, which were bred at CSIRO, were naturally resistant to insecticide.

(The non-defining clause simply gives additional information about the flies.)

Compare: (defining) The brother who lives in Canberra is a doctor.

*There are several brothers. The one living in Canberra is a doctor.*

(non-defining) The brother, who lives in Canberra, is a doctor.

*There is one brother. He is a doctor. He lives in Canberra.*
ESSAYS

Refer also to the appropriate section in the First Year Biology Skills booklet and read the previous notes on *Scientific Writing* before you write any essay. Use the following format

- Abstract
- Introduction
- ‘Body’ (with subheadings as appropriate)
- Conclusion
- References

Only Abstract and References need to be subheadings. Use Introduction and Conclusion as subheadings if you wish (but never ‘Body’ - see below).

**Abstract**

Your abstract is a brief statement of the contents of the essay. It is usually written last but is inserted at the beginning of the work. An abstract should:

- contain enough information to clearly express the main point(s) of the essay
- not be simply a reiteration of the essay title or question!
- encourage a reader to read the whole essay

Writing a coherent and concise abstract of an essay or report is a difficult task. You will find that not all published abstracts, even in peer-reviewed journals, are well written. However, if you want your work read, used and cited by others, you must develop the art of abstract writing so that you can successfully communicate the important aspects of your work.

An abstract is a very important part of any document. It is the first part of your work that is read and it will either encourage the reader to look at the whole work, or turn them off completely. In many literature databases the abstract is included in the reference listing, so it must give the reader a complete and accurate summary of the contents of the article, so they know whether it is of relevance to their own work. At scientific conferences the delegates are given the abstracts of spoken papers and often they are the only written record of the meetings, so they must truly reflect the crucial information the speakers are presenting.

**Introduction**

This is a short section that introduces the topic, refers to any relevant previous work and reviews, and summarizes the current view of the subject. Any definitions that need explanation should be placed here.
‘Body’
Consider the various aspects of the topic and develop the argument you wish to present. Opposing arguments should also be presented. Examples are used to support your arguments. All information taken from any literature source should have a reference citation (see below). Break your argument into paragraphs, each presenting one point. Refer to the *Scientific Writing* notes for tips on how to organize your prose. Use subheadings for major sections of the essay (but do not use the subheading ‘Body’ - the reader should be able to tell this!).

**Keeping to a word limit**
If your first draft is too long you should be able to cut it down by writing more succinctly. Remember that the Wordcount function on your word processing program will count every word, including reference citations, so will probably give you a number greater than the actual number of words of text.

**DO NOT USE FOOTNOTES** to include long pieces of additional information you wish to include. If anything is not relevant enough to be included in the text of your work, it is not relevant! You might also be able (within reason!) to summarize information in a table, which does not count towards the word limit. For example if you wanted to present data on the preferred body temperatures of a large number of reptiles, it would be more efficient to tabulate this information, along with the reference citations, rather than write it out in the text of your essay. If you need to give long lists of species names or raw data, then writing or tabulating them in an Appendix may be appropriate.

**Conclusion**
Your argument is drawn together here and the main points are stated in reference to the title of the essay.

**References**
This is a list of all the literature used *and cited* in your essay or report. Whenever you use information from a published source you must cite the reference from which it came (*i.e.* write the author’s surname and the publication date) within the text of the essay. You must not include any reference in your References list that you may have read on the topic but that you did not cite in the text. The formatting of a reference list is very precise. As with scientific journals we require you to follow strict formatting rules for the sake of consistency and clarity. Follow the format given in the previous notes on referencing in the *Scientific Writing* notes.

Take extreme care if citing information from Web sources. Check that the source or author is reputable and be sure you do not cut and paste text. Penalties for plagiarism at the University of Sydney are severe and include expulsion from the University.

A sample evaluation sheet for essays is given on the next page.
# ESSAY EVALUATION SHEET

**STUDENT NAME: ________________________________**  **SID: __________**

<table>
<thead>
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<td><strong>Structure</strong></td>
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<tr>
<td>Appropriate title, abstract, adequate introduction and conclusion. Organisation of text, figures, logical progression of sections, etc.</td>
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<td><strong>Style</strong></td>
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<tr>
<td>Scientific style: Appropriate level and style; concise; no anthropomorphisms or “Women’s Weekly-esque”; not chatty. Correct scientific conventions. Penalise for verbosity.</td>
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<tr>
<td>English style:</td>
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<tr>
<td>Spelling, grammar, punctuation, sentence construction.</td>
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<tr>
<td><strong>Content</strong></td>
<td>55</td>
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<tr>
<td>Overall quality, factually correct, relevant information, topic adequately covered.</td>
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<tr>
<td><strong>Referencing and citation</strong></td>
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<td></td>
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<tr>
<td>Citations used correctly, reference list correctly formatted, appropriate number of references.</td>
<td></td>
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<tr>
<td><strong>Penalties</strong></td>
<td></td>
<td>-10</td>
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<td>Each day late</td>
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<td>Failing to follow directions</td>
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<td>-10</td>
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<tr>
<td><strong>TOTAL ESSAY MARK</strong></td>
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I certify that:

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(2) I understand that failure to comply with the *Student Plagiarism: Coursework Policy and Procedure* can lead to the University commencing proceedings against me for potential student misconduct under Chapter 8 of the *University of Sydney By-Law 1999* (as amended);

(3) this Work is substantially my own, and to the extent that any part of this Work is not my own I have indicated that it is not my own by Acknowledging the Source of that part or those parts of the Work.

Name: ________________________________  Signature: ________________________________

Date: ______ / ______ / 20__
REPORTS

Read the previous notes on Scientific Writing before you write any report. Follow the links from the Generic Skills Website or your unit of study Blackboard site to refer to the Learning Module Writing a Report in Biology.

Reports in Intermediate Biology

By the time you reach your Intermediate studies, you should be refining your report-writing technique and writing in a more mature manner. As with all scientific writing you should aim to be concise. Instead of writing ‘The final measurements are shown in Table 1’ and then discussing the actual values in the next sentence, you can save words by saying something about the table and measurements in the same sentence, e.g. ‘Dwarf plants treated with gibberellic acid grew to almost twice the length of the controls, as indicated by a doubling of internode length (Table 1).’

No piece of practical work, any more than a piece of original research, is complete until it has been written up. The purpose of ‘writing up’ is to communicate what you have done, why you have done it, and the outcome, to a reader who may be interested in what you have been doing. Even though you may never use the results of your class experiments again, by writing up your experiments you will be gaining useful experience in writing, which will assist you in your future career. Most of the comments below relate equally to practical reports and published scientific papers.

Although good scientific writing requires a good command of language, elegant prose is not essential. Your primary purpose is to communicate straightforwardly, coherently, and without ambiguity. Clarity of writing is a first priority and this is best achieved in short, declarative sentences. Remember that aphorism much beloved by scientific journal editors: “Easy writing is damned hard reading; easy reading is damned hard writing!”

The Report

In general, you should organize your report into an Abstract, Introduction, Methods (or Materials and Methods), Results (which includes data tables and figures), Discussion, References (alphabetical list of works you have referred to throughout the text) and Appendices, if applicable. Each of these sections should be written as subheadings.

Title

The title should be short yet informative. Include the name of the species studied or fieldsite, where applicable.
Abstract
An abstract should be an informative summary of the whole work. Remember that when you are a working scientist, the abstract may be the only part of your papers that most people read. It is not meant to set up a mystery to tempt the reader to look at the whole work. The criteria are the same as for an essay abstract (above). In the case of a practical report, the abstract should clearly state the aims, results and conclusions of your investigation, not simply reiterate the title of the report. Do not use phrases such as ‘The impact of these findings for the future conservation status of the bilby is discussed’.
You should briefly describe the results and the implications!
(You may not be required to write an abstract for all reports in your undergraduate courses so read the individual instructions for each assignment. All published research reports and papers should have an abstract.)

Introduction
The Introduction should set the scene for the study by making clear why the study is important and interesting. The Introduction should provide a sense of the background, context and rationale for what you are about to report. It should tell the reader: (i) why your study was of interest, and (ii) what is known to date about your field of immediate study. Draw attention to previous work in this area. Include a brief introduction to the organisms and the location of fieldwork (briefly - details should be given in the next section).

Remember that most journal readers are likely to be generally interested in your field, but are not necessarily expert in it - so write accordingly. It may be necessary to define unfamiliar terms. In any laboratory report, it is of course essential that you show that you understand the context of your work.

Start with the broad context and quickly focus down to the immediate reasons for your project. Follow the general rules for scientific writing. Cite relevant references from the literature that give your work particular meaning (but don’t include every paper you have ever read on the subject, just the really pertinent ones). Don’t use direct quotations - you should paraphrase the original information. State the objectives of your practical work, but don’t include material in detail that belongs more appropriately in the later sections of your report. Take extreme care not to plagiarise text from published works and Web pages.
Materials and Methods

This section describes how you carried out your study. It should not read like a recipe but explain in complete sentences how you did the experiment. Write what you did in the past tense but write statements of fact in the present tense, e.g. ‘males are smaller than females’ (fact, present); ‘we placed three plants in complete darkness’ (what you did, past). In some cases it may be appropriate simply to cite the schedule of a laboratory or field manual, if that provides a detailed description of the procedure you used (e.g. ‘A quantitative analysis of anthranilic acid was carried out according to the procedure outlined in the 2012 Cell Biology Manual.’). In journal articles, authors often refer to previously published papers (often their own!) for details of techniques. Comment on any changes to the manual procedure that might have been necessary. If you or your group performed only part of the procedure, you should explain what was your own contribution to the class or group exercise. If you had to set up an experimental procedure for yourself, you will need to describe that procedure in relevant detail.

In most cases you should present a brief summary of how you went about an experiment or field collection. The simple principle to follow is that another worker should be able to repeat your procedure exactly, and without need to consult other sources, unless you cite a detailed chemical analysis or technical procedure from another paper (e.g. ‘Pigments were extracted according to the technique in Artherson [1964]). Include a statement about any statistical tests you performed to analyse the data. It may be appropriate to include the name of suppliers of specialist equipment or biological products, e.g. ‘foetal bovine serum (CSL, Australia)’. Include a brief justification for your use of particular techniques, species, sample sizes and/or assumptions.

You do not need to describe familiar materials (e.g. the use of a thermometer does not need to include a description of a thermometer). Give a brief discussion of the methods you used, e.g. sampling body fluids from an animal and how you analysed the sample. If you carried out work in the field, describe the general site, and how and why you chose to take samples from particular areas within the site. This can be a lengthy part of the report and therefore you need to be concise. In stating the location, precision is required; a person from another part of the world should be able to find it.

Results

This section is a presentation of the data resulting from the experimental procedures outlined in your Materials and Methods. This does not simply mean a list of tables presenting all your data. The Results section should be a written account of the important results of your investigation, in which you direct the reader to the relevant tables and figures in logical sequence.

Summarize your data clearly and concisely, using tables and/or figures (graphs, plots, diagrams, drawings). You will need to decide which format makes for a more lucid or emphatic presentation. You may wish to use subheadings, where appropriate. If you are writing reports on physiological or ecological experiments you should also include results of any statistical tests of your data, and these should be included in your statements or tables of data (e.g. as a separate and appropriately headed column for p values), e.g. ‘Gibberellic acid significantly increased stem length in pea seedlings (p = 0.002)’.
Keep in mind the following guidelines:

- Every major point you make in the text should be illustrated in either a table or a figure. At the same time, however:
  - be sparing in your use of tables and figures: if you can present a result in a sentence, do so; but if the sentence requires additional ‘proof’, then don’t hesitate to use a table or figure to support your statement.
  - do not present the same data in both a table and a figure (journal editors abhor duplication and therefore wasted space in their journals!).
- Each table and figure should have an explanatory legend: e.g. Table 1. Diversity of leaf litter organisms at Site 1. Place the legend below a figure but above a table.
- Processed data should appear in the Results section: raw data, statistical calculations and calibration curves can be included as an Appendix after the References section of the report.
- Don’t include any table or figure that is not referred to in the text.
- Number figures and tables in the same order in which you refer to them in the text (starting at 1). Capitalize the words figure and table when referring to them specifically, e.g. Figure 3, Table 4.2.
- You do not need to direct your reader to ‘see Figure 1’ or ‘see Table 2’. The thylacine (Fig. 1) has a stiff tail, which it cannot wag. is sufficient.

Remember that the Results section is not the place to provide explanations or interpretations of the data: this is done in the Discussion. You should, however, describe any trends in the data by comparing and contrasting results from different sites, treatments, etc. If your experiment failed it may be appropriate to use another student’s data, which you should clearly acknowledge.

**Discussion**

The first sentence of your Discussion is critical - it should tell the busy reader whether it is worth reading further. Thus the first sentence is likely to contain your most significant conclusion. Don’t be afraid to be original, if you have an opportunity. Organize the Discussion to follow the order in which you presented the results.

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3 It is some time since the unfortunate Roger Bacon, a scientist of remarkable originality, was condemned to prison for daring to introduce ‘certain novelties’ (i.e. new ideas) into his work.
Communication

The Discussion section is where you draw the whole exercise together and really make your impact on the scientific world (or at least your lecturer, as one representative of that world). Do the results all point to a single conclusion? Do they agree with other published data? Is your original hypothesis supported by your data? Are your results within the normal bounds of error? You might comment on the procedures used in the investigation and suggest further studies that would be needed to validate or expand on your results. Discuss the meaning of trends in the data. Include (if possible) information drawn from previous work in the area and discuss any differences between your results and expectations based on this previous work. Use the primary literature (journal papers) rather than a textbook for your references.

As a undergraduate you are not expected to produce original science but you are expected to show that you understand how, in many respects, class exercises and experiments are not always perfectly designed enterprises (your laboratory work is a training ground for research in science and fully-fledged scientific experiments are not always easy to engineer in a training laboratory). Don’t be afraid to criticize an experimental procedure if you feel justified in doing so. You should understand and be prepared to discuss the ways in which your procedure differs from a perfectly executed experimental procedure. You should also critically appraise the technical limitations and shortcomings of the work you carried out. At the same time, however, don’t suggest that every piece of apparatus ‘could have been’ inaccurately used/read/calibrated. It is not permissible to put down every suspect outcome to the effects of ‘human error’ (you should not be allowing sloppy technique to affect your experiments) or ‘experimental error’ (unless you know where the error lies). Touch on any problems but don’t try to make the reader feel sorry for you because of these. Discussion of such problems should form a minor part of the report. You may suggest further experiments that would help to address your question, but you need to be specific: don’t say ‘further work is needed’ without outlining the sort of experiments or studies required and how they will help to address the question.

References

Follow the directions and format given in the section on Scientific Writing. Include ONLY those references you cited in the text of the report.
POSTER PRESENTATION

Scientific posters range widely in content format and unfortunately, at most scientific conferences, quality. A lot more goes into making an effective poster than you might think. There are considerations of the size and amount of text, the size and type of graphs, and the role and number of table and figures, including decorative images. The goal of a scientific poster is to give the viewer an encapsulation of your work, as effectively as possible, in the shortest amount of space and time.

BEFORE YOU PREPARE A POSTER, look at some of the posters around the School of Biological Sciences. Think about whether or not each poster is effective by considering the following questions:

* Is the objective clearly stated?
* Is the information laid out logically?
* Is it concisely written, so that the point is made without unnecessary detail?
* Is it easy to read? Is it interesting?
* Is it easy to see from a distance?
* Is the level of detail appropriate for the audience?
* Do you feel that it adequately addresses the topic in the space given?

If any poster does not meet all of these criteria, ask yourself why not and consider what you would do to change it.

Poster Checklist

• Size: This will be specified by organisers of poster sessions for conferences; for undergraduate presentations an appropriate size is 60 cm x 80 cm.

• Title: Easy to read, relevant and informative.

• Written information: concise, relevant and readable from at least 2 metres away (at least 18 point type). Not too much text in one place.

• Is there a theme that links all the information together? Consider how the viewer would proceed through the information - is there a logical sequence?

• Pleasing to the eye. Text and figures/photos sensibly and attractively incorporated.

• Each figure is referred to in the text of the poster.

• Reference citations are included in the text.

• All photographs, graphs or diagrams are referenced. (You should include the name of the photographer on photographs.)

• Your name and institution (for conferences) appears on the FRONT of the poster. (For undergraduate presentations, your name only - NOT your student number.)
This is an example of a marking scheme for a poster assignment.

POSTER COVER / EVALUATION SHEET

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<th>Item</th>
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<tr>
<td>Font readable; title eye-catching; no garish colours or fussy additions; quality of illustrations; effective use of graphics. Overall impression (would I stop to read it amongst twenty others?)</td>
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<td><strong>Structure</strong></td>
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<tr>
<td>Appropriate title; organisation of text: logical progression, easy to follow; neat, figures relevant and referred to in text, incorporated theme.</td>
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<tr>
<td><strong>Scientific Style</strong></td>
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<tr>
<td>Appropriate level and style; concise; correct scientific conventions.</td>
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<tr>
<td><strong>English Style</strong></td>
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<td>Spelling, grammar, punctuation, sentence construction.</td>
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<tr>
<td><strong>Content</strong></td>
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<tr>
<td>Overall quality, factually correct, relevant information, appropriate detail; interesting; original.</td>
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<tr>
<td><strong>Referencing and citation</strong></td>
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<td></td>
</tr>
<tr>
<td>Citations correct, figures/photographs referenced; reference list correctly formatted; appropriate number; journal references used</td>
<td></td>
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<td><strong>Penalties: Each day late</strong></td>
<td>-10</td>
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<td><strong>TOTAL POSTER MARK</strong></td>
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Name: __________________      Signature: __________________

Date: ____ / ____ /20___
ORAL PRESENTATION

The success of an oral presentation depends on many things, not least of which is **enthusiasm**: both for the topic itself and for your audience. Enthusiasm is contagious: if you appear interested in the topic you can transfer that interest to your audience. You must try to engage the audience: maintaining **eye contact** with them is a good start.

Keep it **simple**: remember that your audience is probably hearing the information you present for the first time so you need to organize your talk to explain terms and proceed logically from one point to another. Use overheads or slides to present dot points as you go to help your audience follow the talk. You may like to use a **summary** overhead (either at the beginning or the end: twice is probably superfluous). You will probably have a time limit for your presentation so try not to repeat information unnecessarily. Don’t be afraid to incorporate **humour** into your talk: it will relieve your nerves and help to engender interest and empathy in the audience (provided what you say is actually humorous).

**Be prepared**

You must fully understand your topic so that you can speak confidently and free yourself from having to read your notes verbatim. Try to avoid writing out the whole text of your talk, but if you must, then highlight **keywords** and phrases in the text so you can use them to prompt your memory of whole sections. Once you become more experienced you can write just the keywords to guide you through the talk.

Assume that all things technological will break down so have **backups**: if you are using Powerpoint projection it is a good idea to have overheads or slides on hand in case of computer breakdowns.

**Visual aids**

Use overheads or slides with **dot points** that summarize your talk. Don’t put too much information on any one page: a good rule is about five dot points per page/slide. Put prompts in your notes to remind you when to refer to visual aids.

Avoid the temptation to use all the decorative borders and backgrounds that computer packages such as Powerpoint provide. You don’t want your visuals to be so busy with decoration that the information gets lost and the audience is distracted from your message. Your graphics should be simple to understand and thus should only include the information and data that you will have time to speak about. Refer to the entry on **Chartjunk** in the **Graphical Techniques** section of this manual.

**Voice and body**

Try to warm up your voice and facial muscles before you start speaking. Even humming softly can help to warm up your vocal cords. Speak in a natural tone of voice and don’t speak in a monotone. If you need to pause to think, try to train yourself actually to **pause**, *i.e.* say nothing, rather than fill the void with *um* or *er*. Try to practice this technique even in normal conversation. Pauses can be used judiciously to focus the audience’s attention: they will wait for you to continue, rather than get irritated by listening to you *um* and *ah*.
Don’t speak too slowly or quickly. Nervousness often makes people speak too quickly so it may help to write prompts in your notes reminding you to slow down.

Your body language is important, as is your general appearance, which should be neat and tidy. You should face the audience and try to make eye contact (but don’t stare at the same person in the front row for the entire talk!). Direct your gaze to the back of the audience. Remember that EVERYTHING you do in front of your audience can be distracting, e.g. fidgeting with notes, making constant hand gestures, or wearing an inflammatory message on your T-shirt.

You will learn to control your nerves with practice. If you feel very nervous you should avoid holding items such as pages of notes (use a lectern if possible) or using a laser pointer, which magnifies the slightest hand tremor.

Rehearse
If possible, you should rehearse your talk in front of your peers or (further down the track) your research supervisor. Become familiar with the multimedia technology you will be using and make sure you know where the on-off switches are for the computer, projection system and room lights.

Summary
Simplicity: well-organized and logical
Preparation: notes, graphics, voice
Enthusiasm: it’s contagious!
Avoid: monotone
Keywords: don’t read notes
Speech: not too slow or fast
Maintain: eye contact
Avoid: cluttered visuals
Rehearsal: text, use of projectors
Technology: know thine enemy!

REFERENCES
The following Website provides more hints on how to give effective oral presentations. While they may not be specifically related to scientific talks, the general guidelines are the same.

http://lorien.ncl.ac.uk/ming/dept/tips/present/comms.htm
University of NewcastleUponTyne

If you wish to improve your vocal delivery, an excellent reference is:
Berry, C, (1975) Your voice and how to use it successfully (Harrap: London)
Fisher Research 808.5 52
RESEARCH, INQUIRY AND INFORMATION LITERACY

The particular skills required for acquiring knowledge include the ability to identify, access, organize and communicate information in both written and oral English, and to have an appreciation of the requirements and characteristics of scholarship and research. You will be applying and refining these skills as you proceed through the coursework and assessment work of your units of study.

TAKING LECTURE NOTES

Good lecture notes will accurately and coherently record the information in the lecture. Remember you will get only one chance to take the notes so don’t try to write down everything the lecturer says: listen and summarize the information. There are two reasons for this: in the first place it is not possible to write down every word as someone speaks, and in the second place simply regurgitating what the lecturer says will not enable you to score well in examinations. For a good mark you need to add information from other sources and to show understanding of the topic, not simply recollect facts.

Accept that you have to spend some time after each lecture expanding on your notes for them to be a useful learning aid.

The first requirement for taking good notes is lots of paper.

Spread your notes out, leaving blanks where you miss something, so you can add it later. Leave space for adding more detail when you revise your notes (using the textbook or other references).

Use subheadings within the notes and indent underneath the subheadings.

Use shorthand - abbreviations and contractions that you understand.

* Delete articles and unnecessary pronouns: e.g. ‘a’, ‘the’, ‘this’.

* Reduce use of verbs: e.g. ‘is’, ‘are’, ‘produces’, ‘is found’ are often superfluous.

* Develop contractions: e.g. ‘P’ for protozoa, rather than writing out the whole word each time. (Similarly, LOH = Loop of Henle, IOL = Islets of Langerhans.)

* Use dashes to complete words, e.g. Gol__ Ap______ will later be transcribed as Golgi Apparatus.

* Word endings can be abbreviated with superscripts. e.g. evol^n = evolution; evol^d = evolved

* Abbreviate what you hear: ‘in the vicinity of’ can be written as ‘near’; ‘as a result of’ becomes ‘be’ (because) or ‘dt’ (due to).
Useful abbreviations

<table>
<thead>
<tr>
<th>Longhand</th>
<th>Shorthand</th>
<th>Longhand</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>and</td>
<td>+ (or &amp;)</td>
<td>leads to</td>
<td>→</td>
</tr>
<tr>
<td>with</td>
<td>c</td>
<td>increases; increasing</td>
<td>↑; ↑ ing</td>
</tr>
<tr>
<td>without</td>
<td>co (or wo)</td>
<td>decreases; decreasing</td>
<td>↓; ↓ ing</td>
</tr>
<tr>
<td>related to</td>
<td>rt</td>
<td>about, approximately</td>
<td>~</td>
</tr>
<tr>
<td>due to</td>
<td>dt</td>
<td>results in/produces</td>
<td>⇒</td>
</tr>
<tr>
<td>with respect to</td>
<td>wrt</td>
<td>results from/is produced by</td>
<td>⇐</td>
</tr>
<tr>
<td>depends on</td>
<td>d</td>
<td>therefore</td>
<td>∴</td>
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</table>

Rewrite your notes, converting your shorthand to longhand, on the SAME day as the lecture. Consult your textbook, laboratory notes and other reference books to fill in details. You should spend an hour per lecture and this will save you an equal or greater amount of time when you come to revise for exams.

Summarize your notes - a 7 page lecture CAN become a 1\(\frac{1}{2}\) page summary.
LIBRARY INFORMATION SKILLS

All Intermediate students will be expected to become proficient in the use of the library and the information search technology available. In certain units of study students will be required to attend a library information skills tutorial at the start of Semester 1 and complete an information skills assignment based on the skills learnt during this tutorial. During the information skills workshop you will receive instructions from the Badham librarian on how to use the Web-based literature search engines. The tutorials are also available from the library databases home page for students who do not have this workshop timetabled into their tutorial program.

The University of Sydney Library has developed an Information Skills Program to ensure that you are:

* able to identify and express your information needs;
* proficient at accessing, evaluating, interpreting and managing information from both print and electronic sources;
* competent in the use of information resources relevant to your studies;
* introduced to the concept of lifelong learning and able to exploit emerging technologies.

This program is available on the Web for self-paced learning and will develop your information skills as you require them. You will have the opportunity to test what you have learnt at the end of each tutorial by completing an on-line quiz accessible through Blackboard. The whole program is accessible at http://sydney.edu.au/library/skills/.

You can also access the program via Blackboard under the name of your unit of study (e.g. Invertebrate Zoology - Information Skills). From here you will find links to program modules covering the skills that you should have as a second year student and relevant quizzes that you are required to complete. (Scroll to the bottom of the page.)

The modules include:

1. How to reference
2. Finding journal articles using databases
3. Scholarly vs non-scholarly resources
4. Search smarter, search faster
5. What is EndNote?

You can download the information in each module as a pdf or watch and listen to the representative student experiences.
The Biological Sciences Librarian in Badham Library is available to assist you with your research and guide you in selecting and using appropriate resources, including databases. Please do not hesitate to call upon any of the staff at Badham Library for assistance.

Here are some useful links to information in the library:

Library catalogue:
http://opac.library.usyd.edu.au/

Badham Library (includes Library hours):

Off-campus access:

Information Skills Program:
http://sydney.edu.au/library/skills/

Databases of particular interest to Biological Sciences students:

REFERENCE MANAGEMENT

The notes on Scientific Writing include some general hints on cataloguing your library of reference books and journal papers. It is extremely important to correctly reference your work, whether you are writing an essay, report or presenting photographs in a poster. If you have used material from a Webpage, you must cite the owner of the copyright, the URL of the site and the date you accessed the site. When you first use any reference you should write down ALL the details of the publication that you will need to write in your reference list. It is irritating and time-consuming to have to relocate a journal article just to find out such details as the page numbers. Writing each reference onto a file card is a convenient method of keeping track and it is then a simple matter to order the appropriate cards alphabetically to compile your reference list.

Alternatively you could use a reference database program, such as Endnote. EndNote is a personal bibliographic software program that allows you to organize your references and automatically create a reference list for your essays or assignments. A feature of the EndNote software makes it possible to connect to selected library catalogues and online databases and to incorporate references directly into an Endnote library of references that you have created.

The University of Sydney has a site license that makes the software available to authorized University of Sydney staff and students. The Endnote software is available for use on computers around campus. Information on Endnote and obtaining the software is available at http://libguides.library.usyd.edu.au/endnote. You can download a pdf of the training information (scroll to Endnote Classes) and/or watch the training videos.
COMPUTING SKILLS

As a Science student and graduate you will be expected to be familiar with and proficient in the use of electronic information systems (email, internet, databases) and word processing, spreadsheet and statistical analysis software. In the School of Biological Sciences we would expect you to be using MSWord and MSEXcel programs for word processing and data manipulation. Both programs are available on computers in the Access Centres in Carslaw and Fisher. Remember to keep a printed copy of any assignment you submit at university and to backup the electronic version on CD, USB or another computer in case of hard drive crashes.

Using Word and Excel

The following documents are available from the Generic Skills website. There should also be a direct link to the site in the left-hand navigation bar in Blackboard.

- MSWord basic functions
- MSWord formatting hints
- MSEXcel basic functions


Formatting documents in Word

Take some time to read through the formatting sections at Microsoft Office Online and in the Help menus in your Word program to learn how to improve the appearance of your documents. A simplified guide to some features of formatting (paragraph and heading styles, table formatting, text flow, etc.) can be found at the Generic Skills website.

Handling data in Excel

Use Microsoft Excel for preparing spreadsheets of data that can be used for calculations, graphical presentations and, in some versions, simple statistical tests of your data. If you are a beginner, practice typing in text and changing the format of cells by clicking on Format, Cells and exploring the Number, Font, Alignment and Borders menus. You can edit text by highlighting the appropriate cell and clicking into the text box at the top of the page.

Information on using some of the statistical and graphical functions in Excel is given in this manual in the section on Data Presentation (and is also available at the Generic Skills Website).

Share your experience

The most efficient way to learn about useful functions within software programs is to have someone show you. Share your expertise with others and it should be reciprocated.
Email and the Web

All undergraduate students are provided with a University of Sydney email account. Accessing your email is free on campus. If you want to use your email account from home and already have an Internet Service Provider you can configure your normal email application to receive your USyd mail or use the USyd Web mail system.

Information on activating and using your Sydney Mail account and charges for downloading is available at http://sydney.edu.au/ict/student/getting-started/index.shtml. You must read and agree to abide by the Conditions of Use and the University of Sydney Code of Conduct when you activate your address.

Computer viruses

Computer viruses are becoming more common and are often contained in attachments to emails. They are particularly damaging to PCs and can automatically be sent from your computer, once infected, to email addresses in your address book. If you open an attachment or .exe file that contains a virus it will immediately infect your computer. Your computer cannot, however, be infected by a virus by just opening an email message.

Computers on campus are regularly updated with anti-virus software. You should ensure that your home computer has appropriate anti-virus software that is regularly updated and you should only trust email attachments from users who also use appropriate and regularly updated anti-virus software. Norton antivirus software is available for download from the USydNet site and you should download the monthly virus definitions file to maintain your protection.

To avoid infection with new viruses you should be very careful when accessing email attachments. Do not open Word or Excel attachments from senders you do not recognize or trust; and do not open files with the suffix .exe. Most recent email-related viruses attack PCs. Mac users are still vulnerable to Macro viruses in Word or Excel documents and can unknowingly transmit viruses to PC users.

The following sites give detailed information about computer viruses:
http://www.symantec.com/avcenter/ is the information site for a manufacturer of anti-virus software.
http://www.research.ibm.com/antivirus/SciPapers.htm is IBM’s virus research site, with links to research papers on computer viruses.

Netiquette

Netiquette refers to a basic code of behaviour governing the use of the internet. Communicating via the computer screen is very different to face-to-face communication and what you type and send is a permanent record that can be saved, retrieved and forwarded to others. The normal rules of courtesy should apply even more stringently to electronic communication than other types of communication, as you cannot gauge the response of the recipient as you can in normal conversation. Remember that you must agree to abide by the University of Sydney Code of Conduct, which includes the statement that ‘you must not offend, harass or threaten another person, nor store or transmit material designed or likely to do so’.
Because of the convenience of email, lots of people forget that email correspondence should be bound by much of the same etiquette as normal letter writing. Remember when you send an email that it is polite to address your recipient appropriately (e.g. Dear Sarah/Mr Elliott/Prof. Hinde) and end the message with a salutation (e.g. Cheers/Regards/Love, as appropriate) that includes your name, and surname if you are corresponding with a member of academic staff. (There may be several Stevens in your class and your Unikey (e.g. hwon1234) does not identify you appropriately.) It is also polite to use correct English in your emails. If you expect the recipient of your email to take the time to read your message, then you can take the time to proofread the message and make sure it is understandable. A badly written email can leave a lasting (and usually poor) impression on your reader. Many email programs now have automatic spell-checking so it should not be too difficult to correct your spelling.

You should respect the time of your colleagues (and strangers!) and refrain from sending large amounts of unsolicited mail. You should be fairly certain that a person wishes to or needs to receive your messages. Don’t extract email addresses from messages you have been sent to add to your mailing lists. You can keep your own mailing lists private by using nicknames and groups for address lists and using the Bcc: (blind carbon copy) function. Check the Help pages of your email program.

The following sites offer recommendations on appropriate use of the internet:
http://www.albion.com/netiquette/corerules.html (This is a large site that is extracted from the book on Netiquette by Virginia Shea)
http://www.stanton.dtcc.edu/stanton/cs/rfc1855.html (Advice on using email, mailing lists and newsgroups, with an extensive bibliography)
http://www.albury.net.au/new-users/netiquet.htm (This is an abbreviated version of the previous site)

Emailing academic staff

The unit coordinator for your unit of study may contact you by email at times throughout the semester, so check your university email regularly. In turn, we receive a significant amount of email from students. Do be aware that we may not get back to you immediately or even on the same day. Please email staff members only if all other avenues of enquiry have failed (see point 1. below). Please use your University email address for all formal correspondence with university staff, and follow the conventions given below, to ensure your emails are read and answered efficiently.

1. Don't email staff with questions about the basic organization of the unit of study, as this information is available at the beginning of your unit of study manual and on Blackboard. Check emails that have been sent to you by staff and the announcements on Blackboard before emailing staff.

2. If you do need to contact staff, please use your University email and write a meaningful Subject line, so that we can tell it is a legitimate student enquiry. Because of the prevalence of spam these days, staff may delete email without subject lines and email from unrecognized senders without opening the messages! Note that your hotmail nickname (e.g. fluffyrabbit3000) will mean nothing to university staff and your email will probably be trashed (in some cases automatically, by the University’s anti-Spam software).
4. Proofread your emails for grammar and spelling before you send them to ensure they will be understandable. Use correct sentence structure: this includes capital letters for the beginning of sentences, a capital letter for the first person 'I' and full-stops at the end of sentences. Do not send SMS-style messages: note, for example, that the second person pronoun is 'you' not 'u'. If you get into the habit of typing correctly when you write emails, it should be automatic when you have to type up assignments.

5. DO NOT TYPE IN CAPITAL LETTERS AS IT LOOKS LIKE YOU ARE SHOUTING AT US!

6. Be polite - note that all email messages you send through the University servers are kept permanently on record in the University archives. A good rule-of-thumb is not to write anything in an email that you wouldn't want to see printed on the front page of the Sydney Morning Herald! (Remember those female lawyers a few years ago, whose abusive emails became front-page news?)

7. When replying to a message, determine whether it is relevant to include the entire copy of all previous emails and delete what is not relevant. If you use Reply To a previous email to avoid typing in the recipient’s address and your message is not relevant to the original message, remove the previous message AND change the “Subject:” to make it relevant to your outgoing message. It is annoying to receive an email entitled, say, “Re: exam information” when the student is asking about enrolment in next year’s units or the end-of-semester party!

**Checklist for emailing academic staff**

Before you hit Send, check that you have:

* read the unit of study manual, timetable, Blackboard announcements and emails from staff to see if your query has already been addressed
* addressed the recipient of the email in your message
* used correct English grammar and spelling
* proofread your message
* identified yourself fully at the end of the message
* included your student number if it is an enquiry about unit of study assessment or enrolment
* removed the previous five or six email messages in your reply.
Chain letters

**DO NOT** forward chain letters or any emails that exhort you to ‘send this message to as many people as you can’, even if they sound like humanitarian gestures. These messages are hoaxes that are started by malicious users with the intent to clog up email servers. Refer to the link on the Generic Skills Website for more information.

**Virus hoaxes and urban legends**

The majority of warnings you will receive about computer viruses will be hoaxes. If you receive a virus warning you should send it to your Internet provider for verification. **DO NOT** forward unchecked virus warnings.

Refer to the following Websites for more information:


There are thousands of urban legends circulating on email networks, with dire warnings about foods, medicine, and just plain wild stories. **DO NOT** forward these stories, as they are equivalent to computer viruses and also circulate incorrect and sometimes damaging information. [http://www.snopes.com](http://www.snopes.com) is one of the more authoritative sites on internet hoaxes. For the truth about asbestos in tampons, ‘toxic’ aspartame, or the subject of the latest scare campaign, use the Search function.

**Spam**

Spam is unsolicited advertising that is sent to email addresses. **DO NOT** send these emails on to others. There are many sites that give information and offer services to help filter spam from your mailbox. If you are getting unsolicited emails from known sources you can set up filters within your email program to automatically trash messages from specified email addresses.
RECORDING AND REPORTING DATA

**Significant figures**

If you measured the mass of an animal with a digital balance accurate to 1g you might get a measure of 67g. This figure indicates that the true value of the mass lies somewhere between 66.5 and 67.5 g. The value is written with two significant figures. If the same animal is weighed with a more sensitive balance you might get a measure of 67.0g, meaning the true mass of the animal is somewhere between 66.95g and 67.05g. Clearly the second measure is more accurate (closer to the true value) and it therefore has a greater number of significant figures (three). The final zero is significant as it tells us important information about the accuracy of the value. If this second value were expressed in kg it would read 0.0670kg - which is still accurate to three significant figures. The first two zeros in the value tell us of its magnitude but do not add to its accuracy so they are not significant. Similarly, the values 34.0mL, 0.000654g, 0.00900M, 0.632g and 4.56 x 10^4 km are all accurate to three significant figures.

**Scientific notation and significant figures**

Note that the last value in the previous paragraph might also be written as 4560. This, however, would cause some confusion, as the exact number of significant figures, hence the accuracy of the value, is not clear. Scientific notation is used to avoid this confusion. If our original animal mass were now expressed in mg it would be 67000mg. How many significant figures are there here? It would be difficult to say if this was the only information you had. It would be better to write it as 6.70 x 10^4 mg (given that you actually know its accuracy) to make it clear that there are only three significant figures.

**Significant figures in calculations**

Why this emphasis on significant figures? Because in many areas of biological work you will be using raw data to calculate certain derived parameters, and the accuracy (number of significant figures) in your raw data will influence the accuracy to which you can calculate these derived parameters. You will also be using calculators, which will give you lots of meaningless decimal places in your calculations. The rule is that if one or more measured values are used in a calculation, the answer can only be reported to as many significant figures as in the LEAST accurate value contributing to the answer. In other words, the accuracy of your final answer is determined by your ‘sloppiest’ measured quantity.

*e.g.* If the masses of separate organs taken from an animal were given as 21g, 45.8g and 1.008g, the sum of these weights should be expressed not as 67.808g (five significant figures) but as 68g (two significant figures). (If you want the value to be more accurate you would weigh each organ with the same balance, so the raw values all have the same number of significant figures.)
The same rule applies to multiplication, division, and logarithmic calculations. Your final result should be rounded off to the appropriate number of significant figures. Don’t round off intermediate values within the calculation. (Note that integers, indices and values such as π used in calculations (e.g. 2πr, πr²) do not have any inaccuracy so do not restrict the number of significant figures in the final result.)

**Precision and accuracy in measurements**

Measurements are termed accurate if the values obtained are close to the true value. In making accurate measurements the systematic errors (see below) are small.

If several measurements are made and they all lie close together they are termed precise. The values may not, however, reflect the true value. In making precise measurement, the random errors (see below) are small.

Your measurements should ideally be both accurate and precise.

*e.g.* Say you are trying to fire arrows at a bullseye. The figures below illustrate a few possible outcomes (not including missing the target altogether!).

- The precise shots hit the target at about the same point.
- The accurate shots hit the bullseye.

\[ \text{precise, inaccurate} \quad \text{precise, accurate} \quad \text{imprecise, accurate} \quad \text{imprecise, inaccurate} \]

**Types of error**

(i) **systematic** - *e.g.* an offset or incorrect zeroing of an instrument may lead to a systematic shift of the readings in one direction. (*e.g.* the butcher’s thumb on the meat scale)

(ii) **random** - caused by human limitations (*e.g.* individual response time in using a stopwatch), the limit of the scale on your measuring instrument or careless mistakes. Random error can be reduced by taking repeated measurements.


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\(^4\) This program was developed by Rosanne Quinnell, Mark Curran and Bill Allaway, with the assistance of the (former) Centre for New Technologies in Teaching and Learning (NeTTL) and funding from the Student Progression Assistance Scheme at the University of Sydney.
DATA TYPES: SCALES AND VARIABLES

Variables are values that can be ‘measured’ on some scale.

Types of scales

Nominal scales
Unordered categories indicated by arbitrary numbers.

*e.g.* Sex: female = 1, male = 2.
Colour: red = 1, pink = 2, white = 3.

Nominal variables have no real numeric properties.

Ordinal scales
Ordered categories indicated by ordered numbers.

*e.g.* Condition of hospital patients: 1 (comfortable), 2 (stable), 3 (guarded), 4 (critical).
Horse gait: 1 (walking), 2 (trotting), 3 (cantering), 4 (galloping).

Note that the intervals between categories may not be equal.
Ordinal variables have no real numeric properties.

Interval scales
Ordered quantities with a defined unit of measurement so that there are equal intervals between successive values. *e.g.* the Fahrenheit and Celsius temperature scales.

The difference between two numbers on an interval scale is a measure of the difference in the property being measured.

*i.e.* the difference between 40°C and 20°C is the same as that between 60°C and 40°C.

The position of zero on an interval scale is arbitrary.

*i.e.* 0°C does not mean no temperature and 40°C is not twice as hot as 20°C.
Variables on an interval scale have true numeric properties.

Ratio scales
Similar to an interval scale but the position of zero is unique and indicates absence of the property.

*e.g.* Length, weight, number of individuals, Kelvin temperature: Zero Kelvin indicates the total absence of heat and 40K is twice as hot as 20K.

Types of variables

Discrete and continuous variables
Variables that can assume either a finite or countable number of values are *discrete*. They can be either qualitative or quantitative. *e.g.* 7, 4, 3

Variables that can assume any value in some interval are *continuous*. *e.g.* 43.4°C, 45.7kg.
Qualitative and quantitative variables

Variables measured on either the nominal or ordinal scales are called qualitative. Variables measured on either the interval or ratio scales are called quantitative.

Statistical analysis of different types of variables

Nominal
Frequency distributions, frequency histograms, and stem-and-leaf plots may be constructed using nominal data. Statistical techniques such as contingency table analysis and Chi-square tests can be used. The measure of central tendency is the mode (most common value). The median and mean cannot be used.

Ordinal
As for nominal data, plus ranking and non-parametric procedures. The measure of central tendency is the median, as this takes order into account. The mean cannot be used as the numbers assigned to the categories of an ordinal variable are arbitrary.

Interval
All techniques used on nominal and ordinal variables may be used, plus many more. Mean, variance, correlation, regression and various parametric statistical calculations are applicable. The measure of central tendency is the mean.

Ratio
All statistical techniques and calculations may be applied.
GRAPHICAL TECHNIQUES

Specific graph types are used for different types of data. Examples of each of the following categories can be seen at the Generic Skills Website. It is expected that you know the difference between the independent (abscissa, $x$) and dependent (ordinate, $y$) axes.

**When is it appropriate to use a scatterplot?**
When your variables are measurements of a variable for different individuals (or cases or species) and both $x$ and $y$ axes are continuous. A scatterplot allows you to illustrate a possible relationship between the $x$ and $y$ variable, e.g. metabolic rates of different species of mammal over a large size range. In the case of exponential relationships it can be useful to plot the data as log values.

**When is it appropriate to connect data points to make a line graph?**
When your variables are continuous and it is valid to interpolate between measured data points, e.g. reaction rate of an enzyme vs temperature, metabolic rate of a lizard as a function of air temperature, time-series graphs when the independent ($x$) axis is time.

**When is it appropriate to draw a ‘line of best fit’?**
When there is valid dependent relationship between the $x$ and $y$ variables that can be expressed by a function. This may be a regression line and may be linear, quadratic or polynomial.

**When it is appropriate to use a bar graph?**
When your variables are non-related values of measurements for different groups. e.g. metabolic rates of three different lizard species at one temperature. The variables can be discrete or continuous.

**When it is appropriate to use a histogram?**
When your data are discrete counts of the frequency of occurrence of a variable. e.g. the number of students scoring particular marks in a quiz; the number of fronds in each size class in the bracken fern example over the page. These sorts of graphs are commonly referred to as frequency histograms.

**When is it appropriate to use a pie chart?**
Rarely. When you wish to represent each datum as a percentage of the whole. A pie chart is a circle divided into sections so that the size, or angle, of each sector is directly proportional to the percentage of the whole it represents, e.g. the breakdown of a household income; the percentage abundance of different phyla in the world.
Indicating dispersion of data in graphs

The standard deviation or standard error is often indicated in a graph - as crosshairs around a mean point or as error bars on a bar graph.

What to avoid in graphics packages

Exaggerations produced by 3-D graphics

The physical representation of numbers should be directly proportional to the numerical quantities and the number of information-carrying dimensions should not be greater than the number of dimensions in the data (Tufte, 1983). A common misrepresentation is to use volumes to represent one-dimensional data. Three-dimensional bar graphs and pie charts can disproportionately exaggerate large quantities and give a false impression of differences between data points and the magnitude of trends.

Chartjunk

This is the name Tufte (2001) gives to all unnecessary and elaborate decorative and shading devices in graphs, such as cross-hatching, barring, etc. These devices are now all too available in computer graphics packages and do little other than line the pockets of toner manufacturers, as they use up lots of ink without adding any more information to the data. At best they are unnecessary and at worst they are totally distracting (and cause eyestrain!).

Useful references


Cleveland, W.S. (1994) The elements of graphing data (AT&T Bell Laboratories: Murray Hill, N.J.) Fisher Research and Madsen 519.1 474 A


Types of graphs:

http://www.statsoft.com/textbook/stgraph.html
(Produced by the manufacturers of Statistica, a statistics software package)
HYPOTHESIS TESTING

You may have covered certain tests in First Year Biology and/or First Year Mathematics. These could include the Chi-square test for goodness of fit, and the t-test for comparing the means of two sets of data.

The **Chi-square test** is used to test whether relative proportions conform to hypothesized proportions, *e.g.* if the outcome of a genetic cross conforms to or differs from the predicted outcome. This test is appropriate when there are several categories (*e.g.* phenotypes) and a discrete number of entities in each. A model is used to predict the relative proportions of entities in each category.

The **t-test** is used to test for significant differences between the means of two sets of data. The following pages give a basic explanation of why we need to use such tests for biological data.

**Useful Websites**

Elementary concepts in statistics:  
http://www.statsoft.com/textbook/stathome.html  
(Produced by the manufacturers of Statistica, a statistics software package)

**References**


**INTRODUCTION**

When we perform experiments and collect data in biology we want to use the outcomes of these experiments to make valid scientific interpretations and predictions. Because of the nature of biological material there will always be differences between organisms and we need to take account of the large variability between organisms, from the individual to the population level. Therefore we need to sample widely, replicate measurements and perform statistical analyses of our data in order to form any accurate conclusions.

**Variation within populations**

If you carry out an experiment on a particular species, you will be using a very small sample of individuals from the available population. The variation in your sample will reflect the variation within the whole population from which you sampled.
Example 1. If you want to measure differences in growth rates of a plant species under different imposed conditions (say, fertilizer levels, or temperature regimes), the plants you use would show some inherent variation in growth rate even under identical conditions. If you subject groups of these plants to different conditions, and they exhibit differences in growth rate, you will have to determine whether the observed differences are due to the differences in growing conditions, or are just a reflection of the inherent variability between individuals.

Example 2. If we were trying to find out the length of a frond (leaf) in a bracken fern population we could measure the length of each frond from a sample of 100 bracken fronds. The sample should be representative of the population and not be biased in any way. For example you should not choose to measure only the plants that stick up above the rest as these would be the tallest plants and they would be most likely to have longer fronds. Ideally the 100 fronds should represent a random sample of the bracken population. The data are presented as the frequency of measurements in a series of 10 cm size classes so that measurements are to the nearest 0.1 metre.

<table>
<thead>
<tr>
<th>Size class (m)</th>
<th>No. of fronds in size class (frequency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>4</td>
</tr>
<tr>
<td>0.8</td>
<td>7</td>
</tr>
<tr>
<td>0.9</td>
<td>6</td>
</tr>
<tr>
<td>1.0</td>
<td>8</td>
</tr>
<tr>
<td>1.1</td>
<td>16</td>
</tr>
<tr>
<td>1.2</td>
<td>18</td>
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<tr>
<td>1.3</td>
<td>20</td>
</tr>
<tr>
<td>1.4</td>
<td>12</td>
</tr>
<tr>
<td>1.5</td>
<td>5</td>
</tr>
<tr>
<td>1.6</td>
<td>4</td>
</tr>
</tbody>
</table>

From these data it is easy to see that there is considerable natural variability in the length of bracken fronds. It is also clear that there is a strong pattern in this variation: most of the fronds were in the 1.3 metre size class with fewer and fewer fronds in classes at either larger or smaller sizes. This distribution of measurements is the most common pattern found in biological populations and is referred to as a normal distribution.

Sampling

It is normally impossible to measure all the individuals in any population, or take all the measurements that one would like, due to constraints of time and money. Therefore, biologists must sample populations and try to ensure that the sample measured is representative of the whole population.
When you look at any normal distribution of a population variable you should see that there are two pieces of information necessary to adequately describe the measurements made: one is some means of reporting the value of the measurement; the second is some means of describing how spread out the measurements are. For the first case we could state which size class had the highest frequency (1.3m): the mode. Alternatively we could give a middle value with half of the readings above it and half below it: the median (1.2m). Another way would be to add up all of the readings and divide by the number of readings to get an average value: the mean (1.1m).

The second case is more difficult and a number of statistics have been derived to describe the spread or variation about the mean value. The most commonly used are the variance, the standard deviation and standard error. If you are not already familiar with these terms refer to the notes on Measures of Central Tendency and Variability at the Generic Skills Website.

**Extrapolation of experimental results to the population at large**

It is not easy to extrapolate validly from the experimental regime to the natural state of the organism, or from the results of experiments on one taxon to another.

**Example.** The lethal temperature measured in the laboratory for a marine mollusc may:

(i) be irrelevant on the rock platform where the mollusc actually lives, due to the possible confounding effects of desiccation, wave action, etc.; and

(ii) not necessarily be applicable to any other species of mollusc, OR any population of the same mollusc from any other area, due to similar reasons, or because they may have a slightly different genetic makeup from your experimental sample.

Biologists must be able to design experiments and interpret experimental results, so that these factors can be taken into account, and valid conclusions can be made.

**What is an experiment?**

We can define an experiment as a planned inquiry to obtain new facts or confirm or deny the results of previous experiments. An experiment may be designed to test an hypothesis, answer a question, or estimate an effect.

Hurlbert (1984) defines two types of experiment:

1. **Mensurative** experiments: measurements are made at one or more points in space or time.

   **Examples:**
   
   (i) Measuring the population density of a particular beetle at two different altitudes.
   
   (ii) Measuring the water-holding potential of a soil before and after the invasion of a weed species.

Such experiments do not involve the imposition by the experimenter of some external factor(s) on the experimental units. Thus all experimental units are treated the same way, with differences between groups being out of the experimenter’s control.
2. Manipulative experiments: the choice of treatment for each experimental unit is made by the experimenter, and is randomized (so there is no SYSTEMATIC difference between units in different treatments except that imposed by the experimenter).

Examples:

(i) Measuring the water-holding potential of the soil in three agricultural plots, each planted with different densities of a crop.

(ii) Monitoring the life span of three groups of fish in three different aquaria containing different levels of dissolved oxygen.

PRINCIPLES OF EXPERIMENTAL DESIGN

1. The experimenter must be able to clearly define the question being asked, the experimental units, and the treatments being tested

An experimental unit is ‘that unit or system on which one is going to make one or more measurements’ (Hurlbert, 1984). (A distinction is made here between that unit which receives a particular treatment, and the actual unit being measured by the experimenter. They often are one and the same, but making this distinction can avoid confusion in certain cases.) The experimental unit could be a single rat, or a stand of trees, or a bacterial plate.

A treatment is the variable factor imposed on an experimental unit. This could be a standard diet, a dose of drug (or the effect of a drug with different levels of dosage), a particular temperature (or the effect of temperature with levels of treatment at different temperatures), etc.

2. Random assignment of treatments to experimental units

Every treatment should have an equal chance of being assigned to any experimental unit. Say, for example, we wish to compare the effects of two different diets on white rat growth. An individual rat is the experimental unit, or to be more exact, an individual rat, its cage, and the location of its cage can be considered as the experimental unit. This more exact definition reminds us that randomisation procedures should be adopted at three levels: in assigning treatments to rats, rats to cages, and cages to locations. It should be obvious that it would be invalid to put all rats receiving one diet into one room, and all those receiving the second diet into another, as there could possibly be a climatic difference, or other type of difference, between the two rooms. Note that this example also demonstrates the need for interspersion of treatments (see 3. below) to ensure that treatment differences are not confounded by room differences. The advantage of randomisation is that the experimenter need not know what the possible confounding effects might be: the act of randomisation takes them into account.

3. Randomisation and interspersion of treatments

Randomisation and interspersion of treatments is often essential to a good experimental design, in order to take account of possible periodicity or trends in variables that are out of the experimenter’s control.
Example 1. Randomisation
An ecologist wants to survey the plant species in an area, which consists of a series of dunes, spaced 25 metres apart. The plant species growing on the tops of the dunes (‘dry’ species) would be different to those growing in the swales between the dunes (‘wet’ species). If the experimenter was unaware of this regularity in the topography (and hence the vegetation), chose to record the vegetation every 25 metres, and his first observation happened to coincide with a dune, then each successive observation would coincide with a dune and none of the wetter species in the swales between the dunes would be recorded. Spacing his observations at random intervals throughout the study area would be much better.

Example 2. Interspersion of treatments
In a laboratory experiment, there may be more light at one end of the laboratory than at another. If different treatments were placed in different parts of the lab (at different distances from the window), the variation in the amount of light reaching the plants could confound the effects of the treatments being studied. For this reason it is desirable to intersperse plants receiving different treatments. Similar trends in light availability, soil type or water availability in plots of land used for field experiments (e.g. in testing the effects of different fertilizer treatments on crop yields) make interspersion of treatments mandatory.

There is also a potential problem of one replicate being influenced by the one next to it. In most experiments this is to be avoided and one usually achieves this by randomisation of the placements of replicates. Note, however, that in some experiments the placement of replicates is of vital importance and it is necessary to ensure a particular arrangement by using a systematic design.

Systematic design
The requirements for randomisation and interspersion will always be determined by the nature of the particular experiment being performed. And in some cases, it may not be desirable to randomly arrange experimental units, e.g. in a behavioural experiment to test for food preferences, moth larvae are given a choice of food plant to utilize. It may be necessary to set up the food plants in a highly systematic way, rather than randomly, so that each larva is given an equal chance of choosing one or the other of the two species.

4. The need for replication within treatments
Replication is necessary to determine the variability within each treatment group. Care must be taken to ensure that replicates encompass the possible sources of variability, and that they are independent of each other.

Example 1: Say you wish to compare the rate of an enzyme reaction from rats held at two different temperatures. Replication is achieved by extracting and assaying the enzyme from many rats held at each temperature. It would not be valid to use one rat from each temperature and to do the assay ten times per rat. This approach gives no information on the variability between individuals and any conclusions drawn from the results would be highly suspect. (Hurlbert [1984] calls this pseudoreplication.)
The number of replicates required for an experiment depends on several factors, of which the most important are:

(i) the degree of precision required; and

(ii) the magnitude of the variability within the material being studied. Certain material is more variable than others. Consider the problem of soil heterogeneity: some soils are more uniform than others, and, for the same precision, less replication is required on uniform soil than on heterogeneous soil.

Often, preliminary experiments are carried out to determine the extent of variability (the variance) in the measures being used, in order to determine the amount of replication necessary, and often at what level it should be concentrated.

**Example 2:** Measuring insect density on trees before and after being treated with different insecticides: there may be more variability between different trees than between different leaves on the one tree, so to get an accurate measure of density as a result of each insecticide, it would be better to sample several leaves from many trees, than to sample lots of leaves from the same tree.

**Example 3:** In our previous example of enzyme assay on rats: there is more variability between individual rats than between individual assays from the one rat, so replicating of rats is more important than replicating within rats.

**Notes on treatments and level of treatments**

Treatment is the term used for the experimental manipulation imposed as part of an experimental design. For example, the effect of environmental variables on the population growth of grain beetles could be investigated by manipulating temperature and humidity. One possible experimental design would impose two treatments: a temperature treatment and a humidity treatment. Each treatment might have three levels applied: e.g. 20°C, 25°C and 30°C for temperature and 60%, 70% and 80% for humidity. In such an experimental design there would be nine separate sets of manipulations, which then is multiplied by the number of replicates needed, to cover all combinations of the three levels of each treatment.

In a more simple design that considered one variable only, temperature, one might find two levels of treatment being imposed: e.g. high (30°C) and low (20°C) temperature. Sometimes these might be referred to as a high temperature treatment and a low temperature treatment, but strictly they should be called the high and low levels of the temperature treatment.

Although this does sound a little like semantic quibbling, distinguishing between different LEVELS of treatment becomes important in experiments where there is more than one variable being applied by the experimenter, as in the first example described above (temperature and humidity are varied).
5. Adequate controls
There are several meanings of the term ‘control’ in an experimental design.

(i) Any treatment against which one or more treatments are to be compared. It might be an ‘untreated’ treatment (with no imposition of an experimental variable), a ‘procedural’ treatment (as when mice injected with saline solution are used as controls for mice injected with saline containing some drug), or simply a different treatment.

(ii) Regulation of the conditions under which the experiment is conducted, so that the experimental and control systems are identical in every respect except for the treatment variable imposed and its effects.

(See page 191 of Hurlbert (1984) for a full discussion of the use and misuse of the term ‘control’ in experimental design.)

STATISTICAL TESTING OF DIFFERENCES BETWEEN TREATMENTS

How different is different in Biology?

When you are making measurements as part of an experiment, one of the most obvious questions to consider is whether the numbers you are collecting are the same or different. At first glance this seems to be a trivial question: for instance it would seem to be perfectly obvious that the number 30 is different from the number 20, but we will look at some examples that may make you think twice about that. Science is all about the asking and answering of questions and, in this, Biology is no different from other sciences. However, Biology does differ in one sense, in that we deal with populations of living organisms that will always have an inherent natural variation.

A physicist measuring the density of water quite reasonably expects that the measured density of any two samples from the same source will be the same and any small differences that may be detected represent errors of measurement.

There are situations when differences in measurements of the density of water may be expected, such as when one sample comes from the sea and another from a freshwater lake: in this case the difference would relate to differences in salinity. However, differences may be found within the one sample if the physicist is measuring parameters at the atomic level, as this is where quantum physics takes over and one now deals with probabilities. At this level the physicist now expects to find differences between measurements on individual molecules and begins to talk about results being ‘on average’.

Such situations always apply in biology because of the natural variation between individuals in the population; hence it is important that you understand the need to think in terms of average values or mean values to represent any population of organisms rather than considering individual values. You will have encountered the necessary concepts in first year mathematics in the sections dealing with statistics and you might wish to refresh your memory from the lecture notes you made.
Example 1
Study the following data, showing litter size in rats treated with the fertility drug, Multisprog, compared to litter size in untreated rats. There is a degree of variability within each set of data but obviously much greater variability between the two data sets.

<table>
<thead>
<tr>
<th>Litter size of untreated rats</th>
<th>Litter size of rats treated with Multisprog</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td>Mean</td>
<td>6.0</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>2.6</td>
</tr>
<tr>
<td>Standard error</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Example 2
Data from a second experiment, comparing litter size in untreated rats with that in rats treated with the new fertility drug, Babyboom. In this case there is greater variability within each treatment, so any difference between the treatments is not quite so obvious.

<table>
<thead>
<tr>
<th>Litter size of untreated rats</th>
<th>Litter size of rats treated with Babyboom</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Mean</td>
<td>6.6</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>4.1</td>
</tr>
<tr>
<td>Standard error</td>
<td>1.2</td>
</tr>
</tbody>
</table>
There must be some way of systematically (and objectively) testing the data when the differences are not obvious by inspection.

This is the purpose of statistical tests of data: to compare the variability BETWEEN the treatments to that present WITHIN the treatments.

If the between treatments variability is much greater than that within treatments, there can be said to be a real treatment effect. If the probability of this difference between treatments happening by chance is relatively low, then the difference between the two treatments is said to be SIGNIFICANT. The words ‘significant difference’ are used frequently in the scientific literature, and refer to the results of such statistical tests. Hence you should use the words with caution i.e. ONLY when you are referring to the results of such tests.
Table 1. The length in millimetres of adult beetles taken from six different areas (A,B,C,D,E and F). The data are shown correct to three significant figures.

Mean values ($\bar{x}$), standard deviation ($s$) and standard error ($se$) are shown for the first two columns only. Use your calculator to calculate the missing values.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>10.0</td>
<td>18.0</td>
<td>20.0</td>
<td>28.0</td>
<td>17.0</td>
<td>15.0</td>
</tr>
<tr>
<td>2.</td>
<td>20.0</td>
<td>20.0</td>
<td>30.0</td>
<td>30.0</td>
<td>21.0</td>
<td>45.0</td>
</tr>
<tr>
<td>3.</td>
<td>15.0</td>
<td>19.0</td>
<td>25.0</td>
<td>29.0</td>
<td>19.0</td>
<td>49.0</td>
</tr>
<tr>
<td>4.</td>
<td>30.0</td>
<td>22.0</td>
<td>40.0</td>
<td>32.0</td>
<td>21.0</td>
<td>30.0</td>
</tr>
<tr>
<td>5.</td>
<td>25.0</td>
<td>21.0</td>
<td>35.0</td>
<td>31.0</td>
<td>22.0</td>
<td>11.0</td>
</tr>
<tr>
<td>6.</td>
<td>1.0</td>
<td>19.0</td>
<td>11.0</td>
<td>29.0</td>
<td>20.0</td>
<td>35.0</td>
</tr>
<tr>
<td>7.</td>
<td>20.0</td>
<td>20.0</td>
<td>30.0</td>
<td>30.0</td>
<td>19.0</td>
<td>40.0</td>
</tr>
<tr>
<td>8.</td>
<td>39.0</td>
<td>21.0</td>
<td>49.0</td>
<td>31.0</td>
<td>20.0</td>
<td>25.0</td>
</tr>
<tr>
<td>9.</td>
<td>35.0</td>
<td>23.0</td>
<td>45.0</td>
<td>33.0</td>
<td>23.0</td>
<td>30.0</td>
</tr>
<tr>
<td>10.</td>
<td>5.0</td>
<td>17.0</td>
<td>45.0</td>
<td>33.0</td>
<td>23.0</td>
<td>30.0</td>
</tr>
</tbody>
</table>

mean $\bar{x}$ | 20.0 | 20.0 |
standard deviation ($s$) | 12.57 | 1.83 |
standard error ($se$) | 3.97 | 0.577 |

1. Would you consider samples A and C to be similar or different?
2. Would you consider samples B and D to be similar or different?

**How are you able to answer these questions? What criteria do you use to judge?**

This is the realm of statistics and it is why all of you as biologists should have at least an elementary understanding of how to carry out basic statistical testing. Even more importantly, you should have a thorough understanding of why statistical tests are necessary and when they should be used. This point must be emphasized because it is a relatively simple matter to go to a biostatistics textbook to remind yourself exactly how to do a test, **but you must know that a test needs to be made.**

The first step in answering the questions asked is to reconstruct those questions in a manner appropriate to statistical analysis. This form is referred to as a **null hypothesis** ($H_0$) and I will frame the two questions in that way.

$H_01$. The samples A and C are drawn from the same population (or from two populations with the same mean).

$H_02$. The samples B and D are drawn from the same population (or from two populations with the same mean).
When null hypotheses are framed in this way it is possible to test any apparent difference between populations at the appropriate level of significance (for most purposes in biology this is 5%, which denotes the probability that such a result might occur entirely by chance). If the probability is less than 5% ($p < 0.05$) then the null hypothesis is rejected and we conclude that there is a significant difference between the samples.

The simplest test for difference between samples from two populations is the t-test. The test takes account of the distribution of values within each sample and the difference between their mean values. There are two basic assumptions in the use of this test: the first is that the sample data are drawn from a population that is normally distributed; the second is that the two samples have the same variance ($s^2$). For many of the variables measured in Biology this will be true; however, you should be aware that it is necessary to test these assumptions before the t-test can be considered valid.

The difference between sample means ($\bar{x}_1 - \bar{x}_2$) is compared to a measure of the variation within both samples ($se_{1,2}$ = the standard error of the difference between the means) to test whether any difference observed is significant.

1. The ‘within samples’ variation is measured as the standard error of the mean for each sample and is obtained by dividing the standard deviation by the square root of the size of each sample ($n$).

$$\text{standard error of Sample 1} = se_1 = \frac{s_1}{\sqrt{n_1}} \quad \text{standard error of Sample 2} = se_2 = \frac{s_2}{\sqrt{n_2}}$$

2. The ‘between samples’ variation is calculated by adding the standard errors of the two samples and taking the square root.

$$\text{standard error for the difference between means} = se_{1,2} = \sqrt{se_1^2 + se_2^2}$$

(This can also be written as $\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}$ where $s$ = standard deviation)

The test statistic, $t$, is calculated by dividing the difference between the means by the standard error of the difference between means.

$$t \text{ test statistic} = \frac{\bar{x}_1 - \bar{x}_2}{se_{1,2}}$$

(This can also be written as $\frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}}$ where $s$ = standard deviation)

The resulting value is compared to the critical t value obtained from statistical tables. The appropriate number of degrees of freedom will be $df = (n_1-1) + (n_2-1)$. 
Research, Inquiry and Information Literacy

Worked example

Is there a significant difference between the length of beetles from Areas D and E?

Null hypothesis: There is no significant difference between the lengths of beetles from sites D and E. \( i.e. \ \bar{x}_D = \bar{x}_E \)

(Note that it is valid to use the t test as the data are normally distributed and the variances of the two sets of data are the same.)

<table>
<thead>
<tr>
<th></th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{standard error of Sample D} = se_1 = \frac{s_1}{\sqrt{n_1}} = 0.6
\]

\[
\text{standard error of Sample E} = se_2 = \frac{s_2}{\sqrt{n_2}} = 0.6
\]

\[
\text{standard error of diff. betw. means} = se_{1-2} = \sqrt{se_1^2 + se_2^2} = 1.095
\]

\[
\text{t test statistic} = \frac{\bar{x}_1 - \bar{x}_2}{se_{1-2}} = 9.13
\]

Look up the critical t in statistical tables

Critical t at \( p = 0.05 \) with 18 degrees of freedom = 2.1

\[
\text{t test statistic (9.13)} > \text{critical t (2.1)}
\]

Conclusion: Reject the null hypothesis \( \bar{x}_D \neq \bar{x}_E \)

There is a significant difference between the lengths of beetles from sites D and E.

Exercise: Use another two sets of data (say, A and C) from the table above and repeat the test. The critical t value will be the same (since the number of samples from each site, hence the degrees of freedom, are the same.)
FORMULATION OF HYPOTHESES

An hypothesis must be worded so that it is testable, and so that the outcome of the experiment can be interpreted as supporting or discounting the hypothesis. For Example 2 above, you might suggest an appropriate hypothesis would be something like: Babyboom is a better fertility drug than Multisprog in increasing litter size in rats. There are three outcomes possible - no difference in litter size between treatments, larger litter size with Multisprog than with Babyboom, or larger litter size with Babyboom than with Multisprog. One of these outcomes supports the hypothesis, and two do not. But do these two other outcomes disprove the hypothesis? And how would you statistically test the data?

For ease of statistical testing, most hypotheses are worded in the negative, and termed NULL HYPOTHESES e.g. ‘There is no difference between the effect of two different fertility drugs on the litter size in rats’. This may seem a trivial exercise in semantics, but using a null hypothesis means that a well-designed experiment should provide a definite ‘yes’ or ‘no’ outcome. If the results and the appropriate statistical testing show a real difference between the two, the null hypothesis is rejected, and we can conclude there is a significant difference between the effect of the two different drugs on litter size in rats. If no real difference is found, the null hypothesis is accepted, and we conclude that there is no significant difference between the effects of the two drugs. In either case, the outcome and conclusion are very clear.

In the previous section you were introduced to null hypotheses worded as ‘The samples A and B are drawn from the same population’. If samples A and B had different experimental treatments applied to them, and the null hypotheses was tested and rejected, you would conclude that there was no effect of the treatment on the samples. When wording your own null hypotheses, make them as relevant to the experimental situation as possible, as demonstrated below.

Example: The density of fungal hyphae is found to correlate with the level of extractable phosphorus in a forest soil. Two possible hypotheses to explain this correlation are:

A. That the level of extractable phosphorus directly determines the amount of fungal growth; or
B. That the amount of fungal hyphae directly determines the level of extractable phosphorus in the soil.

The first hypothesis can be worded as a null hypothesis, as follows:
A1. There is no change in the density of fungal hyphae in soils when extractable phosphorus levels are changed.

Exercise: Suggest how this hypothesis might be tested experimentally.
(What are the experimental units, and the different treatments you would apply?)

Word the second hypothesis (B) as a null hypothesis (B1), and suggest an experimental design to test it.
USING MSEExcel FOR STATISTICAL FUNCTIONS

MSEExcel can be used to perform the following statistical functions:

1. Create frequency histograms of continuously variable data sets.
2. Perform a t-test to determine if there is a significant difference between two sets of data.
3. Prepare a scatterplot.
4. Calculate a correlation coefficient.
5. Calculate a chi-square.

(N.B. The analysis tools are not always loaded when you install Excel, so to use them on your home computer you may need to do Install them using the Add-Ins function. They are not available in the most recent version of Word for Macintosh so don’t discard Excel 2003!)

If you need assistance with basic Excel functions refer to MSEExcel – a quick guide to basic functions at the Generic Skills Website.

1. Create a frequency histogram of continuously variable data

Once you have opened or created a file of data, you need to create a list of values that you want plotted on the x axis of your graph. This is called the Bin range. e.g. for height values ranging from 120 cm to 200 cm you might choose x axis values of 120, 125, 130, 135, 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200. You need to create this list in another column on the worksheet containing your data. (For a long list you can do this quickly using a calculator that adds a set value to the value above, then copying and pasting this function down as many rows as you need.)

Select Tools, Data Analysis. Scroll down the list, select Histogram and click OK. A new window will appear and you need to enter the following information:

Input range: click in this box then use the mouse to highlight the data you wish to plot. (Use click and drag, or click on the first value in the list, hold down the mouse button while you press Shift then click on the last value in the list.) The cell range will automatically appear in the box.

Bin range: click in this box then highlight the bin range values you entered on your worksheet.

Click on New worksheet ply, enter a name for the new sheet if you wish, click on Chart output then OK.

The histogram will be plotted in a new worksheet on the screen. The Bin values and their frequencies will be displayed in a table at the left hand side of the graph. (To return to your data, click on the appropriate tab at the bottom of the workbook.)
Refer to Help, Contents and Index, Analysing Statistical Data, Histogram analysis tool for further details.

2. Perform a t-test
Select Tools, Data Analysis. Scroll down the list, select t-test: Two sample assuming unequal variances and click OK. A new window will appear and you need to enter the following information:

Variable 1 range: highlight the column of data that are the values for variable 1. (Click on the first value in the list, hold down the mouse button while you press Shift then click on the last value in the list.) The cell range will automatically appear in the box. If you include the column heading in this range, tick the Labels box.

Variable 2 range: highlight the column of data that are the values for variable 2. If you include the column heading in this range, tick the Labels box.

Hypothesized mean difference: Enter 0.

Output range: click in this box then select a region on your worksheet where you want the data table displayed. You can do this by clicking on a single cell, which will become the top left cell of the table.

The table will include the mean and variance for each variable, degrees of freedom, the t-statistic for the data, the critical t and probability value for the one-tailed and two-tailed test. You should look at the two-tailed probability value. If this is less than 0.05, the difference between the means is significant.

Refer to Help, Contents and Index, Analysing Statistical Data, Perform a t-Test analysis for further details.

3. Prepare a scatter plot
Highlight the two columns of data you wish to plot. Make sure the x axis data is in the first column. Click on Chart Wizard, select XY (Scatter) and click on Next. The plot will appear in the Chart Wizard window. This window allows you to select the range of the data, which will automatically be included if you have previously highlighted the data. Click on Next, adjust the chart title if necessary and enter titles (AND units!) for each axis, in the Value (X) Axis and Value (Y) Axis boxes. You can choose to remove gridlines and the legend in the appropriate windows. The changes will be displayed in the preview window. Click on Next when you have finished in this window. Select As new sheet and enter a name for this worksheet if you wish. Click on Finish and the plot will be displayed in a new worksheet in your workbook. (You can view different sheets by clicking on the appropriate tab at the bottom of the workbook.)

You can adjust the origin point on any axis by clicking on the axis then selecting Format, Selected Axis. (Alternatively, hold down Control key, click on the axis and select Format Axis from the pop-up menu.) Select Scale and set the minimum value to the point you want at the start of that axis. Repeat for the second axis if necessary. Experiment with changing the Font and Number style of the axis.
4. Calculate a correlation coefficient

If you have measured two variables in a group of individuals, such as foot-length and height, you can calculate how closely the variables are correlated with each other.

Select Tools, Data Analysis. Scroll down the list, select Correlation and click OK. A new window will appear and you need to enter the following information:

**Input range:** highlight the two columns of data that are the paired values for the two variables. The cell range will automatically appear in the box. If you include the column headings in this range, tick the Labels box.

**Output range:** click in this box then select a region on your worksheet where you want the data table displayed. You can do this by clicking on a single cell, which will become the top left cell of the table.

Click OK and a table will be displayed showing the correlation coefficient (r) for the data. (Ignore the values of 1 that give the correlation coefficient of each variable relative to itself!) You can test whether the correlation is significant by examining Table 1. Critical values of correlation coefficients at the 5% significance level, using (n - 2) degrees of freedom. (n = the number of rows of data, e.g. 2 columns of data with 10 rows each gives df = 8) If the observed r is greater than the critical value, the two variables are significantly correlated.

(Note that this does not mean they are dependent - to determine a cause and effect relationship requires regression analysis.)

Refer to Help, Contents and Index, Analysing Statistical Data, Correlation analysis tool and formulas for further details.

5. Calculate a chi-square

Using your knowledge of Excel workbooks, you should be able to set up a table with calculators to very quickly calculate a chi-square statistic.

Prepare a table of your data with the top and bottom rows as follows:

<table>
<thead>
<tr>
<th>Specimen number</th>
<th>Measured value</th>
<th>Expected value</th>
<th>((O-E)^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*insert required number of rows for data*

\[
\chi^2 = \sum \left( \frac{(O - E)^2}{E} \right)
\]

Refer to Table 2. Critical values of the chi-square statistic (\(\chi^2\)) at the 5% significance level to determine whether the observed values for your sample vary significantly from the expected values. If the calculated chi-square is greater than the critical value at (n - 1) degrees of freedom, the difference is significant.
### Table 1. Critical values of correlation coefficients at the 5% significance level.

<table>
<thead>
<tr>
<th>Degrees of freedom</th>
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### Table 2. Critical values of the chi-square statistic ($\chi^2$) at the 5% significance level.

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USE OF THE OLYMPUS COMPOUND MICROSCOPE (CH-2)

1. **Plug in** the microscope and **switch** on at the power point. Set the voltage control dial to zero. **Switch on the light using the power switch on the microscope base.** If your microscope has a phase contrast condenser beneath the stage **check that the disc is set to ‘O’ (open).** Open up the iris in the lamp-house and the one in the condenser.

2. **Swing the lowest power objective into position** using the knurled ring on the revolving nosepiece. (Do not hold the objectives and use them as levers when turning the nosepiece.) Adjust the light intensity to a comfortable level using the voltage control dial.

3. Clean the bottom of a prepared glass slide and place it on the stage. Hold open the spring-loaded arm of the specimen holder and move the slide into position. Release the arm GENTLY so you do not chip the slide. Centre the specimen over the light path using the controls beneath the stage.

4. **To focus:** Swing and click the **10X objective** into place above the specimen. Focus with the coarse and then the fine focus adjustment knob. **Clockwise rotation of the knobs raises the stage.** **DO NOT LET THE OBJECTIVE TOUCH THE SLIDE.** Dirt on the eyepieces, objectives and the condenser lens can make focussing difficult. Clean these lenses with fresh pieces of lint-free lens tissue and moist breath only - **nothing else!**

5. After you have focussed on the material, **LOCK THE PRE-FOCUSSING LEVER** (found inside the coarse adjustment lever) by pushing it up. This will prevent further upward travel of the stage and guards against contact between the objective and the slide. Once this lever has been pre-set it can be left in that position.

6. **Binocular adjustment:** Adjust the eyepieces to your own inter-pupillary distance by moving them together or apart. The images from both eyepieces should coincide into one image.

7. **Dioptre adjustment:** Look at the specimen image through your right eye and focus sharply using the fine focus adjustment knob. Then look at the image through your left eye and focus sharply with the dioptre adjustment ring on the left eyepiece. (This adjustment is different for each individual and can be done with or without glasses as you prefer.)

8. **Changing objectives:** The CH-2 has four objectives - 4X, 10X, 40X and 100X. **Note that the 100X objective can only be used with oil immersion** (see 12.). **Swing and click the desired objective into position.** **Fine focussing only should be required.** **DO NOT USE THE COARSE ADJUSTMENT KNOB WITH EITHER THE 40X OR 100X OBJECTIVE!
9. **Adjustment of iris diaphragm aperture:** Remove the right eyepiece and look down the eyepiece tube. Use the iris diaphragm lever below the stage to reduce the observed circle of light to 70-80% of the width of the field of view. You should just see the straight edges of the iris diaphragm impinging on the field of view. **THE IRIS DIAPHRAGM ADJUSTMENT MUST BE REPEATED EVERY TIME YOU CHANGE OBJECTIVES AND AFTER USING PHASE CONTRAST.** With lightly stained specimens, whole mounts or unstained wet preparations, you can create contrast by closing this diaphragm further. This reduces the resolving power of the microscope.

10. Your specimen can be moved left and right or up and down using the stage controls beneath the stage. You can relocate any point on a slide by noting the graduations above the specimen holder before moving the slide and moving back to those coordinates as you desire. Relative sizes of structures can be estimated by knowing the **diameter of the field of view** for each objective. These are:

- **4X objective:** 4.5 mm
- **10X objective:** 1.8 mm
- **40X objective:** 0.45 mm
- **100X objective:** 0.18 mm

11. **Phase contrast:** Living cells (*e.g.* protozoa) often lack contrast and require contrast enhancement optics to become visible. You can switch from bright field (normal) to phase contrast simply by rotating the disc in the condenser so that the number matches the magnification of the objective. You can obtain phase contrast with the 10X, 40X and 100X objectives.

12. **Oil immersion:** Once you have focussed your specimen on 40X swing this objective just out of position. Place a small drop of oil on top of the coverslip and GENTLY swing the 100X objective into position. Only minor focussing using the fine adjustment knob should be required to obtain a clear image. If you cannot obtain a clear image return to a LOW power (10X or 4X) objective (DO NOT SWING THE 40X OBJECTIVE THROUGH THE OIL!) and refocus. Swing the 100X lens back into position and focus again. If you still cannot obtain a clear image you probably have a dirty objective. Seek assistance from a demonstrator. **Always clean the oil off the objective (with lens tissue) immediately after using oil immersion.** If you are using prepared slides, clean the oil off the slide (with Kleenex).

13. **When you have finished** looking at any slide, swing the lowest power objective into position BEFORE you remove the slide from the microscope stage (Remember not to swing the 40X objective through any oil you have used with the 100X objective!). Return the phase contrast condenser to the zero position. Place wet mount slides into the container provided and return prepared slides (after removing any oil) to their appropriate holder. Put the plastic cover on your microscope and **wind the power cord around the outside of the cover - never let the power cord come into contact with the objectives of the microscope.**
APPENDIX: AN ODE TO SPELL CHECKERS

This came to me by email from a former student.

I have a spelling checker
   It runs on my PC.
   It plane lee Marx four my revue
   Miss steaks aye can knot see.

Eye ran this poem threw it.
   Yore shore reel glad two no.
   Its very polished inn its weigh,
   My checker tolled me sew.

A checker is a blessing.
   It freeze yew lodes of thyme.
   It helps me right awl stiles eye reed,
   And aides me when aye rime.

Each frays come posed up on my screen
   Eye trussed too bee a joule.
   The checker pours o’er every word
   Too cheque sum spelling rule.

Bee fore wee rote with checkers
   Hour spelling was inn deck line,
   Butt now when wee dew have a laps,
   Are air oars cot in thyme.

And now bee cause my spelling
   Is checked with such grate flare,
   There are know faults in awl this peace,
   at leased nun that eye yam a wear.

To rite with care is quite a feet
   Of witch won should be proud,
   And wee mussed dew the best wee can,
   Four flaws are knot aloud.

That’s why eye brake in two averse
   Ass Eye dew want too please.
   Sow glad eye yam that aye did bye
   This soft wear four pea seas.