Hilary Glasman-Deal

Science Research Writing

for native and non-native speakers of English

Second Edition

World Scientific

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Hilary Glasman-Deal
Imperial College London, UK

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Preface to the Second Edition

Student: Dr Einstein, aren't these the same questions as in last year's exam?
Dr Einstein: Yes, but this year the answers are different.

Science research writing is changing and developing, influenced by factors that are driving the way that science is communicated and the way that research is accessed. These factors include the global nature of science research, internet reading and the accelerating speed of scientific discovery, all of which are revolutionising the communication models that existed in the twentieth century.

The global nature of science research requires fast, effective and accurate communication that can be understood by all participants in international interactions and research collaborations. The language of science is not owned by English speakers but by its many users worldwide. Researchers who are not native English speakers frequently lead their field. These researchers report their work in high-impact journals and need to write and read research in their discipline fast and effectively. This is creating a global science communication language that codifies research such that it can be accessed by all users, in all countries, and at all levels.

Internet reading is another factor changing the way research is accessed, and this in turn is influencing how it is written. The collaborative nature of STEMM (Science, Technology, Engineering, Mathematics and Medicine) and increases in research funding have increased the volume of research published annually and therefore the amount of reading required for successful STEMM research. In the past, researchers would read hard copies of a limited, carefully-curated set of print journals. Now, however, most achieve a faster and more fluid access to a wider range of research on the internet via information-surfing. Research activity involves extensive title-scrolling to search for relevant studies, and readers may only read one section of the research article — perhaps the Abstract, Results or Conclusion. As a result, titles have become more important, and parts of the research article, particularly the Abstract or Summary, are developing in ways that enable them to be read as independent, standalone documents.

A third factor driving the change in science research communication is the need for speed. Science is moving forward almost faster than it can be reported, and STEMM research requires writers to communicate highly complex information as quickly as possible. In some cases this is to avoid being 'leapfrogged' by other researchers; in others it is because links with industry, patents and spin-off companies demand fast publication. If a paper takes too long to write, there is a risk that it will be partially or completely out of date — and therefore unpublishable — by the time it is submitted. Scientists and journal editors therefore need to communicate the impact of a study as quickly and simply as possible, and this, too, is shaping STEMM research writing.

There are also changes in the nature of research itself: science is becoming more specialised in some cases, and more interdisciplinary in others. This creates a complex communication structure in which highly specialised information sometimes needs to be accessed by non-specialists.

All of these changes are having a profound effect on research writing, with impacts on both the structure and the content of the traditional research article. The form of the research article is in transition, changing to satisfy the fast-moving needs of the research community. The function and content of the Abstract is changing, the location of the Methods section is shifting, the IMRD (Introduction, Methods, Results, Discussion) structure is loosening, and markers of significance such as *Research in Context* panels, one-page summaries and lists of *Highlights* are sometimes included, particularly in the online version of the research article. To participate successfully in the current research environment, researchers need to be aware of — and respond to — these changes and developments in science research writing. They also need to be prepared for those that are coming. This has resulted in two key changes in the Second Edition of this book.

Changes in This Second Edition

The first change reflects the fact that science communication platforms are in transition. In the First Edition, research articles in high-impact journals across a wide range of disciplines were analysed to generate what was then a set of fairly stable writing models for each section of the research article. Those writing models have been significantly updated in this Second Edition to reflect current patterns and trends in research writing, but they can no longer be seen as stable representations. Researchers now need to develop the ability to update their writing models alongside the next round of changes and developments in science communication. Given the fast-moving nature of the changes outlined above, the Second Edition aims to develop writing strategies that are future-proof and which represent a lifelong tool, irrespective of upcoming changes and developments in science communication.

The Second Edition develops these strategies by encouraging writers to use a reverse-engineering approach to writing. Most reading involves passively approaching a text as a source of information. By contrast, reverse engineering a text requires an active reading strategy that involves learning to step back from the information itself and become aware of how that information is delivered. Once developed, reverse engineering can be used by STEMM research writers as a starting point to generate all text types in science research communication now and in the future, including grant proposals, conference abstracts, Letters, technical reports and review articles.

The approach is similar to that of Painting by Numbers, whose marketing slogan was *A beautiful oil painting the first time you try*. Using a Painting by Numbers kit may not turn you into Leonardo da Vinci, but it delivers a strategy for producing recognisably similar paintings.

https://en.wikipedia.org/wiki/Mona_Lisa

In the same way, analysing the organisational scaffold, writing patterns and language in a set of well-written research articles will deliver a strategy for producing a credible, well-organised and readable research article that conforms to the current conventions of comparable articles.

The second major change in the Second Edition is the title, and therefore the readership, of the book. The First Edition was directed towards non-native speakers of English. However, my experience of working with native speaker researchers since then clearly demonstrates that although there are some language issues that are specific to non-native speakers, the *writing* issues are common to all STEMM research writers. The aim of all researchers is to create successful and effective text out of data and information. Given the complexity of most STEMM research projects, this requires a high level of communicative competence. However, 'academic English is no-one's first language'[1], and native speaker researchers, even those at the highest level, experience most of the same challenges as non-native speakers when writing about their research. Experience has shown me that correct English grammar does not guarantee a successful text, and that the reverse is also true: a text may be well-written and therefore communicate successfully and accurately despite some language errors. I have therefore shifted the focus of the book to language and writing issues that are common to both native and non-native STEMM researchers, and particularly to those issues which have an impact on meaning and readability.

Since the First Edition was published in 2009, *Science Research Writing* has been translated into Chinese, Japanese and Korean, and is used around the world at universities and research institutes, by instructors teaching English for Academic Purposes (EAP) and English for Specific Academic Purposes (ESAP) to STEMM researchers and students, as well as by STEMM researchers who are native speakers of English. These users of the book have contributed to many of the changes in the Second Edition, including the addition of a Checklist and Tips chapter that summarises the writing issues dealt with in other Units.

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Introduction

Writing for a reader: wrapping information in a narrative

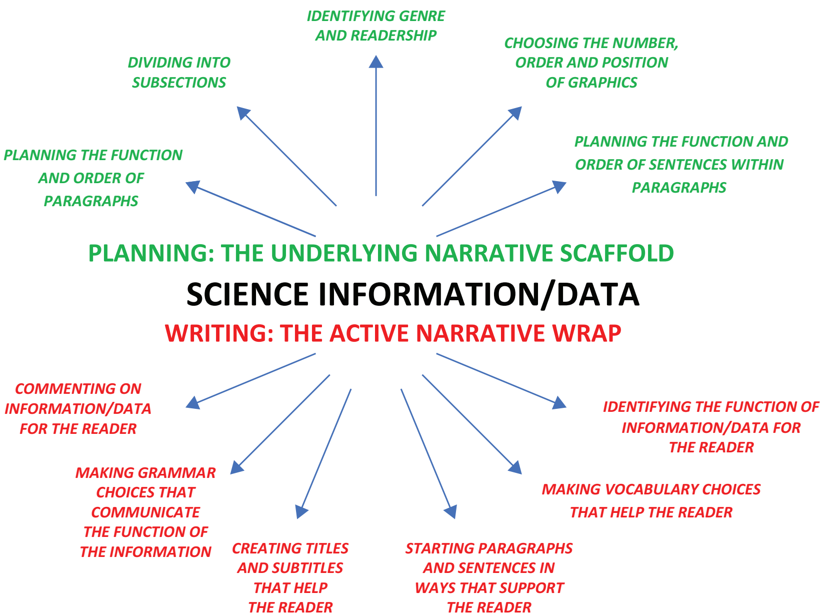
Science research writing is not simply about presenting information, or even about presenting information clearly. In the first place, information itself is neutral — it has no intrinsic function. If the writer does not explicitly identify and communicate the function of the information and how it relates to the rest of the text, the reader cannot understand why it is there. This interrupts the flow of the article and therefore its readability. Secondly, science research writing is about developing or changing the reader's knowledge; this requires a strong narrative wrapped around the information that leads logically and patiently to the conclusions that the writer wishes to draw.

The writer's familiarity with the scientific content of the research makes it hard for that writer to see why a narrative is necessary. Prior to writing up, the writer may have been working closely for months with colleagues who share both general and specific knowledge of the topic and the study. Communication within this group is very implicit, since those colleagues all know why, how and what is being done. When the writer is ready to report the study to outsiders, that implicit understanding can no longer be taken for granted and a conscious effort must be made to consider how much can be assumed about the reader's knowledge and to supplement that knowledge wherever necessary. This is particularly true given the increasingly multidisciplinary nature of science research. The range of researchers and stakeholders wanting access to science research is unpredictable, and it is growing.

A written text is therefore not an information repository, nor is it a naturally-occurring flow of words and sentences; it is an artefact created for a reader. **The aim is not simply to make it possible for the reader to understand; the narrative should be strong enough to make it impossible for the reader NOT to understand.**

What does a narrative wrap look like?

To communicate research, the science has to become language. A narrative wrap is the communication scaffold that surrounds the information and makes it intelligible to the reader. Decisions about titles, subheadings, paragraph function and the order of graphics form part of the narrative wrap and create a meaningful framework for the information. Within the text itself, narrative is achieved by the writer commenting on and identifying the function of the information, as well as by less obvious means such as paragraph-entry sentences and choice of verb tense. Tools and guidance for the narrative wrap are discussed throughout the book. **The narrative wrap turns science information/data into readable, effective text.**



Planning: The Underlying Narrative Scaffold

IDENTIFYING GENRE AND READERSHIP What am I constructing? A research article, a review article, a grant proposal, a Letter, a poster and a conference abstract are different genres, and each requires a different structure and a different approach to content. Adopting a cut-and-paste approach as you move between different genres results in a shapeless, unfocused text. Before you begin planning your text, reverse engineer a current example of the relevant genre as a model.

Who might read this? Where do I pitch the information level of my text? What can I assume that all potential readers know? How quickly can I move into scientific detail? Is the readership of this text likely to become more interdisciplinary in the future?

DIVIDING INTO SUBSECTIONS Are there standard subsections for this type of text in this field? How many subsections are normal in my target articles? What is the average length of these subsections? Does my work fit neatly and logically into these subsections? If not, is the way I have divided my text into subsections more appropriate?

CHOOSING THE NUMBER, ORDER AND POSITION OF GRAPHICS (i.e. figures, tables, images) Do I have a good reason for including each graphic? What is the most logical order of my graphics? Where is each one most useful to the reader? Position each graphic within the surrounding text so that it doesn't interrupt the narrative flow of the text but rather comes at a natural point within the narrative, i.e. exactly when the reader becomes aware of wanting to see it.

PLANNING THE FUNCTION AND ORDER OF PARAGRAPHS Do all my paragraphs have an identifiable function? Is that function clear to the reader? Is the order of paragraphs logical?

PLANNING THE FUNCTION AND ORDER OF SENTENCES WITHIN PARAGRAPHS Do all my sentences have an identifiable function? Is that function clear to the reader, or will they wonder why I have included it here? Does each sentence fit with the overall function of the paragraph? Does each sentence follow logically from the next?

Writing: The Active Narrative Wrap

COMMENTING ON INFORMATION/DATA FOR THE READER Have I (perhaps incorrectly) assumed that what I think about the information/data is obvious to all potential readers?

IDENTIFYING THE FUNCTION OF INFORMATION/DATA FOR THE READER Have I (perhaps incorrectly) assumed that the function of the information/data is obvious to all potential readers?

MAKING GRAMMAR CHOICES THAT COMMUNICATE THE FUNCTION OF THE INFORMATION Have I thought about the meaning and impact of the verb tense I am using in each sentence? Have I made grammar choices that resolve (or create) potential ambiguity?

MAKING VOCABULARY CHOICES THAT HELP THE READER Have I considered the needs of the global reader? Am I using vocabulary consistently?

STARTING PARAGRAPHS AND SENTENCES IN WAYS THAT SUPPORT THE READER Does the start of each paragraph help the reader see where I am going in that paragraph? Have I closed the gaps between sentences and started them in a reader-friendly way?

CREATING TITLES AND SUBTITLES THAT HELP THE READER Does my title represent and predict the content or is it just the original 'working' title that I haven't really thought about since I began the project? Is my title a normal length for this type of article? Do my subsection titles work for the entire subsection? Do my subtitles help the reader enter the subsection? Does everything in this subsection 'fit' the subtitle? Are my subtitles a normal length for this type of article? Are subtitles normally grammatical sentences in my target articles? Are they supposed to summarise the content of the subsection?

What strategy is used in this book?

A classic approach to writing is the genre-based approach, which deals with the structure and content of different types of texts. Genre-based instruction is widely used to teach writing. However, although this approach is good at telling writers **what** they need to do, it is less effective when it comes to telling them **how** to do it. For example:

WRITING THE DISCUSSION SECTION:

Highlight the most significant results, but don't just repeat what you've written in the Results section. **HOW DO I DO THAT?** Show how these results relate to the original question. **HOW?** Discuss whether or not your results are consistent with what other investigators have reported. **TELL ME HOW!** Look at alternative ways to interpret your results. **HOW DO I DO THAT?** Discuss how your results fit into the big picture. **HOW EXACTLY DO I 'DISCUSS' THAT?**

To answer questions of this type, users of this book are shown how to develop a reverse-engineering approach. They are guided towards deconstructing successful current research writing in their own field to create models for their own writing. I have used this reverse-engineering approach at Imperial College London and other universities around the world, analysing thousands of recently-published research articles in a range of STEMM disciplines to construct and validate the basic models, the grammar, and the language lists in the book. The Centre for Academic English at Imperial College London uses the approach to teach STEMM writing to early-stage researchers, as well as training more experienced research writers to develop and apply it. A key advantage of the reverse-engineering approach is that it responds well to the fast-changing nature of research writing: once the strategy becomes familiar, writers can adjust and update their models alongside the next round of changes in science writing and publication platforms.

The aim of this book is to provide a quick, do-it-yourself guide for writing science research for publication. The reverse-engineering approach can be understood quickly, used independently, and tailored to the needs of all STEMM research disciplines and all STEMM texts, including grant proposals, conference abstracts and industry reports. The approach is *descriptive* rather than *prescriptive*. Instead of offering advice or telling writers what to do and what not to do, the aim is to begin by generating a highly accurate description of the type of writing each individual writer wants to produce. Accurate descriptions alone, however, do not generate written text — describing something is not the same as being able to do it, so in addition to a description of *what to do*, the key contribution of this approach is that it then helps the writer to discover *how to do it*, and to apply that knowledge.

The strategy is as follows:

1. **Build a sentence-based/paragraph-based model identifying the functions of a successful text**, for example: *This sentence identifies a gap in the research* or *This paragraph maps the contribution of this study onto the literature.*
2. **Mine successful texts for vocabulary to communicate these functions**, for example, the words and phrases that *identify a gap in the research.*
3. **Identify and master the relevant grammar, language and writing skills that achieve these functions**, for example, *verb tense choices*.

4. **Continually reinforce, adjust, update and develop 1–3 above via reading in the field.**

The last step in the process: **Continually reinforce, adjust and develop 1–3 above via reading in the field** is essential. Science research writing is not a static genre; it is in transition, and successful writers need to be willing and able to upgrade as the genre develops. The key to success is to refer to a set of target research articles (or review articles, conference abstracts etc.), update that set constantly and update the models accordingly.

The models, grammar/language and vocabulary presented in each chapter are the result of analysing over 2,500 recently-published research articles in a range of STEMM disciplines in order to generate a toolkit that is reliable and has high face validity.

Key messages:

- **THE CONTENT OF SCIENCE RESEARCH SHOULD BE ACCESSIBLE TO ALL READERS.**
- **THE READER NEEDS TO BE SHOWN THE FUNCTION OF DATA OR INFORMATION, NOT JUST PRESENTED WITH IT.**
- **THE AIM IS NOT SIMPLY TO MAKE IT POSSIBLE FOR THE READER TO UNDERSTAND; THE AIM IS TO MAKE IT IMPOSSIBLE FOR THE READER NOT TO UNDERSTAND.**
- **EVIDENCE-BASED GUIDANCE CAN BE OBTAINED BY STUDYING THE STRUCTURE AND LANGUAGE OF SUCCESSFULLY-PUBLISHED PAPERS.**

Who is this book for?

The book is designed to enable science researchers, both native and non-native speakers of English, to write more effective research papers for publication. The reverse-engineering strategy described in the book can also be adapted to produce other research-related STEMM writing such as reports, conference abstracts and review papers. In addition, since a research paper is a microcosm of a thesis, it can also be used to write a PhD thesis. In fact, many institutions permit PhD candidates to organise and submit the thesis as a series of linked published papers, since this solves the problem of writing the thesis and the relevant papers at the same time.

Why might I need it?

Science does not exist until it is published[2]. Good writing enhances the chance of publication, and publication is a key goal of research; when you share your work via publication you become part of the global science community. In addition, high-quality publications attract funding and lead to participation in high-level projects. Writing and publishing a research paper is also the best way to develop your career. If you turn your thesis or project into a useful paper, your CV will look more professional, and will be more competitive internationally.

Good scientists, however, are not always good writers. Some find it difficult to organise information optimally, or to represent their research concisely and effectively. Others find writing burdensome and may feel discouraged by the prospect of writing. This slows the writing process down — sometimes to a total stop. In the current global context, research needs to be published quickly. This book is designed to speed up this 'lab-to-journal' process by providing the information, vocabulary and skills you need so that you can write quickly, confidently and independently.

As a science researcher, you read and understand highly complex material in your field with little effort. However, you may find it harder to produce well-written texts at that level, or you may feel that your writing does not represent the content or impact of your work effectively. In this book you will learn to use your existing reading ability and the material you read to develop the relevant writing skills. You don't need to learn much more than you already know; you just need to make that knowledge active, rather than passive. Science writing is easier than it looks.

Why not simply use proof-readers, or (in the case of non-native researchers) translation software?

Turning to proof-readers or translators for help resolves some language errors, but may not resolve writing issues. They may not notice some errors, because a sentence which is grammatically correct will still be wrong if it does not mean what the writer intended. The wrong verb tense, for example, may make a finding (*X occurred*) look like a known and accepted truth (*X occurs*). In addition, a proof-reader or translator may not check whether your writing fits conventional patterns in your field. For example, you may have forgotten to justify your choice of method or explain how your results relate to your original question. A proof-reader or translator is unlikely to notice this, but it could mean that the peer reviewer or journal editor rejects your paper as unprofessional. Another example is that if your conclusions are translated in language that is more forceful or positive than you intended, your paper may fail at the review stage because the reviewer cannot find adequate justification in your results for the conclusions thus stated.

There is an additional difficulty associated with using translators or translation software. English academic writing follows certain cultural norms; these are evident in the choice of vocabulary and even in the way information is organised into paragraphs. If the cultural writing norms of the writer are very different from those of the reader, the translated text will look odd, and key aspects of research paper writing, such as explicitly identifying the value of the study, may be so understated as to be unrecognisable. Another fast-emerging issue is that ownership of confidential material is harder to control once the material has passed through internet-accessible translation software or editing tools.

Will the book help me to become the 'first author' of my paper?

The first author is more visible in the literature than co-authors, and is more closely linked with the research (e.g. Wu *et al.,* 2019). The rules and conventions for the order of multiple authors vary across different research disciplines, but if you depend on colleagues to do much of the writing for you, this may affect your status as first author, so a central aim of this book is to improve your ability to write independently.

Does the book focus on vocabulary and grammar?

Science is international. This has an impact on the language of science publication, and drives both native-speaker writers as well as non-native writers to communicate their research in language that is clear and accessible to readers around the world. Whatever your first language, most of the people who read your paper will not be native speakers of English. Science research writing therefore uses a fairly restricted range of language to express and negotiate meaning. This is good news for non-native speakers! It means that they do not have to master the whole of English; to write successful, clear papers it is only necessary to master a relatively small subset of English vocabulary. The language used to negotiate meaning in a research paper consists of a limited set of commonly-used words and phrases. The non-technical vocabulary used in scientific writing also consists of a limited set of words and phrases. These are used as a kind of code that makes it possible to communicate accurately with researchers around the world.

The issue around grammar is more complex. As noted above, correct grammar does not ensure accurate or effective communication; equally, a text may be well-written and therefore communicate successfully and accurately despite some grammar errors. Rather than focusing on grammar rules, the book directs all writers towards using grammar, for example verb tense, in ways that *communicate the intended meaning* clearly and unambiguously.

I have taught English for Academic Purposes to STEMM students for over 30 years. For the past 25 years I have been teaching PhD and post-doctoral research writing in the Centre for Academic English at Imperial College London, where I also consult with individual PhD students, postdocs and academic staff — native speakers as well as non-native speakers — who are writing a thesis, research paper, or textbook. I also deliver workshops to research groups around the world. This book is based on the two most useful things I have learned:

1. **Science writing does not need to be stylish or elegant; its primary aim is to communicate clearly and accurately.** Using elegant English may actually make your research article less accessible, or even less accurate. For example, using a thesaurus to avoid repetition is counter-productive; a *framework* should not suddenly become a *methodology,* an *approach* or a *model* without warning. Repeating the same word creates an echo which enables the reader to recognise and track concepts through the paper, and ensures that the concepts themselves remain stable and consistent.
2. **Good organisation and good writing can compensate for language errors, but error-free language does not compensate for poor organisation or poor writing**. A text in perfectly grammatical English will be ineffective and even unintelligible if the information is jumbled or presented incoherently.

How does the book work?

The book takes the research article as a typical example of a STEMM text. Reports, dissertations and theses are constructed in a similar way, but the research paper is of a more manageable size for analysis.

The Units in the book are ordered according to IMRaD (Introduction, Methods, Results, Discussion) for the sake of simplicity. Although IMRaD is no longer the only available model for research writing, most research articles do contain an Introduction, a description of what was done/used, the outcome of what was done/used and a discussion of that outcome. However, IMRaD is not normally the order in which the writer produces the research paper, nor is it always the order in which it appears in a journal, or the order in which the paper is likely to be read. Writers often produce the Methods section first, then the Results, then the Discussion/Conclusion, then the Introduction, and finally the Abstract and Title. In addition, some journals present the Methods or Experimental section at the end of the paper or as supplementary material. Readers, too, rarely read in IMRaD order. They may begin with the Title/Abstract, but then jump straight to the Results section or the Methods, depending on their interests. Nevertheless, in this book the sections of a research paper are presented in the IMRaD format for ease of reference, and to demonstrate the order of information as it generally appears in print.

The book is divided into eight units. Unit 1 deals with the Introduction, Unit 2 the Methods, Unit 3 the Results, Unit 4 the Discussion, Unit 5 extends the reverse-engineering method used in previous Units to the Conclusion section, Unit 6 deals with the Abstract, Unit 7 the Title and Unit 8 contains a checklist and writing tips.

The structure of the first two units is similar. For example, Unit 1 begins by building a basic generic model of an Introduction. Extracts from recently-published Introductions are included to demonstrate how the model operates in the real world. This is followed by a list of useful vocabulary taken from over 2,500 recently-published research articles in different disciplines, together with examples of sentence patterns that show how the words and phrases are used in the Introduction. At the end of the Unit there is a Language and Writing Skills section designed to respond to frequently-asked questions. There are not many grammar exercises in the Language and Writing Skills sections at the end of each Unit; this book is intended to be a *fast and easily-accessible guide* rather than a language textbook. Where grammar issues are discussed, the aim is not to identify rules for 'correct' grammar, but rather to avoid ambiguity.

At this stage in Unit 1, you will have a robust generic model of an Introduction, a list of useful words, phrases and sentence patterns for each part of the Introduction model, and a language/writing skills guide that responds to FAQs about grammar and writing skills in the Introduction. If you do the tasks in the unit, you will be able to put the model, vocabulary and language/writing skills together to write an Introduction. At the end of Unit 1 you write a simple Introduction using what you have learned and compare it with a sample answer in the Key. This pattern is repeated in Unit 2.

In Units 3, 4, 5 and 6 you are encouraged to reverse engineer your own target research articles to create the models, and then check and adjust them against the generic, universal models presented in each Unit. The tasks throughout the book are designed to help you develop reverse engineering to the point where it becomes an automatic adjunct to your reading strategies. If you read the book without completing the exercises and tasks, you will have an intellectual understanding of what to do but you may find it hard to put it into practice. Knowing *what* to do is not the same as knowing *how* to do it. At the moment, you may be focusing very strongly on the information content of research articles, and you may not be paying much attention to the way that the content is delivered. However, once you become aware of the structure and language used to deliver the content, this creates a 'learning circle' in which your research *reading* actively and continually informs your research *writing*.

What other material or books do I need?

As a science researcher you need to write in a way which is as similar as possible to current successfully-published writing in your field. The book shows you how to use the journal papers you read to develop the appropriate writing skills, so you need to collect a set of target research articles before you start. The set should consist of at least four recently-published research papers from the journals you usually read. You will use these target research articles to adapt what you learn to your own writing, and you should update the set frequently.

Your target research articles should:

- **be written by a researcher/research team at an English-speaking institution, or by a native speaker of English.**
- **deal with subject matter which is as close as possible to the kind of research you are doing.**
- **be reasonably short (less than 15 sides including graphs and tables).**
- **be taken from the journals you wish to publish in.**
- **be no more than five years old, given the speed at which science research writing is developing and changing.**
- **be research articles that you consider to be well written.***
- **have clearly-defined Introduction, Methods, Results, Discussion and Conclusion sections, or other identifiable subsections that fit the kind of work you are doing. It will help if these have subtitles so that you can locate them easily. The subtitles may vary in different disciplines and in different journals; for example the Methods section may be called *Procedure, Model, Materials and Methods, Methodology, Experimental, Data Collection* or some other variation.**

**I am grateful to Professor Monique Dorang for this point.*

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UNIT 1

How to Write the Introduction

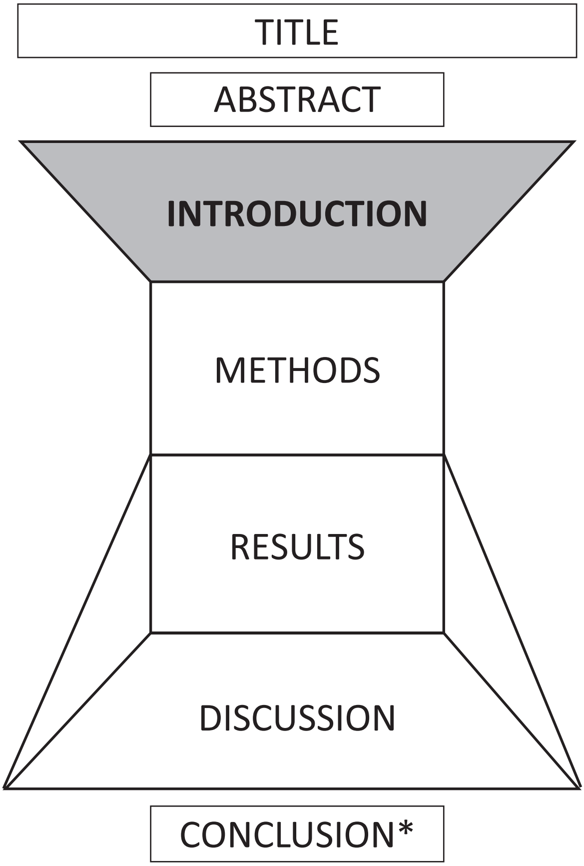

Fig. 1.1 The shape of a research article

*Some journals call this section CONCLUSION and others call it CONCLUSIONS but this does not seem to reflect the number of conclusions that are drawn.

> *It is unfortunate that in an environment in which so many individuals must publish for the sake of their own careers [...] that only a limited effort is made to understand the structure of written papers. It is an eminently teachable topic. Detailed, evidence-based guidance is needed for potential authors, and can be derived from a study of the structure of papers that are successfully published in leading journals.*[3]

1.1. The Structure and Content of the Introduction

As you can see, Fig. 1.1 is symmetrical. This is because many of the things that are in the Introduction occur — often in reverse order — in the Discussion. For example:

- At the start of the Introduction you write an opening sentence which enables your reader to 'get in' or start your paper/thesis; at the end of the Discussion you 'get out' by finding an appropriate way to end.
- During the Introduction you generally present past or current research and/or knowledge about the topic; in the Discussion you show how your study contributes to that research or advances that knowledge.
- At some point in the Introduction you state the specific problem your study focuses on or identify a gap in the existing research that will be filled in your paper; in the Discussion you discuss to what extent you have resolved that problem.
- At the end of the Introduction you need to enable readers to move into the central section (usually the Methods and/or Results); at the end of the central section you need to enable readers to move into the Discussion.

Notice that the Introduction narrows towards the central report section, and the Discussion widens after it. This represents the way information is ordered in the Introduction and the Discussion: in the Introduction you start out by being fairly general and gradually narrow your focus towards your own study, and the opposite is true in the Discussion.

1.2. Building a Model

The structure of the Introduction is similar in most research fields, and the content links directly to the structure. This Unit will show you how to build and use an Introduction model that answers the following three questions:

How do writers normally start an Introduction?
What is normally included in an Introduction, and in what order?
How do writers normally end an Introduction?

1.2.1 EXERCISE 1: How to build a simple model by reverse engineering

Using the reverse-engineering approach discussed on pages xvii–xviii, look at the first Introduction below and write a short description of what the writer is doing in each sentence. Note that you are not describing or summarising *what the sentence is saying* (the content of the sentence); instead, you are working out *what the sentence is doing* (the function of the sentence). One way to identify the function of a sentence is to look at the tense of the main verb. What is that verb tense normally used for? Is the verb in the same tense as in the previous sentence? If not, why has the writer changed the tense?

Remember that your model is only useful if it can be transferred to other Introductions, so don't include content words such as *polymer* or you won't be able to use the model to generate Introductions for your own research articles.

Keep your description simple; Sentence 7 has been done for you as a guide to the level of detail to aim for. Once you have completed the description of the first Introduction, test and adjust your model by applying it to the Introduction in Section 1.3.1, and then to the Introductions in your target articles.

A light-weight chitin-PLA composite for load-bearing biomedical applications

Introduction

1 *Biomass-derived polylactide (PLA) has received much attention in recent years due to its biodegradable[1] and biocompatible[2] properties.* ***2*** *Biomass-derived PLA is produced from renewable feedstocks such as* *corn and sugar cane.* ***3*** *It has outstanding molding properties for use in biomedical applications such as scaffolds for tissue engineering*[3,4]*.* ***4*** *However, its weakness under impact has significantly limited its use.*

5 *Biomedical applications require materials with the lowest possible toxicity so although metals such as aluminium have been used to strengthen PLA for industrial applications*[5,6]*, these are not appropriate for biomedical use*[7]*.* ***6*** *One way to strengthen polymers for biomedical applications is to incorporate a layer of keratin, a material that occurs naturally in the mammalian anatomy, and there has been extensive research regarding keratin-PLA composites*[8,9,10]*.* ***7*** *For example, Penney et al. (2012) showed that incorporation of keratin fillers in the PLA matrix could be achieved using blending techniques*[8]*.* ***8*** *However, although the effect of keratin on the mechanical properties of copolymer systems was demonstrated over two years ago*[9]*, keratin adds considerably to the weight of the composite, and little attention has been paid to the selection of an alternative biocompatible material.*

9 *The present paper presents a set of criteria for selecting such a component.* ***10*** *On the basis of these criteria it then describes the preparation of a biomass-derived polymer blend using chitin, a long-chain polymer found in many places throughout the natural world.* ***11*** *This combination formed a novel lightweight copolymer in which the incorporation of PI significantly increased resistance to impact while retaining the biocompatible features of keratin.*

In Sentence 1, the writer	
In Sentence 2, the writer	
In Sentence 3, the writer	
In Sentence 4, the writer	
In Sentence 5, the writer	
In Sentence 6, the writer	
In Sentence 7, the writer	**mentions a key research study in this area.**
In Sentence 8, the writer	
In Sentence 9, the writer	
In Sentence 10, the writer	
In Sentence 11, the writer	

1.2.2 Key

In Sentence 1 *Biomass-derived polylactide (PLA) has received much attention in recent years due to its biodegradable[1] and biocompatible[2] properties.* **the writer establishes the importance of this research topic.**

If you wrote **the writer introduces the study** for Sentence 1, that won't help when you come to write your own research paper, because it doesn't tell you *how* to 'introduce' the study. You may have started previous Introductions by describing the specific problem you are trying to solve, or the method you plan to use, but when you look at published work in your field you will see that this is not how most research papers begin, and therefore it may not be the best way for you to begin. Many research articles begin by establishing how or why the topic is useful or important, so in your target articles you will often find something in the first sentence like *much study in recent years* or *a major role* or *widely-used.*

What verb tense should I use in the first sentence?

Phrases that refer to recent time like *in recent years* or *in the past five years* are normally followed by the Present Perfect tense (*Much study in recent years* ***has focused*** *on.../The status and function of the port* ***has evolved*** *rapidly over the past three years.*). If you are focusing on the current situation, it is common to use the Present Simple tense (*There* ***are*** *substantial benefits to be gained from...*). It's worth noting, however, that what is *recent* or *current* now will not be *recent* or *current* in five years' time, so if you are hoping that your research article will still be relevant five years from now, consider using an identifiable date, e.g. *since 2018.*

What if I don't have the confidence to say that my research is important?

If most authors of similar research papers in your field begin by establishing the significance of the topic but you don't, it may seem to the editor or reader that your research topic is NOT important. Check your target journal — it's not a question of confidence; it is about writing in an accepted, conventional way. If most target articles in your field begin this way, yours should too; don't be shy about stating why or how your research topic is important or useful.

Do all research papers begin like this?

No, they don't. As always, the target readership is the deciding factor. Some research topics are very narrow, and all those who will want to read your research paper are part of a small research community for whom a statement about the importance of the field is unnecessary, and possibly even inappropriate. In that case, it is common to begin with a statement about the specific focus of research in the field, a definition of a key term or some factual information necessary to understand the topic. An example of this is Sentence 2:

> **In Sentence 2** *Biomass-derived PLA is produced from renewable feedstocks such as corn and sugar cane*. **the writer provides background factual information for the reader.**

Sentence 2 is in the Present Simple tense, which is the verb tense used for accepted/established facts. Research papers often begin, either in the first sentence or the first paragraph, with accepted or established facts. This ensures that all readers have the appropriate background information to process the rest of the paper.

So what kind of fact should I start with?

This depends on how wide your subject — and therefore your readership — is. If your research area is very narrow, many of your readers will have a good level of background knowledge and you can start with fairly specific information. If your paper is likely to attract a wider or more interdisciplinary audience, then you should start with more general background information and even consider including background facts which seem obvious to you. You can find good examples of that first fact by checking **similar papers published recently in your target journal.**

Note that if you resubmit the paper to a different journal, the readership of that journal may be either narrower or wider, so you cannot simply re-send the original version. In particular, you may need to adjust the first sentence to ensure that it responds to the needs of a different readership. The golden rule is: **check recent editions of the journal you are submitting to,** and start your Introduction in the same way as other authors who have successfully submitted their work on similar topics to that journal.

What if there are several background facts I want to start with, not just one? How do I know which one to begin with?

The shape of the Introduction in Fig. 1.1 starts wide and gradually narrows. This means that you start with a fairly general item of information, one that many of your readers already know. This represents a 'meeting place' fact from which all readers can start together, after which you can move on to more specific information. Always show your readers the general picture before you proceed to the details: show them the wall before you start to talk about the bricks!

How much background information should I provide?

It is extremely difficult to predict what knowledge readers bring to the paper. Your readers are not part of your research group, so the background information that is very familiar to you and your colleagues is not necessarily known to all potential readers of your research paper. Given that most research reading is now done via the internet, readers may access the paper from a different discipline or even a non-STEMM discipline. As a general rule it is better to provide slightly too much background information than slightly too little.

In addition, if you jump straight from very general to very specific information early in the Introduction this is likely to cause difficulties, particularly for the interdisciplinary reader. It is therefore essential to close the information gaps between the opening sentences (see Section 1.5.2) so that all readers can move smoothly through the background information in the Introduction.

I'm still not sure where to begin.

If you are still stuck for a first sentence, look at the keywords you are considering. If similar recent papers in your target journal begin with a definition of or a fact about one of those keywords, consider starting with that; if they begin by establishing the importance of the topic, begin with that. Remember the key message: ***EVIDENCE-BASED GUIDANCE CAN BE OBTAINED BY STUDYING THE STRUCTURE AND LANGUAGE OF SUCCESSFULLY-PUBLISHED PAPERS.***

Can't I start by describing the specific problem I am hoping to solve?

Most authors don't, because it's sometimes difficult to describe the specific problem until readers have enough information to understand it. It's also very hard to limit yourself to one sentence about the problem you are hoping to solve, and before you know it, you've written a lot of specific detail about the problem which your readers can't process because you haven't yet given them the relevant background.

In Sentence 3 *It has outstanding molding properties for use in biomedical applications such as scaffolds for tissue engineering*[3,4]. **the writer does the same as in Sentences 1 and 2, but in more detail, using citation references to support the background facts and the claim for importance.**

There are citation references in Sentence 3 — does that mean that this is part of a review of the research in this area?

No, a short review of previous and current research and knowledge usually comes later in the Introduction, and is more likely to focus on the methods or results of individual studies. This is simply a citation reference for the background facts.

How do I decide whether or not to include a citation reference for the background facts?

One reason for including a citation is that plagiarism (failing to give others the appropriate credit for their work) is unethical. Secondly, a citation reference gives your reader the chance to find and read the study mentioned. The third reason is that failing to provide such references implies that you are not familiar with research in your area.

Deciding whether to include a citation reference also depends on when the study was published, and the extent to which the findings of that study are accepted as facts by the research community. Many facts which are now accepted by researchers began their life — perhaps years ago — as research findings. For example, in Sentence 2, the information that *Biomass-derived PLA is produced from renewable feedstocks such as corn and sugar cane* originally came from research, and was probably initially reported in the Present Perfect tense*: Lawrence et al. have found that biomass-derived PLA can be obtained* *from renewable feedstocks such as corn and sugar cane* or the Past Simple tense: *Lawrence et al. (2000) found that biomass-derived PLA can be obtained from renewable feedstocks such as corn and sugar cane.* However, once that research finding becomes well established, such statements start to appear in the Present Simple tense, with the citation attached: *Biomass-derived PLA is produced from renewable feedstocks such as corn and sugar cane (Lawrence et al., 2000)*, and eventually the citation simply drops off and the information becomes part of the accepted factual background to the topic*: Biomass-derived PLA is produced from renewable feedstocks such as corn and sugar cane.*

The only way to get this right is to **check current usage in your field**. A journal article from five years ago may use a verb tense that is now no longer appropriate, so using that tense implies that you are not up to date with developments in your field. Search engines such as Google Scholar are a good resource for this. If most researchers in your field currently use the Present Simple tense when they state a particular fact, follow their lead if you also state that fact. If most are still including a citation reference, follow their lead. It is exciting to realise that once your status as a published researcher is established in your field, you will have earned the right to make such decisions yourself.

In Sentence 4 *However, its weakness under impact has significantly limited its use*. **the writer describes the general problem area or the current research focus of the field** *(weakness under impact)***.**

Notice that the writer is still not describing the specific problem which their own research paper will deal with; s/he is referring to the current focus of the field, i.e. the problem of *weakness under impact*. This is presented as a problem which many researchers in this field are interested in, and which leads to the specific problem that this paper will deal with.

In Sentence 5 *Biomedical applications require materials with the lowest possible toxicity so although metals such as aluminium have been used to strengthen PLA for industrial applications[5,6], these are not appropriate for biomedical use[7]*. **the writer extends the problem area/current focus of the field** *(toxicity)***.**

In Sentence 6 *One way to strengthen polymers for biomedical applications is to incorporate a layer of keratin, a material that occurs naturally in the mammalian anatomy, and there has been extensive research regarding keratin-PLA composites*[8,9,10]. **the writer links the general problem area to published research and refers to other studies.**

In Sentence 5, some citation references are in the middle of the sentence. When should a citation reference come in the middle of the sentence?

When it is necessary to avoid confusion, for example if the citation only refers to part of your sentence. Your citation location should make it clear which part of the information comes from which study. This is not only a matter of professional courtesy, it is also misleading to imply that all of the information in a sentence comes from all of the studies cited at the end of that sentence.

In Sentence 7 *For example, Penney et al. (2012) showed that incorporation of keratin fillers in the PLA matrix could be achieved using blending techniques*[8]. **the writer mentions a key research study in this area.**

How many research studies should I mention in the Introduction?

As always, consult your target research articles. It is worth noting that if many authors collaborate to write the paper, or if the paper itself takes a long time to write, the literature and knowledge review in the Introduction may become over-long and lose focus. Every study that you mention in the Introduction should be both *relevant and essential* to the research background of your own study, and should lead towards the motivation for your study.

How do I decide which research studies to mention in the Introduction?

Relevance is crucial. The literature and contributions review in a research article is not a list or a summary of what you have read. It is **a carefully-narrated journey through selected relevant research and the contributions of that research** that has a specific aim: to demonstrate to the reader that the study reported in the paper is justified, and that the approach is valid. If you include irrelevant studies you will break the thread of the narrative.

Deciding which research studies to include in the Introduction is directly related to the problem or question that has provided the motivation for your study, so select research that demonstrates the development and evolution of research towards that problem or question.

Another function of the literature and contributions review in a research article Introduction is that it identifies where the study is located on the research 'map' of the field. When you read a research paper you generally recognise some of the studies mentioned in the Introduction, and this helps you see where the study fits into the field. In the same way, the selection of names and references you choose to mention in the Introduction will help your readers to see where your study is located on the research 'map'.

How do I organise and link those studies?

Ordering and organising those studies and linking them with a rational narrative is essential. You can't just pour a description of previous and current research onto the page in any order and without a linking narrative, or it will look like a shopping list. A carefully-planned and well-narrated literature and contributions review makes it easy for the reader to understand how the research has developed, and much more importantly, how and why it leads to your study.

To keep the review in the Introduction on track, plan and organise the research contributions according to an organisational pattern. Here are three possible patterns:

- *General-to-specific*
  Writers frequently start with general research in the field, possibly a review article, and gradually move to research that is closer to the problem or gap dealt with in the present study. This is the most common pattern.
- *Different approaches/theories/models*
  In some papers, studies are grouped according to the approach or method they used. Grouping similar studies together helps you avoid the 'tennis match' effect where you go backwards and forwards beginning each sentence with *However* or *On the other hand.*

- *Chronological order*
  This may be appropriate, for example, if the development of your field is related to political decisions and laws such as those relating to pollution or fracking.

To link the studies and contributions, consider words or phrases such as:

[ref] also observed that…
[ref] resolved this by…
[ref] were the first to…
A pioneering study by [ref] demonstrated…
A similar approach was used by [ref], who…
An alternative approach was proposed by [ref], who…
According to [ref], it is highly likely that…
Importantly, [ref] noted that…
In order to resolve this, [ref] analysed/developed...
In that study, although…
In their recent work, [ref] has suggested that…
It was later shown by [ref] that…
One [potential] implication of [ref]'s results is that…
Other studies have focused on…, for example, [ref] and [ref] attempted to…
Recently, it has been shown/suggested that…
Soon after, [ref] proposed…
Subsequently,…
Taken together, these studies suggest that…
The most systematic review is that in/of [ref]…,
These findings challenge the work of [ref], who…
This approach was further developed by [ref], who…
This methodology was adapted by…
To address this issue, [ref]…
To overcome these problems, a different approach was used by/in [ref].
Within five years, [ref] developed a…

Signalling language like *however/therefore* can also effectively and concisely drive the narrative from one item in the literature and contributions review to the next. For more on this see **Section 1.5.2 Linking sentences and information together**.

In Sentence 8 *However, although the effect of keratin on the mechanical properties of copolymer systems was demonstrated over two years ago*[9], *keratin adds considerably to the weight of the composite, and little attention has been paid to the selection of an alternative biocompatible material*. **the writer identifies a problem or gap in the research.**

This is where you begin to move towards your own paper or study, and the specific problem you will deal with. This is normally done either by identifying a gap in the existing knowledge or by indicating that there is a problem in previous research. It is conventional to introduce it with a signal such as *However* or *Although*, and these words have an 'instant recognition' feature that alerts the reader to the gap. Note that in professional writing it is unusual to put the gap or problem in the form of a question; it is normally stated as a prediction, suggestion or hypothesis.

Don't be shy about pointing out the problems in previous research. In the first place it may be necessary to identify those problems in order to explain why you have done your study. In the second place, the language used here is usually respectful and impersonal, and therefore not offensive.

The reader may need more background information at this stage; for example, details of the properties of the material which you are investigating, or a description of the specific part of the device which you plan to improve. Research writing requires a surprising amount of background information, and it is better to offer slightly too much than too little.

At this stage you move directly to your own paper or study. You can describe it, say what its purpose or focus is, give its structure or a combination of these.

In Sentence 9 *The present paper presents a set of criteria for selecting such a component*. **the writer describes the present paper or study.**

Should I use the passive or the active here?

This depends on factors such as the potential for ambiguity, the style of the target journal and whether you prefer to focus on yourselves as authors or on the study. See **Section 1.5.3 Passive/Active choices** for details and guidance about this.

What verb tense should I use?

Writers normally use the Present Simple tense to describe the work itself (*This paper is organised as follows/This study focuses on…*) and the Past Simple tense to talk about the aim of the work (*The aim of this project was…/ Our aim was…*). This is because in 'real time', the aim existed before the work was done. It is also possible to state the aim in the Present Simple tense (*The aim of this study/paper is…*), particularly in cases where the aim is only partially achieved.

In Sentence 10 *On the basis of these criteria it then describes the preparation of a biomass-derived polymer blend using chitin, a long-chain polymer found in many places throughout the natural world*. **the writer outlines the method reported in the paper.**

Although writers often mention the method or results in the Introduction, if you provide too much detail of these, the Introduction can become very long and lose focus. As always, check current target articles for guidance.

In Sentence 11 *This combination formed a novel lightweight copolymer in which the incorporation of PI significantly increased resistance to impact while retaining the biocompatible features of keratin*. **the writer announces the main result, using language that explicitly identifies the achievement of the study ('happy' ☺ words)** *(novel, lightweight, significantly increased)***.**

1.2.3 The Introduction model

These are the sentence descriptions collected in Section 1.2.2 by reverse engineering the Introduction:

In Sentence 1, the writer	establishes the importance of this research topic.
In Sentence 2, the writer	provides background factual information for the reader.
In Sentence 3, the writer	does the same as in Sentences 1 and 2, but in more detail, using citation references to support the background facts and the claim of importance.
In Sentence 4, the writer	describes the general problem area or the current research focus of the field.
In Sentence 5, the writer	extends the problem area/current focus of the field.
In Sentence 6, the writer	links the general problem area to published research and refers to other studies.
In Sentence 7, the writer	mentions a key research study in this area.
In Sentence 8, the writer	identifies a problem or gap in the research.
In Sentence 9, the writer	describes the present paper or study.
In Sentence 10, the writer	outlines the method reported in the paper.
In Sentence 11, the writer	announces the main result, using language that explicitly identifies the achievement of the study ('happy' ☺ words).

We can streamline these so that our Introduction model has FOUR basic components. It's not necessary to use everything when you write an Introduction; the model should be considered as a flexible menu.

GENERIC INTRODUCTION MODEL	
1	**ESTABLISH THE IMPORTANCE OF THE TOPIC/FIELD** **PROVIDE BACKGROUND FACTUAL INFORMATION** **PRESENT THE GENERAL PROBLEM AREA/CURRENT RESEARCH FOCUS**
2	**PRESENT PREVIOUS AND/OR CURRENT RESEARCH AND CONTRIBUTIONS: the research 'map'**
3	**LOCATE A GAP IN THE RESEARCH** **DESCRIBE THE PROBLEM YOU WILL ADDRESS** **PRESENT YOUR MOTIVATION AND/OR HYPOTHESIS** **IDENTIFY A RESEARCH OPPORTUNITY**
4	**DESCRIBE THE PRESENT PAPER, sometimes mentioning aims/ results/methods/conclusions, and often including 'happy' ☺ words**

When you have looked at many Introductions, you will notice that:

- almost all research article Introductions begin with something in Component 1.
- almost all research article Introductions end with something in Component 4.
- in some Introductions, Component 2 is a summary of current knowledge. This is generally in the Present Simple tense but may still need citation references.
- in some Introductions the GAP or PROBLEM in Component 3 is not stated explicitly. This is because the motivation for the study may be simply to extend previous research, or the gap/problem may be implicit in the description of the present study and its aims.
- additional background factual information in the Present Simple tense occurs *at every point where the author considers it necessary for readers*.

1.3. Testing and Adjusting the Model

1.3.1 A demonstration of the model

To demonstrate the model, clues to the model components are in **bold** type in the Introduction below. Read the Introduction carefully and note how the vocabulary and verb tenses link up with the model.

Rapid fragmentation of neuronal networks at the onset of propofol-induced unconsciousness[a]

Introduction

General anesthesia **is** a drug-induced reversible coma **commonly** initiated by administering a large dose of a fast-acting drug to induce unconsciousness within seconds **(1)**. This state **can be** maintained as long as needed to execute surgical and many nonsurgical procedures. One of the most **widely used** anesthetics is propofol, an i.v. drug that **enhances** GABAergic inhibitory input to neurons **(2–4)**, with effects in cortex, thalamus, brainstem, and spinal cord **(5–7)**. **Despite** the understanding of propofol's molecular actions, it is **not clear how** these effects at molecular targets affect single neurons and larger-scale neural circuits to produce unconsciousness.

The effects on macroscopic dynamics **are** noticeable in the EEG, which **contains** several stereotyped patterns during maintenance of propofol general anesthesia. These patterns **include** increased delta (0.5–4 Hz) power **(8, 9)**; increased gamma (25–40 Hz) power **(9)**; an alpha (~10 Hz) rhythm **(10–12)** that **is** coherent across frontal cortex; and burst suppression, an alternation between bursts of high-voltage activity and periods of flat EEG lasting for several seconds **(13, 14)**. In addition, slow oscillations (<1 Hz) **have been well characterized** in deeply anesthetized animals and **are associated** with an alternation of the neuronal membrane potential between UP (depolarized) and DOWN (hyperpolarized) states **(8, 15)**.

Although these patterns are observed consistently, it is **unclear** how they are functionally related to unconsciousness under general anesthesia. **Most studies have focused on** a deep steady state of general anesthesia **and have not used** a systematic behavioral measure to track the transition into unconsciousness. This steady-state approach **cannot** distinguish between patterns that are characteristic of a deeply anesthetized brain and those that arise at the onset of unconsciousness. Unconsciousness **can occur** in tens of seconds **(4)**, but many neurophysiological features **continue** to fluctuate for minutes after induction and **are** highly variable between different levels of general anesthesia **(1, 16)**. Therefore, identifying the specific dynamics associated with loss of consciousness (LOC) **requires** an examination of the transition into unconsciousness, linking neurophysiology with behavioral measures.

In addition, the dynamic interactions between cortical areas that underlie these EEG oscillations are **not well understood**, because **few studies** have simultaneously recorded ensembles of single neurons and oscillatory dynamics from sites distributed across the brain. Consequently, how propofol acts on neural circuits to produce unconsciousness **remains unclear. A leading hypothesis suggests that** anesthetics disrupt cortical integration **(17, 18)**. Identifying the mechanism by which this disruption might occur **requires a better understanding of** how the spatial and temporal organization of neural dynamics evolves during induction of unconsciousness.

To address this question, **we investigated** both neuronal and circuit-level dynamics in the human brain during induction of unconsciousness with propofol. **We obtained** simultaneous recordings of single units, local field potentials (LFPs), and intracranial electrocorticograms (ECoG) over up to 8 cm of cortex, enabling us to examine neural dynamics at multiple spatial scales with millisecond-scale temporal resolution. **We used** a behavioral task to identify within seconds the time at which patients became unresponsive to auditory stimuli, which we defined as LOC.

Our results reveal a set of neurophysiological features that accompany LOC that, together with previously reported effects **(8, 9, 15)**, enable a multiscale account of this profound shift in brain state. **We find that** LOC **is marked** by the abrupt onset of slow oscillations (0.1–1 Hz) in the LFP. Power in the slow oscillation band **rises** sharply at LOC and **maintains** this increase throughout the post-LOC period. Neuronal spiking **becomes** coupled to the local slow oscillation within seconds of LOC: Spiking **occurs** only in short intervals of activity that are interspersed with suppression lasting hundreds of milliseconds, periodically interrupting information processing. These periods in which activity may occur **are** not simultaneous across the brain, implying that information transfer between distant (>2 cm) cortical networks is impaired. Cortical networks therefore **are fragmented** both temporally and spatially, disrupting both local and long-range communication. However, small-scale (<4 mm) functional connectivity measures **remain similar** to the conscious state, and neuronal spike rates can recover to baseline levels after LOC despite continued unresponsiveness. **This result demonstrates** that short periods of normal spike dynamics still can occur during unconsciousness. **We conclude that** the slow oscillation **is** a fundamental component of propofol-induced unconsciousness, marking a functional isolation of cortical regions while significant connectivity **is** preserved within local networks.

1.3.2 EXERCISE 2a: Identifying the model components

Here are two full-length Introductions from research articles in different fields. Read them through and use the words/phrases in **bold** type to identify the model components. Citation references are in **bold** type to draw your attention to where they are considered necessary, and in most cases the main verb is in **bold** to draw your attention to the verb tense.

1 Organic vapor phase deposition: a new method for the growth of organic thin films with large optical non-linearities[b]

Introduction

There is considerable interest in organic materials with large second-order hyperpolarizabilities for use in non-linear optical (NLO) devices such as modulators and frequency doublers **[1]**. To achieve a high figure of merit for such NLP devices **requires** a material with a non-centrosymmetric bulk structure and low dielectric constant.

To this end, NLP-active chromophores **are traditionally incorporated** into a polymer matrix and electrically poled to achieve the necessary bulk symmetry. **However**, such materials **are limited by** their **low** glass transition temperatures and **poor** stabilities at elevated temperature.

Recently, single crystals of organic and organometallic salts **[2–4] have been shown to** possess extremely large second-order ($x^{(2)}$) NLP effects leading to a high second harmonic generation (SHG) efficiency. The naturally non-centrosymmetric crystal structures of these compounds **obviates** the need for external poling. Furthermore, these salts **have** a high optical damage threshold and sufficient stability with respect to temperature to withstand many conventional semiconductor fabrication processes. In particular, highly pure single crystals of the salt, 4’-dimethylamino-N-methyl-4-stilbazolium tosylate (DAST) **[2]**, **have been shown to** have a value of $x^{(2)}$ at least 10^3 times greater than that of urea due to dipole alignment of the cation and anion constituents of the DAST structure. To illustrate this alignment, the DAST bulk crystal structure is shown in the inset of Fig. 1.

For many applications, such as waveguide devices, **it is desirable to** grow NLO materials into optical quality thin films. **Although** thermal evaporation in a high vacuum environment **has been used** to grow thin films of many organic **[5–7]** and inorganic materials, the technique **is not always applicable** to highly polar molecules **[8]** or organic salts. For example, when heated in vacuum, DAST **decomposes** before vaporization. Although in situ reactions of multicomponent organic molecules to synthesize polymer films **previously has been demonstrated** using vacuum techniques as physical vapour deposition or vapour deposition polymerization **[9]**, attempts in our own laboratory at double-source co-evaporation of DAST neutral precursors 4’-dimethylamino-4-stilbazole (DAS) and methyl p-toluenesulfonate (Methyltosylate, MT) to form DAST **have been unsuccessful**, due in part to the radically different vapour pressures of DAS and MT, which leads to highly non-stoichiometric growth.

In contrast, atmospheric or low pressure (e.g. milliTorr) vapour phase epitaxy (VPE) **has been used** to grow epitaxial thin films of many III–V compound semiconductors, such as InP and GaAs, where there is a large difference in the vapour pressures of the group III and group V atomic constituents **[10]**. **This method was recently extended** to allow the growth of III–V and II–VI semiconductors from volatile organic precursors **[11]**. **Here,** a high vapour pressure compound (typically a metal halide or a metallorganic) of each respective metal **is** carried independently, via a carrier gas, to a high temperature reaction zone. In this zone, the compounds **are** deposited onto a heated substrate where they thermally **decompose** and react to yield the desired III–V compound. The excess reactants and reaction products **are** then exhausted from the system via a scrubber.

In this paper we apply the techniques of VPE to grow films of DAST by the reaction of two volatile organic materials in a hot-wall, atmospheric pressure reactor. By nuclear magnetic resonance (NMR) analysis, **we find** that the stoichiometry of polycrystalline DAST films is >95% pure (limited by instrumental sensitivity). **Using** X-ray diffraction and other analytical techniques, **we observe** a significant dependence of film quality, such as ordering and crystallite size, on the substrate composition and other deposition conditions used for growth, **suggesting that** it may be possible to generate optical quality thin films of DAST and similar organic salts and compounds by OVPD using suitable substrates. **To our knowledge, this is the first** demonstration of the deposition of ordered thin films of a highly non-linear optically active organic salt using atmospheric vapour phase techniques.

2 Identification and characterisation of the early differentiating cells in neural differentiation of human embryonic stem cells[c]

Introduction

The developmental processes of **many** organs and tissues in an embryo **originate** from the pluripotent cells of the inner cell mass (ICM) in the blastocyst. As development proceeds, these cells gradually **acquire** specialized traits, becoming committed to specific fates and losing their potential to differentiate into other cell types. For example, the development of the central nervous system **is initiated** following gastrulation by the induction of the neuroectoderm, a process by which embryonic cells **acquire** a neural fate to form a single layer of neuroepithelial cells **[1]**. These cells subsequently **give rise to** neural stem and progenitor cells, which **undergo** further differentiation to neurons and glia **[2]**. This multi-step cell fate determination that occurs during embryonic neurogenesis **is** delicately orchestrated by many signalling pathways and transcription factors. **Although considerable efforts have been focused on** ascertaining the emergence of these earliest potential neural cells and the regulatory mechanisms that govern the process of neural induction, they have **yet to be fully defined**. This is largely **due to the lack of** adequate tissues from the early developmental stages.

Human embryonic stem cells (hESCs) derived from the ICM of blastocysts **are** capable of self-renewal in culture indefinitely and meanwhile **retain** the developmental pluripotency of the embryonic founder cells, having the potential to differentiate into all the cells and tissues in a human body **[3]**. Therefore, they **provide** not only a potential source of specialized cells for regenerative therapies but also a **valuable** in vitro model to study early human development, particularly as the direct study of early human embryo development **is severely hampered by the inability** to obtain adequate amounts of tissues at all developmental stages. Although differentiation of ESCs may not fully recapitulate the development of the embryo, increasing **evidence demonstrates that** their lineage-specific differentiation nonetheless reflects the developmental progression of that cell type in vivo **[4–7]**. Therefore, the use of hESCs to investigate early human embryo development **may provide valuable insights** into early developmental processes, including neural induction.

The Oct4 transcription factor **plays** an essential role in the maintenance of pluripotency and self-renewal of ESCs **[8, 9]** and **is** also a critical reprogramming factor **[10]**. In mouse, Oct4 **is** initially expressed in all the blastomeres of the morula, with its expression becoming successively restricted to the ICM of the blastocyst. After gastrulation, the expression of

Oct4 **is** concentrated in the primitive ectoderm and **persists** through E7.5 in unsegmented areas, but **is** downregulated as development continues. By E9.5, its expression **is** limited to primordial germ cells **[11]**. In humans, Oct4 expression **remained** at stage 9 post-implantation embryos **[12]**. In the absence of Oct4, embryos **are** unable to form pluripotent ICM and **fail** to produce any other lineages, except for extraembryonic trophoblasts **[13]**. Correspondingly, forced downregulation of Oct4 in mouse and human ESCs **results** in their differentiation into extraembryonic lineages **[8, 14, 15]**. Taken together, **this implies that** Oct4 **plays** a significant role in embryogenesis and early lineage differentiation.

We have previously shown that hESCs can be efficiently differentiated to neural progenitors by the inhibition of BMP **[16]**. During the initial differentiation, expression of Oct4 **remains** detectable for at least one week until the formation of neuroepithelial cells after week 2. **Little is known about** these early differentiating cells and **it is not clear whether** this initial Oct4 expressing population differ from undifferentiated hESCs. **In this study**, **we** carefully **identified and isolated** this initial differentiating cell population and **demonstrated** that these cells are distinct from undifferentiated hESCs and committed neural progenitor cells (NPCs), exhibiting intermediate features between the two. The identification of these early neural differentiating cells will provide a **valuable** cell source which **can be used** to elucidate the molecular mechanisms that regulate neuroectoderm development.

1.3.3 EXERCISE 2b: Identifying the model components

Here are six more full-length Introductions from research articles. Underline the words and phrases that help identify the model components, then check your answers with the Key on pages 35–44.

1 The oxidative corrosion of carbide inclusions at the surface of uranium metal during exposure to water vapour[d]

Introduction

The interaction between metallic uranium surfaces and water vapour is considered to be most important in regard to the environmental corrosion of the metal. Numerous studies have examined the initial stages of these interactions [1–7]. However, there have been discrepancies in the published data describing kinetic laws, pressure dependence of the reaction rate constant and activation energies. The precise mechanism for uranium corrosion is not entirely clear with different mechanisms proposed arising from the results of the undertaking studies [1–7]. Existing discrepancies in the published data may, in part, be related to differences in the provenance and purity of the metal used by different groups. The reactivity of impurity species such as carbide, may have affected recorded data. This work aims to provide data for an improved understanding of the role of impurity phases in the uranium–water reaction, samples of uranium containing 600 ppm carbon were analysed during and after exposure to water vapour at 19 mbar pressure, in an environmental scanning electron microscope (ESEM). Samples were analysed using secondary ion mass spectrometry (SIMS), focused ion beam (FIB) imaging and sectioning and transmission electron microscopy (TEM) with X-ray diffraction (micro-XRD).

2 A GPU-tailored approach for training kernelized SVMs[e]

Introduction

Support Vector Machines (SVMs) are among the most popular general purpose learning methods in use today. SVM learning amounts to learning a linear predictor, with regularization (corresponding to a “large margin”) ensuring good generalization even in very high dimensions. This predictor need not be linear in the input representation: it is possible to learn a linear predictor in some extremely high dimensional space specified implicitly through a kernel function. SVMs were originally suggested in the context of binary classification, but more recently variants following the same principles have also been developed and successfully applied to more complex prediction tasks such as multiclass classification and prediction of structured outputs such as sequences.

Training an SVM amounts to solving a quadratic programming problem (see Section 2). Although general-purpose quadratic programming solvers can only handle fairly small SVM instances, much effort has been made in the past two decades to design special purpose solvers that can handle large-scale SVM instances. This effort resulted in widely-used packages that can solve both "linear" SVMs (i.e. where the prediction is linear in the input representation) and "kernelized" SVMs (where a non-linear kernel defines the linear prediction space). For linear SVMs, stochastic methods such as PEGASOS [13] and Stochastic Dual Coordinate Ascent [8] have recently been established as being effective at solving extremely large SVM instances, typically in less time than that which is required to read the data into memory. For kernel SVMs, most leading solvers are based on decomposing the dual optimization problem into small subproblems [11, 9, 4, 1, and see also Section 3]. Such approaches can indeed handle fairly large problems, provided that the data fits in memory, but it is not uncommon for training to require many hours or days, even using state-of-the-art optimizers. There is therefore still a strong need for faster training of kernel SVMs.

One attractive possibility for enabling faster SVM training is to leverage the power of Graphical Processing Units (GPUs). GPUs are highly parallel, structured, computational engines and are now available relatively inexpensively and are found in many modern computers. In this paper we discuss how SVM training can be efficiently implemented on a GPU, and present such an implementation for both binary and multiclass SVMs.

Several authors have recently proposed using GPUs for kernelized SVM training [3, 2] and related problems [6]. These previous approaches, however, primarily focused on pointing out the advantages of implementing standard algorithms on graphics hardware, typically using GPU matrix-multiplication libraries, and not on how these algorithms can be modified to better take advantage of the GPU architecture. We study various algorithmic choices for SVM training in the context of GPUs, discuss how the optimal choices and algorithms on a GPU are different than those for a serial implementation, and arrive at an implementation specifically designed for graphics hardware. As with many previous approaches, we assume that the dataset fits in memory, and focus mostly on the Gaussian kernel, although our implementation can handle any kernel function which can be written in the form $K(x, y) = f(||x||, ||y||, \langle x, y \rangle)$ (see Section 5.2), and our ideas apply even more broadly to any kernel which is an aggregation of element-wise operations.

One particularly significant drawback of other GPU SVM solvers is their lack of support for sparse datasets. On the CPU, taking advantage of sparsity is a simple matter, and sparse datasets are encountered frequently enough that many widely-used SVM solvers treat all input vectors as sparse, by default [9, 4, 1]. On the GPU, however, maximum performance is only achieved if memory accesses follow certain fairly restrictive patterns, which are difficult to ensure with sparse data. In contrast to other GPU SVM solvers, our implementation does take advantage of sparsity in the training set through a novel "sparsity clustering" approach (Section 5.3).

Overall, our implementation is orders of magnitudes faster than existing CPU implementations, and several times faster on sparse datasets than prior GPU implementations of SVM training.

3 Signals from the surface modulate differentiation of human pluripotent stem cells through glycosaminoglycans and integrins[f]

Introduction

Human pluripotent stem (hPS) cells (embryonic stem cells and induced pluripotent stem cells) are promising sources of specialized cells because of two intrinsic properties: they can self-renew indefinitely and differentiate into diverse cell types (1). To selectively guide hPS cell differentiation, precise control cellular microenvironment is needed (2, 3). Considerable effort has been devoted to identify soluble factors that promote differentiation. Additionally, there is interest in developing matrices to support cells during differentiation (4), yet much less is known about how signals from the matrix influence cell fate.

Matrigel is the most widely used substratum for hPS cell propagation (5) and differentiation (6–12); it is derived from mouse sarcoma cells, and although its principal components are laminin, collagen, and entactin, Matrigel consists of up to 1,800 different proteins — including encapsulated growth factors — whose levels vary significantly from batch to batch (13). Accordingly, the contributions of Matrigel-delivered signals to specific phenotypic outcomes — self-renewal or differentiation — are difficult to characterize or control. Elucidating the effects of insoluble signals requires defined substrata. Such defined substrata have been developed for the long-term culture of undifferentiated hPS cells in defined media. A number of surfaces have been described including recombinant proteins (14–16), fully synthetic polymers (17–19), and peptide-modified surfaces (20–23). Surfaces that present bioactive peptides have the advantage that they can be programmed to interact with specific cell-surface macromolecules such as the glycosaminoglycans (GAGs) and integrins.

Defined surfaces can be exploited for differentiation via two distinct mechanisms. First, surfaces can be tailored to present ligands that promote adhesion of specific cell populations during differentiation (24). Second, surfaces can be devised to specifically activate (or mitigate) signal transduction pathways. Here, we use a modular approach to exploit the aforementioned modes to control hPS cell differentiation to each of the primary germ layers. Our results reveal the advantages of defined surfaces for decoding the influence of insoluble signals on cell fate.

4 Evaluation of the damage detection capability of a sparse-array guided-wave SHM system applied to a complex structure under varying thermal conditions[g]

Introduction

Considerable effort has been expended on the development of structural health monitoring (SHM) systems [1–7], because these are widely regarded as capable of significantly reducing inspection costs of safety-critical structures in industries such as aerospace, nuclear, and oil and gas, among others. Successful SHM systems can be considered as those which combine good sensitivity to defects, preferably with the capability of localization and identification, with a low sensor density.

Nondestructive evaluation (NDE) systems based on ultrasonic guided waves generated by deployable arrays of transducers have been applied to the inspection of pipeline, rail, and relatively simple platelike structures [8–14]. These systems take advantage of the fact that certain guided-wave modes are able to propagate through several meters of the structure, often across various structural features, from a single excitation point. Recently, focus has shifted to the development of SHM systems based on guided waves, where a small number of permanently attached transduction units would allow good coverage and real-time, on-demand inspection of complex structures [15–18].

So far, effective commercial applications of systems based on guided waves [9, 10, 13, 14] have been achieved only when processing of recorded time-traces allows straightforward identification of individual reflections, which can then be attributed either to benign structural features (e.g., stiffeners, welds, and supports) or to defects. Simple pulse-echo or pitch-catch signals from complex undamaged structures will usually consist of a large number of interfering reflections that cannot be identified; these unwanted reflections are a source of coherent noise, which is highly detrimental because it can mask reflections from defects in the structure. In these cases, it is necessary to use a benchmark or baseline signal [15, 16, 18], taken at initial stages of operation of the structure, when the possibility of the presence of defects due to fabrication processes has been eliminated by inspection through conventional NDE techniques (NDT). Because the baseline contains information on the interaction of the reflections from benign structural features in the absence of critical defects, subtraction of a current signal from such a baseline will eliminate the coherent noise to a certain degree; if cancellation of coherent noise is sufficiently good, the remaining level of residual will contain only changes in the signals caused by features that were not present initially, such as defects [18]. The quality of the baseline subtraction therefore controls the sensitivity of the system to defects.

It is well known that environmental effects such as stress [19], ambient temperature variations [20], and liquid loading [21] affect the velocity of guided waves; this modifies the time-traces and leads to high levels of residual signal if a single baseline, taken under different conditions, is used. Of these effects, temperature variations are the most commonly encountered, and several authors have developed compensation techniques for temperature changes. These are usually based either on synthetically restoring the signal to the amplitude and phase it had at the temperature at which a reference signal was taken [16, 18, 22] or on a large and detailed look-up database of signals representing environmental conditions commonly faced by the structure [23], [24]; in this work, these methods are called optimal stretch and optimal baseline subtraction, respectively. The advantages and limitations of each of these techniques have been evaluated by different authors, and it has been shown that combining these 2 methods results in a promising temperature compensation strategy [18, 25, 26].

This paper demonstrates results obtained when a sparse-array guided-wave SHM system was applied to a shipping container panel subjected to uncontrolled temperature variations in a nonlaboratory environment. Initially, the suitability of the *A*0 and *S*0 modes for this particular structure was evaluated by studying transmission across the corrugations of the panel. Baselines were acquired from the sparse array over several weeks and the stability of the temperature compensation and baseline subtraction techniques was assessed. Defects of different diameter were machined in the structure and the detection capability of the system was verified.

5 Silica encapsulated heterostructure catalyst of Pt nanoclusters on hematite nanocubes: synthesis and reactivity[h]

Introduction

Metal nanoparticles deposited on specific metal-oxide supports have shown a unique activity as catalysts for heterogeneous reactions.[1–4] Unfortunately, at high reaction temperatures these metal/metal-oxide composite nanostructures are unstable towards sintering.[5–7] Recent work has shown that a porous shell of silica on active nanoparticulate catalysts can stabilize the nanoparticles at high temperatures while maintaining the accessibility of the reactants to the catalyst active sites.[3,5,8] Encapsulating the metal/metal-oxide composite nanostructures using a silica shell, however, is much more challenging than for individual nanoparticles because a strong metal–support interaction is required to avoid detachment during the coating process. The deposition of metal nanoparticles on oxide support is critical for constructing such composite structures.

Hematite (α-Fe_2O_3) has a variety of applications including pigments, gas sensors, and catalysts.[9–11] It is a highly desirable material due to its abundance, low cost, stability, safety, and its resistance to corrosion. Several high surface area nanostructures of hematite such as spherical particles,[12,13] nanorods,[14] nanocubes,[15] nanotubes,[16] and mesoporous[17] structures have been synthesized using solvothermal,[15] flame pyrolysis,[18] solution combustion,[13] electrodeposition,[16] and nanocasting methods.[17] Hematite nanostructures have been investigated as catalysts for CO and CH_4 oxidation reactions,[19] and their properties have been shown to depend upon specific crystal planes.[20,21] Halocarbons, including CCl_4, have been shown to undergo destructive adsorption on the Fe-rich (001) plane of hematite.[20,22] The adsorption of arsenate has also been studied on (012), which is known to be the most energetically stable plane of hematite.[23] The (110) plane is the next most stable following the (001) and (012) faces.[24] Relatively little is known about the reactivity of the (110) surface except the fact that it is active for CO oxidation.[15] A high CO conversion was demonstrated at 230°C over this surface.

Nanoparticles of Pd alloys,[25] Pt,[25,26] and Au[27] have shown particularly high catalytic activity when supported on hematite. High conversion and selectivity for hydrogenation reactions have been observed for Pt nanoparticles supported on γ-Fe_2O_3.[28] The deposition of metal nanoclusters on oxide surfaces has been reported using colloid deposition[26] and seed catalyzed reduction.[5,27] Both methods require pre-formed metal nanoparticles as a source.

Silica shell coatings on either metal or metal-oxide nanoparticles have been reported using sol–gel,[5,29] reverse micelles,[3] aerosol pyrolysis,[30] and atomic layer deposition.[7] Higher thermostability has been observed for the coated nanoparticles presumably due to the stability of the coating providing effective resistance to aggregation of the less stable core particles.[31] The sol–gel method is relatively inexpensive and extendable to commercial scales, and to our knowledge there has been no report of this method used to stabilize metal nanoclusters on metal oxides support nanoparticles.

In this paper the synthesis and characterization of silica encapsulated Pt/α-Fe_2O_3 heterostructures are reported. The Pt nanoparticles[32,33] were ideally deposited by photoreduction from salts on hematite nanocubes and we compared this route with hydrothermal reduction of K_2PtCl_6 in glucose solution. The following questions are addressed: (a) can Pt nanoparticles be deposited on the surface of the nanocubes and the entire heterostructure encapsulated in silica? (b) Is the core/shell heterostructure catalytically active? (c) Is the composite structure stable at the high temperatures required for catalytic reaction and regeneration?

6 Spatially resolved triboemission measurements[i]

Introduction

Triboemission is the collective term for friction-stimulated emission of particles (electrons, ions, neutral particles and photons) that occurs under the severe conditions at the interface between sliding bodies [1]. This type of particle emission is distinct from emission due to other external stimulation, for example, by photons (photoemission [2]) or by heat (thermoemission [3]). The mechanisms that give rise to triboemission are as yet poorly understood. However, it is believed to initiate the chemical reactions that lead to the formation of surface films in boundary lubrication [4, 5]. For example, widely used zinc dialkyldithiophosphate (ZDDP) additives produce boundary films by a mechanism that cannot be driven by contact temperatures and pressure alone [6]. In addition to this, triboemission has been blamed for the degradation of computer hard drive lubricants [7] and has also been linked to flash lights during the fracture of rocks associated in earthquakes [8] and volcanic eruptions [9]. In order to understand the role of emitted particles in these applications — so that boundary lubrication can be enhanced and lubricant degradation prevented — it is necessary to study the mechanisms by which emission occurs.

For this reason, triboemission has been the focus of significant research efforts for over half a century [10].

The first significant triboemission measurements were made by Nakayama *et al*. [11] during scratch tests by a diamond tip. To achieve this, they used a low-voltage-biased collector positioned close to the contact that registered bursts of the electrical current due to the emission of negatively and positively charged particles, while photon emission was measured using a photomultiplier [12]. Their results showed that insulator materials produced significantly higher levels of emission when scratched than metals. Kim *et al*. [13] investigated the emission of electrons using channel electron multipliers (CEMs) and photons using photomultipliers, during abrasion of MgO samples under vacuum. They also measured the kinetic energy of the electrons using a retarding grid. In these studies, photon emission was attributed mainly to deformation and electrons emission to fracture. Molina *et al*. investigated the triboemission of negatively charged particles under vacuum for a wide range of materials (alumina, sapphire, silicon nitride and semiconductors) using a CEM in pulse-counting mode [14–16]. The results from Nakayama *et al*. and Molina *et al*. suggested that triboemission is related to material hardness [14, 17]. Emission is also correlated strongly with the wear of the surface, highlighted by the observation that repeated scratches along a single track result in a decrease of emission with time, due to decreasing wear [14].

From these investigations, it is generally concluded that triboemission of electrons is related to surface fracture during sliding contact. More specifically, Dickinson *et al*. [18] put forward a charge separation model, as shown in Fig. 1. Here, an imbalance of charge is created between opposite faces of a crack as it opens. Due to the small width of the crack, this electric field has a large gradient, which encourages electrons to leave the negatively charged crack face. Due to thermal vibrations, a portion of these electrons do not reach the opposing face and are instead emitted into the surrounding environment. This model, however, does not explain why the energy of the tribo-emitted electrons can be lower than the work function of the sample [14]. To account for these low-energy electrons, Dickinson *et al*. [18] suggested that the work function of the surface could be locally decreased by small defects in the highly strained areas.

Since triboemission measurements typically contain no spatial information, researchers have tried to gain insights into the emission mechanisms by analysing the temporal characteristics of the recorded signals. For example, Molina *et al*. [15] showed that emission patterns are not random and proposed stochastic and chaos-deterministic approaches [16] to characterize their evolution with time. Recently, Nakayama *et al*. [19, 20] and Matta *et al*. [21] have made significant advances in infrared and ultraviolet imaging of the triboplasma, generated at the rear of sliding contacts by gas discharge under ambient conditions. The research described in the current paper differs from these studies, since we are concerned with electron emission mechanisms before interactions with surround gas take place.

One of the main limitations of electron triboemission experiments to date is that they provide only ensemble average values, giving no information relating to spatial location or direction. This shortcoming is, in part, responsible for our lack of understanding of triboemission processes, since it prevents emission measurements from being directly correlated with other surface analyses, such as SEM and AFM. To address this issue, we present experiments using a MCP, in which spatial maps of electron emission are obtained (see Fig. 2). The MCP — which is effectively a dense array of electron multipliers — is located within a vacuum chamber above a stationary diamond stylus that is loaded against a rotating aluminium disc covered with a 5-µm oxide layer (a brittle material on a soft substrate is likely to form cracks and thus induce emission). In this way, bursts of electrons can be visualized, revealing the pattern, direction and temporal characteristics of emission.

EXERCISE 3 Analyse and model the Introductions in your target research articles. Once you have done this you will begin to read differently: as well as reading for content, you will become aware of how that content is delivered. Look at how the paragraphs and sentences start and how they link together. You will start to see the scaffold that holds the information, and this will develop into a lifelong reading-for-writing tool that updates automatically every time you read a review article, a research paper, a conference abstract or any other text.

Key to EXERCISE 2b

1 The oxidative corrosion of carbide inclusions at the surface of uranium metal during exposure to water vapour[d]

Introduction

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Introduction

Considerable effort has been expended on the development of structural health monitoring (SHM) systems [1–7], because these are widely regarded as capable of significantly reducing inspection costs of safety-critical structures in industries such as aerospace, nuclear, and oil and gas, among others. Successful SHM systems can be considered as those which combine good sensitivity to defects, preferably with the capability of localization and identification, with a low sensor density.

Nondestructive evaluation (NDE) systems based on ultrasonic guided waves generated by deployable arrays of transducers have been applied to the inspection of pipeline, rail, and relatively simple platelike structures [8–14]. These systems take advantage of the fact that certain guided-wave modes are able to propagate through several meters of the structure, often across various structural features, from a single excitation point. Recently, focus has shifted to the development of SHM systems based on guided waves, where a small number of permanently attached transduction units would allow good coverage and real-time, on-demand inspection of complex structures [15–18].

So far, effective commercial applications of systems based on guided waves [9, 10, 13, 14] have been achieved only when processing of recorded time-traces allows straightforward identification of individual reflections, which can then be attributed either to benign structural features (e.g., stiffeners, welds, and supports) or to defects. Simple pulse-echo or pitch-catch signals from complex undamaged structures will usually consist of a large number of interfering reflections that cannot be identified; these unwanted reflections are a source of coherent noise, which is highly detrimental because it can mask reflections from defects in the structure. In these cases, it is necessary to use a benchmark or baseline signal [15, 16, 18], taken at initial stages of operation of the structure, when the possibility of the presence of defects due to fabrication processes has been eliminated by inspection through conventional NDE techniques (NDT). Because the baseline contains information on the interaction of the reflections from benign structural features in the absence of critical defects, subtraction of a current signal from such a baseline will eliminate the coherent noise to a certain degree; if cancellation of coherent noise is sufficiently good, the remaining level of residual will contain only changes in the signals caused by features that were not present initially, such as defects [18]. The quality of the baseline subtraction therefore controls the sensitivity of the system to defects.

It is well known that environmental effects such as stress [19], ambient temperature variations [20], and liquid loading [21] affect the velocity of guided waves; this modifies the time-traces and leads to high levels of residual signal if a single baseline, taken under different conditions, is used. Of these effects, temperature variations are the most commonly encountered, and several authors have developed compensation techniques for temperature changes. These are usually based either on synthetically restoring the signal to the amplitude and phase it had at the temperature at which a reference signal was taken [16, 18, 22] or on a large and detailed look-up database of signals representing environmental conditions commonly faced by the structure [23, 24]; in this work, these methods are called optimal stretch and optimal baseline subtraction, respectively. The advantages and limitations of each of these techniques have been evaluated by different authors, and it has been shown that combining these 2 methods results in a promising temperature compensation strategy [18, 25, 26].

This paper demonstrates results obtained when a sparse-array guided-wave SHM system was applied to a shipping container panel subjected to uncontrolled temperature variations in a nonlaboratory environment. Initially, the suitability of the *A*0 and *S*0 modes for this particular structure was evaluated by studying transmission across the corrugations of the panel. Baselines were acquired from the sparse array over several weeks and the stability of the temperature compensation and baseline subtraction techniques was assessed. Defects of different diameter were machined in the structure and the detection capability of the system was verified.

5 Silica encapsulated heterostructure catalyst of Pt nanoclusters on hematite nanocubes: synthesis and reactivity[h]

Introduction

Metal nanoparticles deposited on specific metal-oxide supports have shown a unique activity as catalysts for heterogeneous reactions.[1–4] Unfortunately, at high reaction temperatures these metal/metal-oxide composite nanostructures are unstable towards sintering.[5–7] Recent work has shown that a porous shell of silica on active nanoparticulate catalysts can stabilize the nanoparticles at high temperatures while maintaining the accessibility of the reactants to the catalyst active sites.[3,5,8] Encapsulating the metal/metal-oxide composite nanostructures using a silica shell, however, is much more challenging than for individual nanoparticles because a strong metal–support interaction is required to avoid detachment during the coating process. The deposition of metal nanoparticles on oxide support is critical for constructing such composite structures.

Hematite (α-Fe_2O_3) has a variety of applications including pigments, gas sensors, and catalysts.[9–11] It is a highly desirable material due to its abundance, low cost, stability, safety, and its resistance to corrosion. Several high surface area nanostructures of hematite such as spherical particles,[12,13] nanorods,[14] nanocubes,[15] nanotubes,[16] and mesoporous[17] structures have been synthesized using solvothermal,[15] flame pyrolysis,[18] solution combustion,[13] electrodeposition,[16] and nanocasting methods.[17] Hematite nanostructures have been investigated as catalysts for CO and CH_4 oxidation reactions,[19] and their properties have been shown to depend upon specific crystal planes.[20,21] Halocarbons, including CCl_4, have been shown to undergo destructive adsorption on the Fe-rich (001) plane of hematite.[20,22] The adsorption of arsenate has also been studied on (012), which is known to be the most energetically stable plane of hematite.[23] The (110) plane is the next most stable following the (001) and (012) faces.[24] Relatively little is known about the reactivity of the (110) surface except the fact that it is active for CO oxidation.[15] A high CO conversion was demonstrated at 230°C over this surface.

Nanoparticles of Pd alloys,[25] Pt,[25,26] and Au[27] have shown particularly high catalytic activity when supported on hematite. High conversion and selectivity for hydrogenation reactions have been observed for Pt nanoparticles supported on γ-Fe_2O_3.[28] The deposition of metal nanoclusters on oxide surfaces has been reported using colloid deposition[26] and seed catalyzed reduction.[5,27] Both methods require pre-formed metal nanoparticles as a source.

Silica shell coatings on either metal or metal-oxide nanoparticles have been reported using sol–gel,[5,29] reverse micelles,[3] aerosol pyrolysis,[30] and atomic layer deposition.[7] Higher thermostability has been observed for the coated nanoparticles presumably due to the stability of the coating providing effective resistance to aggregation of the less stable core particles.[31] The sol–gel method is relatively inexpensive and extendable to commercial scales, and to our knowledge there has been no report of this method used to stabilize metal nanoclusters on metal oxides support nanoparticles.

In this paper the synthesis and characterization of silica encapsulated Pt/α-Fe_2O_3 heterostructures are reported. The Pt nanoparticles[32,33] were ideally deposited by photoreduction from salts on hematite nanocubes and we compared this route with hydrothermal reduction of K_2PtCl_6 in glucose solution. The following questions are addressed: (a) can Pt nanoparticles be deposited on the surface of the nanocubes and the entire heterostructure encapsulated in silica? (b) Is the core/shell heterostructure catalytically active? (c) Is the composite structure stable at the high temperatures required for catalytic reaction and regeneration?

6 Spatially resolved triboemission measurements[i]

Introduction

Triboemission is the collective term for friction-stimulated emission of particles (electrons, ions, neutral particles and photons) that occurs under the severe conditions at the interface between sliding bodies [1]. This type of particle emission is distinct from emission due to other external stimulation, for example, by photons (photoemission [2]) or by heat (thermoemission [3]). The mechanisms that give rise to triboemission are as yet poorly understood. However, it is believed to initiate the chemical reactions that lead to the formation of surface films in boundary lubrication [4, 5]. For example, widely used zinc dialkyldithiophosphate (ZDDP) additives produce boundary films by a mechanism that cannot be driven by contact temperatures and pressure alone [6]. In addition to this, triboemission has been blamed for the degradation of computer hard drive lubricants [7] and has also been linked to flash lights during the fracture of rocks associated in earthquakes [8] and volcanic eruptions [9]. In order to understand the role of emitted particles in these applications — so that boundary lubrication can be enhanced and lubricant degradation prevented — it is necessary to study the mechanisms by which emission occurs.

For this reason, triboemission has been the focus of significant research efforts for over half a century [10].

The first significant triboemission measurements were made by Nakayama *et al.* [11] during scratch tests by a diamond tip. To achieve this, they used a low-voltagebiased collector positioned close to the contact that registered bursts of the electrical current due to the emission of negatively and positively charged particles, while photon emission was measured using a photomultiplier [12]. Their results showed that insulator materials produced significantly higher levels of emission when scratched than metals. Kim *et al.* [13] investigated the emission of electrons using channel electron multipliers (CEMs) and photons using photomultipliers, during abrasion of MgO samples under vacuum. They also measured the kinetic energy of the electrons using a retarding grid. In these studies, photon emission was attributed mainly to deformation and electrons emission to fracture. Molina *et al.* investigated the triboemission of negatively charged particles under vacuum for a wide range of materials (alumina, sapphire, silicon nitride and semiconductors) using a CEM in pulse-counting mode [14–16]. The results from Nakayama *et al.* and Molina *et al.* suggested that triboemission is related to material hardness [14, 17]. Emission is also correlated strongly with the wear of the surface, highlighted by the observation that repeated scratches along a single track result in a decrease of emission with time, due to decreasing wear [14].

From these investigations, it is generally concluded that triboemission of electrons is related to surface fracture during sliding contact. More specifically, Dickinson *et al.* [18] put forward a charge separation model, as shown in Fig. 1. Here, an imbalance of charge is created between opposite faces of a crack as it opens. Due to the small width of the crack, this electric field has a large gradient, which encourages electrons to leave the negatively charged crack face. Due to thermal vibrations, a portion of these electrons do not reach the opposing face and are instead emitted into the surrounding environment. This model, however, does not explain why the energy of the tribo-emitted electrons can be lower than the work function of the sample [14]. To account for these low-energy electrons, Dickinson *et al.* [18] suggested that the work function of the surface could be locally decreased by small defects in the highly strained areas.

Since triboemission measurements typically contain no spatial information, researchers have tried to gain insights into the emission mechanisms by analysing the temporal characteristics of the recorded signals. For example, Molina *et al*. [15] showed that emission patterns are not random and proposed stochastic and chaos-deterministic approaches [16] to characterize their evolution with time. Recently, Nakayama *et al*. [19, 20] and Matta *et al*. [21] have made significant advances in infrared and ultraviolet imaging of the triboplasma, generated at the rear of sliding contacts by gas discharge under ambient conditions. The research described in the current paper differs from these studies, since we are concerned with electron emission mechanisms before interactions with surround gas take place.

One of the main limitations of electron triboemission experiments to date is that they provide only ensemble average values, giving no information relating to spatial location or direction. This shortcoming is, in part, responsible for our lack of understanding of triboemission processes, since it prevents emission measurements from being directly correlated with other surface analyses, such as SEM and AFM. To address this issue, we present experiments using a MCP, in which spatial maps of electron emission are obtained (see Fig. 2). The MCP — which is effectively a dense array of electron multipliers — is located within a vacuum chamber above a stationary diamond stylus that is loaded against a rotating aluminium disc covered with a 5-μm oxide layer (a brittle material on a soft substrate is likely to form cracks and thus induce emission). In this way, bursts of electrons can be visualized, revealing the pattern, direction and temporal characteristics of emission.

1.4. Useful Words and Phrases

1.4.1 Language task

EXERCISE 4 Look carefully through the Introductions in this Unit and in your target research articles. Underline or highlight all the words or phrases that could be used in the four areas below and then compare your suggestions with the words and phrases listed in Section 1.4.2. For example:

1 ESTABLISHING SIGNIFICANCE
Look for words and phrases such as *widespread* and *much research in recent years.*

2 PREVIOUS AND/OR CURRENT RESEARCH AND CONTRIBUTIONS
You can't spend the rest of your life writing *they did/showed/found*; sometimes you need to be more specific, so look for verbs describing what exactly was done, for example *calculated, monitored, identified*.

3 GAP/PROBLEM/PREDICTION
Look for ways to say exactly how previous and/or current research is not yet complete, or has not addressed the problem your paper deals with, for example *inefficient, unclear, few studies have focused on*…

4 THE PRESENT PAPER
Look for descriptions of the present paper, its aims, strategy or advantages, for example *we propose, our approach, successful.*

1.4.2 Language for the Introduction

This section lists words and phrases for the Introduction from analysis of over 2,500 published research articles in different disciplines. The list only includes words and phrases which appear frequently and are therefore considered normal and acceptable by writers and editors.

The list will also keep the flow of writing moving. Underneath each list there are examples of how the words and phrases are used in sentences, so look at the sentence examples as well as the list when you are feeling stuck and can't think of what to write or how to continue.

1 ESTABLISHING SIGNIFICANCE (usually in the first sentence)

(an) advantage	attracted (much) attention
(an) attractive approach	benefit/beneficial
(a) central problem	common/ly
(a) challenging area	cost-effective
(a) considerable number	during the past (two) decades
(a) crucial issue	emerging
(a) current challenge	extensively studied
(a) dramatic increase	for many years
(an) essential element	frequent/ly
(a) focus on	great potential
(a) fundamental issue	importance/important
(a) global concern	major
(a) growth in popularity	many/most
(an) increasing number	multidisciplinary interest
(an) interesting aspect	much study in recent years
(a) key technique	now
(a) leading cause (of)	numerous investigations
(a) number of	of growing/great interest
(a) popular method	often
(a) powerful tool/method	play a key/major role (in)
(a) primary cause (of)	principle
(a) (wide) range (of)	recent/ly
(a) rapid development	relevant
(a) remarkable variety	several
(a) significant increase	today
(a) striking feature	typical
(a) traditional technique	valuable
(a) useful method	well-documented
(a) variety of	well-known
(a) vital aspect	wide/ly
(a) worthwhile study	widespread
	worldwide

Here are some first sentences taken from research article Introductions:

- The status and function of the port has evolved **rapidly in recent years**.
- Since the discovery of the first isolated graphene layer, **many** chemical approaches have been developed.
- The **increasing** pressure to eliminate lead has stimulated **great interest** in the search for lead-free solders.
- Fourier transforms are **widely used** in image processing to characterise textures in images.
- The vanadium redox flow battery (VRFB) is an **emerging** energy storage technology.
- Steady-state multiphase upscaling has become **increasingly popular** because it is **fast, robust and computationally cheap**.
- The optic thalamus has been the subject of **numerous investigations**.
- Malaria affects as **many** as 216 million people annually, with 445,000 deaths occurring primarily in children under 5 years old.*
- Control of serum phosphorus levels is **a central goal in** the management of patients with chronic renal failure.
- Heat transfer phenomena **play an important role in** welding.

*Note that such numbers may change over time, so consider including a date (e.g. *in 2019*).

2 VERBS USED TO REFER TO/DESCRIBE RESEARCH ACTIVITY AND CONTRIBUTIONS IN PREVIOUS AND CURRENT RESEARCH

achieve	create	focus on	produce
address	deal with	generate	propose
analyse	define	identify	prove
apply	demonstrate	imply	provide
argue	describe	improve	put forward
assess	design	interpret	recognise
assume	detect	introduce	report
attempt	determine	investigate	resolve
calculate	develop	measure	reveal
categorise	discover	mention	review

carry out	discuss	model	revise
challenge	enhance	modify	show
claim	establish	monitor	solve
clarify	estimate	note	state
collect	evaluate	observe	study
compare	examine	obtain	suggest
conclude	explain	perform	support
conduct	explore	point out	test
confirm	extend	predict	use
consider	find	present	verify

Note: Use these verbs throughout, for example at the end of the Introduction, when you say what you did in your study or what is in your paper.

Here are some examples of how these are used:

- The effect of keratin on the mechanical properties of copolymer systems **was demonstrated** more than two years ago.
- Minelli *et al.* **describe** the use of experts' opinions and empirical evidence.
- NDE systems **have been applied** to the inspection of pipelines.
- Several authors **have developed** compensation techniques for temperature changes.
- The advantages and limitations of each of these techniques **have been evaluated** by different authors.
- Kim *et al.* **investigated** the emission of electrons using channel electron multipliers (CEMs).
- Dickinson *et al.* **put forward** a charge separation model.
- For simplicity, they only **considered** the homogeneity ranges in their model.
- They were the first to **recognise** the importance of studying the effect of genetic variation.
- Initial attempts **focused on determining** the cause of…
- The results on pair dispersion **are reported in**…

3 GAP

Group 1: PROBLEM/CRITICISM

absent	inflexible	(a) challenge
complicated	insufficient	(a) defect
controversial	misleading	(a) difficulty
costly	not able to…	(a) disadvantage
deficient	not ideal	(a) drawback
disappointing	not sufficiently…	(a) flaw
doubtful	not/no longer useful	(a) gap
expensive	of little value	(a) lack
false	over-simplistic	(a) limitation
far from (ideal)	poor	(an) obstacle
fragile	problematic	(a) problem
hard to (detect)	restricted	(a) risk
impractical	severe	(a) shortcoming
inaccurate	time-consuming	(a) weakness
inadequate	unable to	(to) be confined to
incapable (of)	undesirable	(to) fail to
incompatible	unnecessary	(to) fall short of
inconsistent	unrealistic	(to) ignore
inconvenient	unsatisfactory	(to) lag behind
incorrect	unsuccessful	(to) miscalculate
ineffective	unsuitable	(to) misjudge
inefficient	unsupported	(to) misunderstand
inferior		(to) neglect
		(to) overlook
		(to) suffer (from)

Note: These are often signalled by words such as *however, although, while, nevertheless, despite*.

Group 2: RESEARCH OPPORTUNITIES

(an) alternative	more work is needed
(the) next step	not addressed
(to) demand clarification	not dealt with
(to) need to re-examine	not studied

(to) raise the question	not well understood
(to) remain controversial	suggest/s that…
(to) remain unstudied	there is an urgent need…
(to) require (clarification)	to the best of our knowledge
few studies have…	unanswered
ideal candidate	unclear
incomplete	unexamined
it is/seems possible that…	unproven
little evidence is available	unsolved
little work has been done	

Note: Research opportunities are often communicated by using modal verbs such as *may/might/could/would*.

Here are some examples of how these are used:

- The fact that these galaxies are so massive may make them **ideal candidates** for protocluster searches.
- **Little attention has been paid** to the selection of an alternative biocompatible material.
- How propofol acts on neural circuits to produce unconsciousness **remains unclear**.
- The main **drawback** of this approach is that it is **unable** to provide quantitative information.
- **Little is known** about these early differentiating cells and **it is not clear** whether this initial Oct4 expressing population differ from undifferentiated hESCs.
- One of the **limitations** of electron triboemission experiments to date is that they provide **only** ensemble average values.
- This **shortcoming** is responsible for our **lack of understanding** of triboemission processes.
- **However,** the search for a stable oral prostaglandin preparation has been **largely unsuccessful**.
- The high absorbance makes this **an impractical option**.
- **An alternative approach** is necessary.
- Determining the function of these proteins **remains a challenge**.

- **Although** there is general agreement regarding the timing of sea-level events, their amplitude **remains controversial**.
- These can be **time-consuming** and are often **technically difficult** to perform.

4 THE PRESENT WORK

(to) attempt	(is) organised as follows:	**'happy' words** ☺
(to) compare	(is) set out as follows:	able to
(to) concentrate (on)	(our) approach	accurate
(to) describe	(the) present work	advantage
(to) determine	(this) paper	effective
(to) develop	(this) project	efficient
(to) discuss	(this) report	excellent
(to) enable	(this) section	fully
(to) enhance	(this) study	innovation
(to) evaluate	(this) work	new
(to) facilitate	aim	novel
(to) focus on	goal	potential
(to) identify	intention	powerful
(to) improve	objective	practical
(to) investigate	purpose	promising
(to) offer		relevant
(to) outline		robust
(to) predict		simple
(to) present		straightforward
(to) propose		successful
(to) provide		superior
(to) report		unique
(to) reveal		valuable
(to) solve		
(to) succeed		

Here are some examples of how these are used:

- **Our study focuses on**…
- To address this question, **we investigated**…

- Section V **provides several relevant** conclusions obtained from **the study reported in this paper**.
- **The main objective of this study** was **to describe and examine**…
- **In this paper we present** a **robust** method for…
- **The proposed method** combines GWAS data with information from bioinformatics databases in a **coherent and reproducible** way.
- **In this study**, we **carefully identified and isolated**…
- **New** correlations were developed with **excellent** results.
- **We show that** use of glass reactors can be **effective**.
- **To our knowledge, this is the first** demonstration of the…
- **This paper introduces** a scheme which **solves** these problems.
- **To address this issue, we present** experiments using an MCP.
- **Our design** is both **simple** and **accurate,** and can be **fully** integrated into…
- **This paper is organised as follows:**

1.5. Language and Writing Skills

This section deals with four topics that are important in the Introduction and elsewhere:

VERB TENSE CHOICES
LINKING SENTENCES TOGETHER
PASSIVE/ACTIVE CHOICES
PARAGRAPHING

1.5.1 Verb tense choices

As we have seen, most writers present previous research and contributions in the Introduction: the research 'map'. They use a range of verb tenses to do this, generally the Past Simple, the Present Simple and the Present Perfect. The decision of which of these three tenses to use is rarely determined by the rules of grammar; in most cases the decision is made on the basis of meaning. Using a particular verb tense to present previous research and contributions represents a choice about the function of that sentence rather than a grammatical imperative. You choose between Past Simple, Present Simple and Present Perfect according to what you want to say about a particular study or contribution, or how you want the reader to interpret it. In this section we will look at what governs these choices.

Choosing between Past Simple and Present Simple

They found that the pressure ***increased*** *as the temperature* ***rose****.*
They found that the pressure ***increases*** *as the temperature* ***rises****.*

They found that the dielectric structure ***possessed*** *a full photonic bandgap.*
They found that the dielectric structure ***possesses*** *a full photonic bandgap.*

The Past Simple just describes what the authors found in their study; the findings are linked to that study and are not presented as permanent truths. By contrast, choosing the Present Simple reflects a belief that the findings are strong and reliable enough to constitute a permanent truth.

Note, however, that as we saw in Section 1.2.2, many background facts presented in the Present Simple began their life as research findings stated in the Past Simple, and graduated to Present tense status as they became established and accepted. This means that a journal article from five years ago may use a verb tense that is no longer appropriate, and using that tense now would give the impression that you are not up to date with developments in your field. When you are writing about previous research and contributions, **check which verb tense is currently being used for that particular finding or fact**. Search engines such as Google Scholar are a good resource for this, but make sure you search only recent research.

Choosing between Past Simple and Present Perfect

*They **found** that the pressure increases as the temperature rises.*
*They **have found** that the pressure increases as the temperature rises.*

*They **found** that the dielectric structure **possesses** a full photonic bandgap.*
*They **have found** that the dielectric structure **possesses** a full photonic bandgap.*

In these sentences:

(a) Past Simple	I lived in Tokyo for five years	…but I don't live there anymore.
(b) Present Perfect	I have lived in Tokyo for five years	…and I still live there **now**.

the difference between (a) and (b) is the 'time' of the event, i.e. whether or not the writer is still living in Tokyo. In these sentences, however:

(c) Past Simple	I broke my glasses	…but I have another pair/I repaired them.
(d) Present Perfect	I have broken my glasses	…and so I can't see well **now**.

the difference is more complex, and more important for you as a STEMM research writer. In (c) and (d), the 'time' of the event isn't the key difference; it's possible that both (c) and (d) happened last month, this morning, or one nanosecond ago. The event in (d) is in the Present Perfect tense because it is more **relevant to the situation now** than the event in (c). Why is this idea of current relevance important when you write an Introduction? Look at this sentence from the Introduction in Section 1.2.1:

> *However, although the effect of keratin on the mechanical properties of copolymer systems **was demonstrated** over two years ago[9], keratin adds considerably to the weight of the composite, and little attention **has been paid** to the selection of an alternative biocompatible material.*

In this sentence, the writer changes from the Past Simple (***was demonstrated***) to the Present Perfect (***has been paid***) in order to communicate that the latter refers to a current gap in the research. The choice of Present Perfect therefore implies that this research article *will now pay attention to the selection of an appropriate biocompatible material.*

Compare this with the following sentence, in which the writer does not change tense, but continues in the Past Simple:

> *However, although the effect of keratin on the mechanical properties of copolymer systems **was demonstrated** over two years ago[9], keratin adds considerably to the weight of the composite, and little attention **was paid** to the selection of an alternative biocompatible material.*

In the Past Simple, the sentence means that little attention was paid THEN, i.e. two years ago. Perhaps attention has been paid to this problem since then, or perhaps the problem has since been solved. Tense changes are always meaningful, and they always signal a change in the function of the information, so don't choose or change tense randomly.

Check this information about tenses by looking at the way the Past Simple and Present Perfect are used in the Introductions of your target articles. Look in particular at the way the Past Simple tense and the Present Perfect tense are used to describe previous research and the contributions of previous research.

1.5.2 Linking sentences and information together

As a sentence progresses, it becomes easier for the reader to predict where it is going. Take a look at the following sentence:

If you're paying attention to this sentence, you can probably predict what the last word will____.

It's fairly easy to predict the last word of that sentence, but it's much harder to predict the first word of the *next* sentence. At the end of each sentence, writers stop and think about what to write next, but in that thinking time — which may be seconds, hours, days or even weeks — the gap between the two sentences starts to stretch, and may become too wide for the reader to negotiate. The gap between sentences is a dangerous space. Your job as a writer is to close the gap as tightly as possible, so that readers can effortlessly connect one piece of information to the next. Connecting information is not only good for the reader, it is also good for the writer, because it encourages him/her to develop ideas and text in a logical way.

The way that a sentence starts and links to the previous sentences is central to its success, the success of the paragraph and the success of the text as a whole. There are four ways to start a sentence that make the connection with the previous information clear. One way is to **overlap**, meaning to **repeat something from the previous sentence early in the next one**:

*This steady-state approach cannot distinguish between patterns that are characteristic of a deeply anesthetized brain and those that arise at the onset of **unconsciousness**. **Unconsciousness** can occur in tens of seconds...*

*... implying that information transfer between distant (>2 cm) **cortical networks** is impaired. **Cortical networks** therefore are fragmented both temporally and spatially, disrupting both...*

*The pattern of inflammation during an asthma attack is different from that seen **in stable asthma**. **In stable asthma** the total number of inflammatory cells does not increase.*

… although metals such as aluminium have been used ***to strengthen*** *PLA for industrial applications*[5,6]*, these are not appropriate for biomedical use*[7]*. One way* ***to strengthen*** *polymers for biomedical applications is…*

Elucidating the effects of insoluble signals requires ***defined substrata****. Such* ***defined substrata*** *have been developed for the long-term culture of undifferentiated hPS cells in defined media.*

A second way is to use a **pro-form** (*This method, These systems*) to glue the sentences together:

On the basis of ***these criteria*** *it then describes the preparation of a biomass-derived polymer blend using chitin, a long-chain polymer found in many places throughout the natural world.* ***This combination*** *formed a novel lightweight copolymer…*

The effects on macroscopic dynamics are noticeable in the EEG, which contains several stereotyped ***patterns*** *during maintenance of propofol general anesthesia.* ***These patterns*** *include increased delta power…*

Most studies have focused on a deep ***steady state*** *of general anesthesia and have not used a systematic behavioral measure to track the transition into unconsciousness.* ***This steady-state*** *approach cannot distinguish between…*

Many researchers have suggested ***ways*** *to reduce cost without affecting the quality of the image.* ***These methods*** *rely on data structures built during a preprocessing step.*

One of the main ***limitations*** *of electron triboemission experiments to date is that they provide only ensemble average values, giving no information relating to spatial location or direction.* ***This shortcoming*** *is, in part, responsible for our lack of understanding…*

Note that when you use pro-forms, it is easier for the reader if you repeat exactly the same noun as you used the first time. If you have described something as a *device*, the pro-form you use to refer to it next time should be *this device*, not *this technique* or *this method*.

You can begin sentences with *It, They, These* or *This*, but it may be difficult for the reader to work out what these words refer to. Look at these examples:

- *This result was statistically significant and is in line with results in previous studies.* ***This*** *suggests that…*
  Does ***This*** refer to the fact that the result *was statistically significant* or that the result is *in line with results in previous studies*? Or both?
- *The existence of small amounts of impurities will change these properties and* ***they*** *are easily detectable.*
  Does **they** refer to '*impurities*'? '*small amounts of impurities*'? '*these properties*'?

A third way is not to finish the sentence at all, but to join it to the next sentence with a **semicolon**. Joining sentences with a semicolon works well when there are two consecutive sentences that are very closely related, particularly if one of them is short. Using a semicolon to join sentences in this way feels like a long comma rather than a full stop.

The procedure for testing whether components are operationally safe usually takes many hours; this means that tests are rarely repeated.

Simple pulse-echo or pitch-catch signals from undamaged structures usually consist of interfering reflections that cannot be identified; these unwanted reflections are a source of coherent noise, which can mask defects in the structure.

Due to the small width of the crack, this electric field has a large gradient; this encourages electrons to leave the negatively charged crack face.

Sentence length is an important factor in readability, so if you use a semicolon to join sentences in this way, check the overall length of the sentence. Sentences with fewer than 20 words are understood by 90% of readers at first reading; those with more than 40 words are understood by only 10% of readers at first reading. The average sentence length in STEMM research articles is approximately 23.

The fourth way is to use a signal such as *therefore* or *however* to communicate the function of the sentence. They are helpful if they are used correctly, but signals are not simply ‘glue’ to hold sentences together; if they are not used accurately, they can do more harm than good. A sentence beginning with *Moreover* tells the reader that the function of the sentence they are reading is the same as the previous one; in other words, if the previous sentence presented a reason for doing something, this one must do the same. If the previous sentence presented a disadvantage of something, this one must present a further disadvantage. Similarly, a sentence beginning with *Therefore* or *Consequently* must present or describe an effect, result or outcome that is directly linked to an identifiable reason or cause. The causal relationship should be either obvious or made explicit to the reader, rather than existing mainly in the mind of the writer. If it is not obvious, perhaps this indicates that more information is needed before using *Therefore*.

Here are some examples of signals arranged according to their function. It is not a long list because only those which are common in current STEMM writing are included.

CAUSE

The experiment was unsuccessful ________ the measuring instruments were inaccurate.
The experiment was unsuccessful ________ the inaccuracy of the measuring instruments.

due to (the fact that) on account of (the fact that) in view of (the fact that)	as because since

- *as* can also mean *when*, so if there’s any possibility of confusion, choose a different signal. For example, it is not clear whether ***As*** means *Because* or *When* in the sentence: ***As*** *repeated melting homogenised more material, the phase transitions became less prominent*.
- *since* can also mean *from that time*, so if there’s any possibility of confusion, choose a different signal.

RESULT

The measuring instruments were calibrated accurately, ________ the experiment was successful.

therefore consequently	hence as a result	thus so

CONTRAST/DIFFERENCE

British students are all vegetarians, __________ Norwegian students eat meat every day.

however whereas but	on the other hand while	by contrast in contrast

- *on the contrary* and *conversely* don't fit into this category because they don't just communicate difference; they communicate the fact that *exactly the opposite is true*. You can't use them in the sentence above because *vegetarians* and *meat eaters* aren't opposites, they're just different. However, you could use them in the following sentence: *Some experiments used uncalibrated instruments and succeeded;* ***conversely****, other experiments used carefully calibrated instruments and failed.*
- Also, remember that *while* often means *at that/the same time*, so if there's any possibility of confusion, choose a different signal, such as *whereas*.

UNEXPECTEDNESS

A ________ it was difficult, a solution was quickly found.
B ________ the difficulty, a solution was quickly found.
C It was difficult; ________ a solution was quickly found.

A	B	C
although even though though	despite in spite of regardless of notwithstanding	nevertheless however yet but nonetheless even so

Note that *however* and *but* can be used to express **CONTRAST/DIFFERENCE** as well as **UNEXPECTEDNESS**, so if you want to emphasise UNEXPECTEDNESS, choose one of the other signals from this list.

ADDITION/LISTING

We used a batch processing system because it was more effective. ____________ it was significantly less expensive.

in addition moreover furthermore	also secondly (etc.) in the second place (etc.) what is more,

Note that *besides* has more or less the same meaning as the items in the list above, but it's more powerful and is therefore better in persuasive contexts.

TRANSITION

The drug is extremely effective and easy to administer. _________ cost, it is approximately the same price per dose as existing drugs.

with regard to as to regarding	with respect to as for turning now to

It's not necessary (and it looks formulaic) to start every sentence with a signal. Signals are emphatic, and starting each sentence with one creates a jerky, over-emphatic text. To ensure that the information in your text is logical and easy to follow, consider using repetition linkage instead of a signal. This means repeating words across sentences, and particularly at the start of a sentence, to ensure that the reader is carried carefully from one item of information to the next.

Checking that sentences and information are explicitly linked is a valuable self-editing tool, as it forces you to examine the relationships between your sentences. Good linkage helps to create *flow.*

In the Introduction to *Rapid fragmentation of neuronal networks at the onset of propofol-induced unconsciousness* below, sentence-to-sentence linkage is in **bold** type, and repetition linkage is in *italics.* It's surprising how much linkage and repetition there is in the text — and how easy it is to read and understand as a result. After you have looked at this example, check the way sentence linkage and repetition linkage operate in the Introductions of your target articles and the other Introductions in this Unit.

General anesthesia is a drug-induced reversible coma commonly initiated by administering a large dose of a fast-acting *drug* to induce unconsciousness within seconds (1). **This state** can be maintained as long as needed to execute surgical and many nonsurgical procedures. One of the most widely used *anesthetics* is propofol, an i.v. *drug* that enhances GABAergic inhibitory input to neurons (2–4), with effects in cortex, thalamus, brainstem, and spinal cord (5–7). **Despite** the understanding of *propofol*'s molecular actions, it is not clear how *these effects* at molecular targets affect single *neurons* and larger-scale neural circuits to produce *unconsciousness.*

The effects on macroscopic dynamics are noticeable in the EEG, which contains several stereotyped **patterns** during maintenance of *propofol general anesthesia*. **These patterns** include increased delta (0.5–4 Hz) power (8, 9); increased gamma (25–40 Hz) power (9); an alpha (~10 Hz) rhythm (10–12) that is coherent across frontal cortex; and burst suppression, an alternation between bursts of high-voltage activity and periods of flat *EEG* lasting for several seconds (13, 14). **In addition**, slow oscillations (<1 Hz) have been well characterized in deeply anesthetized animals and are associated with an alternation of the neuronal membrane potential between UP (depolarized) and DOWN (hyperpolarized) states (8, 15).

Although these patterns are observed consistently, it is unclear how they are functionally related to *unconsciousness* under *general anesthesia.* Most studies have focused on a deep **steady state** of *general anesthesia* and have not used a systematic behavioral measure to track the transition into *unconsciousness*. **This steady-state approach** cannot distinguish between *patterns* that are characteristic of a deeply anesthetized brain and those that arise at the onset of **unconsciousness. Unconsciousness** can occur in tens of seconds (4), but many neurophysiological features continue to fluctuate for minutes after induction and are highly variable between different levels of *general anesthesia* (1,16). **Therefore**, identifying the specific dynamics associated with loss of consciousness (LOC) requires an examination of the *transition into unconsciousness*, linking neurophysiology with *behavioral measures*.

In addition, the dynamic interactions between cortical areas that underlie *these EEG oscillations* are not well understood, because few studies have simultaneously recorded ensembles of *single neurons* and oscillatory dynamics from sites distributed across the brain. **Consequently**, how *propofol* acts on neural circuits to produce *unconsciousness* remains unclear. A leading hypothesis suggests that anesthetics disrupt cortical integration (17, 18). Identifying the mechanism by which *this disruption* might occur requires a better understanding of how the spatial and temporal organization of neural dynamics evolves during *induction* of *unconsciousness.*

To address this question, we investigated both *neuronal* and circuit-level dynamics in the human brain during *induction* of *unconsciousness* with *propofol*. **We** obtained simultaneous recordings of single units, local field potentials (LFPs), and intracranial electrocorticograms (ECoG) over up to 8 cm of cortex, enabling us to examine neural dynamics at multiple spatial scales with millisecond-scale temporal resolution. **We** used a *behavioral* task to identify within seconds the time at which patients became unresponsive to auditory stimuli, which we defined as *LOC*.

Our results reveal a set of neurophysiological features that accompany *LOC* that, together with previously reported effects (8, 9, 15), enable a multiscale account of this profound shift in brain state. **We** find that *LOC* is marked by the abrupt onset of *slow oscillations* (0.1–1 Hz) in the LFP. Power in the *slow oscillation* band rises sharply at *LOC* and maintains this increase throughout the post-*LOC* period. *Neuronal* spiking becomes coupled to the local *slow oscillation* within seconds of *LOC*: **Spiking** occurs only in short intervals of activity that are interspersed with suppression lasting hundreds of milliseconds, periodically interrupting information processing. **These periods** in which activity may occur are not simultaneous across the brain, implying that information transfer between distant (>2 cm) *cortical* networks is impaired. **Cortical networks** therefore are fragmented both temporally and spatially, *disrupting* both local and long-range communication. **However**, small-scale (<4 mm) functional connectivity measures remain similar to the conscious state, and *neuronal spike* rates can recover to baseline levels after *LOC* despite continued unresponsiveness. **This result** demonstrates that short periods of normal *spike* dynamics still can occur during *unconsciousness.* **We** conclude that the *slow oscillation* is a fundamental component of *propofol*-induced *unconsciousness*, marking a functional isolation of *cortical* regions while significant connectivity is preserved within local *networks*.

1.5.3 Passive/Active choices

Towards the end of the Introduction you usually say what you will do or present in the research article, and you need to decide whether those sentences will be in the Passive or the Active.

There are three options: using *we/our*, using the passive, and restructuring the sentence so that it is in the active, with a non-human subject (*This study demonstrates that…/Section 1 presents…*). The decision of whether to use active, passive or a non-human subject such as *This study* is connected to **style** and **communicative accuracy**.

With regard to **style**, the first thing to do is — as always — to check the journal in question, so start by looking at your target articles. Science writing has traditionally favoured the passive, perhaps because it seems more objective, but this is changing in some fields and in some journals. The passive is still common, particularly in descriptions of methods or experimental procedures, but many interdisciplinary or free-flowing research areas are more flexible and tolerant.

With regard to **communicative accuracy***,* if you use the active, it is important to keep the referent of *we/our* consistent. This is because there is a risk that the referent of *we/our* may become unstable and even change from one sentence to the next. This can have an impact on the ownership of the sentence content. In one sentence *we/our* may refer to 'me and the other authors of this paper' (*we investigated*), in another it may refer to 'me, the other authors of this paper and everyone in my research field, possibly even you (the reader) too (*our knowledge/when we consider*), and in another sentence it may refer to 'me, the other authors of this paper, everyone in my research field, possibly even you…and my grandmother', i.e. people in general (*we know*). If you are using *we/our* to refer to people in general, it may be clearer to use a construction with *It* (*It is known/thought that…*).

A third option is to rewrite the sentence using a non-human grammatical subject (*The present paper describes an algorithm for clustering sequences into index classes/This study presents a set of criteria for selecting such a component/Section 2 reviews existing methods*).

1.5.4 Paragraphing

Why is good paragraphing important?

Paragraphs are powerful non-verbal text elements that provide a visual and intellectual separation between ideas and concepts. A good paragraph generally has a single unifying function, for example, *summarising the implications of the results* or *explaining why a particular technique was used.* Every sentence and indeed every part of every sentence should be relevant to the central function of the paragraph and drive that function forward; 'loose' or irrelevant items interrupt the narrative and cause confusion. If the function of the paragraph is clear to the writer, it will be easier to make it clear to the reader.

Good paragraphing is key to text planning, and good text planning is essential for fast, effective text production. Getting lost in the middle of a paragraph and not knowing how to end it or where to go next is stressful and time-consuming for the writer. The result is often an interruption in the flow of information, and both reader and writer may find it hard to pick up the narrative again. Good paragraphing is a key component of the narrative scaffold that enables readers to process information and, equally importantly, helps writers to create that information.

How long should a paragraph be?

Two common errors in paragraphing are clusters of short or single-sentence paragraphs, and paragraphs that are too long and lose their way. In both cases, it's hard for readers to follow the writer's train of thought. Paragraphs are marked either by indenting the first line or by a double space between paragraphs. Over the years, readers develop a very strong response to these visual signals. This means that each time the reader begins a new paragraph, there is a conditioned response that prepares them for a change or shift to something different. Clusters of short or single-sentence paragraphs make the reading process very jerky because they evoke that 'something different' response inappropriately; in most cases the writer has simply put ideas down randomly rather than organised them into reader-friendly units. Similarly, overlong paragraphs that begin with one idea and end with another or contain too many ideas indicate that the writer has forgotten the reader entirely and is simply 'dumping' information. In both cases, the result is a text that is not reader-friendly and may be confusing.

Check target texts to determine normal paragraph length for that type of text in your field. For example, average paragraph length in research articles is around 150–170 words; some paragraphs exceed 230 words and others are below 80, but it is unusual to find a research article in which *many or most* paragraphs are over 230 words or under 80.

How do I learn good paragraphing?

To understand how good paragraphing works, it is worth looking at why readers are encouraged to skim texts before reading them. Skimming is based on the principle that knowing what a text is about beforehand speeds up the reading process: the more you know about what you are going to read, the faster and more effectively you read. For example, if you read the last page of a murder mystery before you finish the book, the rest of the story is less exciting, but you will read faster. You don't waste time wondering who the murderer is; you know it's the victim's brother, so whenever his name is mentioned you concentrate and read carefully — but you don't bother to read the details about the other suspects. This enables you to read faster by giving you the confidence to ignore things which you know are not relevant.

How does skimming work? And what is the connection between skimming and good paragraphing?

Skimming focuses your attention on the first line or sentence of each paragraph. These sentences provide a simple, basic 'map' of the topics covered in the text, the order in which they are presented and the general direction of the text; in other words, *what the text is about and where it is going*. Skimming generally follows the following pattern:

1. **READ the title**…to predict the content.
2. **CHECK the date and the name/s of the authors**.
3. **READ the Abstract/Summary/Highlights**.
4. **LOOK QUICKLY at the figures/tables** to see how much/what type of visual data is included.
5. **LOOK QUICKLY at the subtitles and the first line or sentence of each paragraph** to get a 'map' of the paper.
6. **READ the Conclusions/last paragraph** to see where the paper is going.

How can I use this to help me to write good paragraphs?

Number 5 above is ***LOOK QUICKLY at the subtitles and the first line or sentence of each paragraph*** *to get a 'map' of the paper.* The importance of the first line or sentence of a paragraph is so well-established that there are even macros that select these from a text and present them as a document that can be used as a way of taking notes without reading. This is because it is conventional in academic writing to start with an entry sentence or phrase which presents the topic, function or aim of the paragraph (see examples on the next page). The other sentences then discuss that topic, describe it, define it in more detail, develop it, give examples of it, rephrase it, explain it, etc. When the topic moves too far away from the first sentence, the writer begins a new paragraph, often with a new entry sentence.

So what's the strategy?

- List each topic/concept/idea that you want to discuss and then order them logically for the reader.
- List the bullet points you want to include for each topic, and then order the bullet points logically for the reader.
- Consider how many paragraphs you will need for each topic.
- Check that each paragraph has a function within that topic, for example to provide factual background/describe the advantage or disadvantage of a method/present an existing theory/explain why you agree with something/provide a detailed example/compare different techniques.
- Make sure that the function of the paragraph is clear to the reader.
- Consider using a statement of intent at the beginning of the paragraph to present the focus or topic of the paragraph and/or link it with the previous paragraph. You can use the sentence linkage strategies described in Section 1.5.2 or explicit phrases such as:

According to this theory, …	These data suggest that…
An alternative approach is…	This is important because…
Another key feature is…	This process occurs in two stages.
Having collected the data, …	To address this question, …
Here, we present…	To confirm…, we…
In order to explore this, …	Turning now to…
On the basis of this finding, …	We argue that…
Our next goal was…	When we consider…
The first evidence for this is…	With regard to…

1.6. Writing the Introduction

In this Unit you have seen that conventional science writing patterns are easy to identify and that they generate text that is readable and effective. In this section you will write an Introduction by bringing together everything in this Unit: the model, the language and writing skills, and the vocabulary.

1.6.1 Write the Introduction

For Exercise 5 below, follow the streamlined Introduction model on page 17 and use the vocabulary in the Language section. Your sentence patterns should be similar to those in your target articles, in the Introductions printed here, and the language should be similar to that in Section 1.4.2. A model answer is provided on page 70.

EXERCISE 5 Imagine that you have just completed a research project to design a bicycle cover which can protect cyclists from injury, pollution, or just from rain. Perhaps you provided a computer simulation of its use, or modelled the ventilation system. Perhaps you were involved in the aerodynamics, or the polymer construction of the material for the cover — or any other aspect of the project.

Write the Introduction for your research article. The title of your paper is **A cover for the single-person pedal-powered vehicle***,* and you should write an Introduction of approximately 250–350 words. Follow the model as closely as possible; make sure your Introduction contains the four main components of the model and use the vocabulary in this Unit for each component. You can lie as much as you like, and of course you will have to create fake research references.

1.6.2 Key

A cover for the single-person pedal-powered vehicle

Introduction

Urban air pollution has become a central issue in transport policy decision-making. Air quality in city centres is linked to the level of vehicle emissions[2], and urban transport policy in the UK aims to reduce the use of private cars in city centres by 25% within the next ten years[3]. As a result, much research has focused on developing environmentally-friendly commuter vehicles such as the Single-Person Pedal-Powered Vehicle (SPPPV). However, although there has been an increase in the sale of SPPPVs, safety and comfort issues need to be addressed if the number of users is to increase to a level at which a significant effect on environmental pollution can be achieved.

Researchers have studied and improved many safety aspects of the SPPPV. In 1999, Wang *et al*. responded to the need for increased safety by designing an SPPPV surrounded by a 'cage' of safety bars[4], and in 2002 Martinez introduced a reinforced polymer screen which could be fitted to the safety bars to protect the cyclist's head in the event of a collision[5]. The issue of comfort has also been addressed by many design teams; in 2008 Kohl *et al.* introduced an SPPPV with a built-in rain/sun umbrella, which could be opened at the touch of a button[6], and more recently, Martinez[7] added a mesh filter which can be placed over the entire cage to reduce the risk of environmental pollution. However, it has been suggested that both the shape of the umbrella and the weight of the mesh filter negatively affect aerodynamic efficiency (Zhang *et al.,* 2019).

In this study, we model the aerodynamic effect of these safety and comfort features and use the data thus obtained to propose a new design which balances design parameters with optimum aerodynamic performance.

TIPS FOR WRITING A READER-FRIENDLY, EFFECTIVE INTRODUCTION

- Plan the whole Introduction, paragraph by paragraph, before you start creating sentences.
- Remember that your Introduction and the research questions or gap you identify must align with the rest of the article, and particularly the Discussion/Conclusion.
- Don't jump too fast from very general to very specific information early in the Introduction.
- Remember that your familiarity with the topic may mean that you are not aware of the reader's need for background information, particularly if you are aiming for an interdisciplinary audience.
- Consider the density of the information and try to match eye-reading speed with brain-processing speed. This may mean using examples or paraphrases to slow down the flow of content, expanding concentrations of information, or breaking long sentences into smaller, well-linked units.
- The way a paragraph starts and links to the previous paragraph is key to the success of that paragraph and the text as a whole. Think about the best way to start each paragraph before you begin typing it.
- The way a sentence starts and links to the previous sentence is key to the success of that sentence, that paragraph, and the text as a whole. Think about the best way to start each sentence before you begin typing it.
- Be aware that you will always understand what you have written, but you're not writing for yourself — what is important is that your reader can understand it. Write for a reader, not for a colleague.

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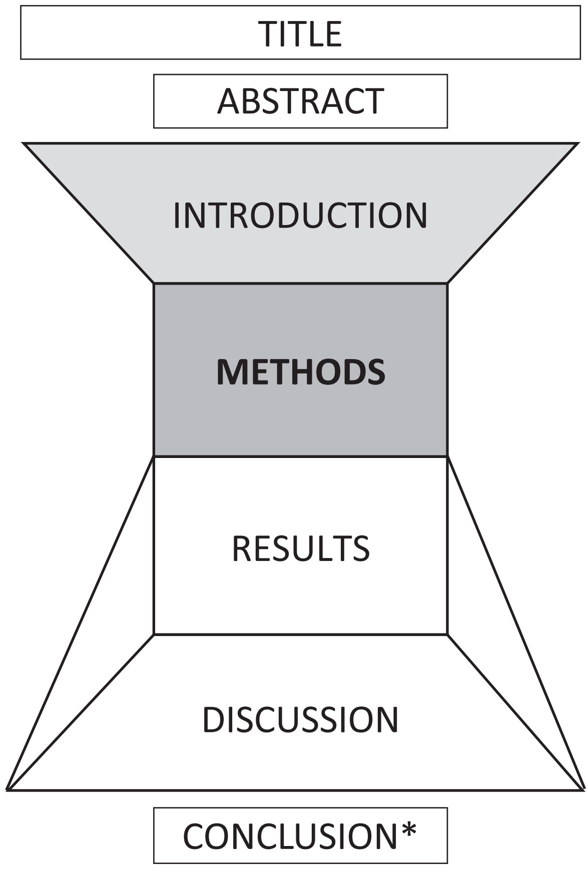
UNIT 2

How to Write about Methods



*Some journals call this section CONCLUSION and others call it CONCLUSIONS but this does not seem to reflect the number of conclusions that are drawn.

2.1. The Structure and Content of the Methods Section

The Methods section has a more flexible structure and content than the Introduction, and its title reflects the many different activities involved in scientific research. In some journals it is called **Methods;** in others it may be called **Materials and methods, Experimental**, **Test methods, Simulations, Model, Experimental design, Experimental work, Experimental techniques,** or **Methodology.** It may even have a specific title such as **Calibration** or **Model-controlled test,** but for simplicity, it will be referred to here as the Methods section.

As discussed previously, the rate at which science research is produced and the way it is communicated affect the structure and the content of research papers. The number of papers published in peer-reviewed journals is increasing, and so is publication using channels such as conference proceedings, open archives and home pages. The total volume of science research published every year and accessible on the internet is estimated to be doubling every ten years; some estimate that approximately 3 million scientific papers are now published every year. This has a huge impact on the way that scientists read and access information, and this impact is evident in the way that the Methods are communicated.

Scientists aim to 'move rapidly through the literature to assess and exploit content with as little actual reading as possible'[4]. This has generated an *information-surfing* approach in which readers often move directly from the Title/Abstract to the Results or even straight to the Conclusion, bypassing the Methods section unless it is the section they are interested in, or is very short. This reading strategy, together with manuscript length restrictions in print journals, is changing the way many Methods sections are communicated. A long detailed or technical description of the method may not appear in the main manuscript of the paper but rather via an online link to supplementary materials.

This does not mean that the writer can ignore the reader's need for information about the method in the rest of the paper. The readers' acceptance of those results and conclusions is linked to their acceptance of the method. If there is little or no information about the method in the rest of the paper, this may affect the overall credibility of the study, particularly if the amount of supplementary material discourages reading. The reader needs sufficient information about the method for the results and conclusions to make sense, and this is generally achieved by including that information in the Results section (see Unit 3). As always, the best guide to the balance between information about the method in the main manuscript and in the supplementary material is to examine your target articles.

As Pop and Salzberg[5] note, although placing supplementary material outside the main manuscript can improve readability, extensive use of supplementary materials may have a range of negative effects; for example, readers may have to sift through many — in some cases hundreds of — pages of supplementary text to find the information they need. In addition, the extent of supplementary information makes it difficult to carry out appropriate peer-reviewing, particularly where there is a need for urgency. A further issue noted by Pop and Salzberg is that some journals, for example, *Nature*, state explicitly that they *do not encourage deposition of references within SI as they will not be live links and will not contribute towards citation measures*[6]. Citations in supplementary materials are not normally tracked by citation indexes, and this has impacts for scholarship, and for ownership of information. Given these issues, it is likely that the rules and strategies for including and accessing supplementary material will be reviewed and revised over the next decade. Pop and Salzberg's proposal that "supplementary items, irrespective of format, be directly hyper-linked from the text itself. Such references should be to specific sections of the supplementary material…"[5] is a way of resolving at least some of these issues.

In whatever form it appears in the future, the Methods section is likely to retain its primary function: to contain enough detailed information to ensure that other researchers can replicate the work done and obtain similar results. This means that the content, language, and narrative aspects of the Methods section are also likely to remain relatively stable, and this Unit will proceed on that basis.

Whether your target articles are 5-page articles accompanied by 100+ pages of Supplementary Materials, or articles in which the method or experiments are reported fully in the main manuscript, using the reverse-engineering strategy in this Unit will ensure that your writing is as similar as possible to your target articles. For reasons of conciseness, this Unit will refer to Methods sections found within the main body of the paper.

2.2. Building a Model

Writing an effective Methods section is not simply a matter of writing up the detailed notes you made during the research period. **Your notes were written for yourself, but the Methods section is written for a reader**. The reader not only needs to know what the method was; equally importantly, s/he also needs information *about* the method. This unit will show you how to build and use a model for the Methods section that answers the following three questions:

What are some common ways to start the Methods section?
What is normally in the Methods section, and in what order?
What are some common ways to end the Methods section?

2.2.1 EXERCISE 1: How to build a simple model

Look at the Methods section below and write a short description of what the writer is doing in each sentence. As with the Introduction, you are not describing or summarising *what the sentence is saying* (the content of the sentence); instead, you are working out *what the sentence is doing* (the function of the sentence). One way to find out what the writer is doing in a sentence is to look at the tense of the main verb. What is that verb tense normally used for? Is the verb in the same tense as in the previous sentence? If not, why has the writer changed the tense?

Remember that your model is only useful if it can be transferred to other Methods sections, so don't include content words such as *groundwater* in your description of the model, or it won't generate Methods sections for other research articles, including your own.

Keep your description simple; Sentence 4 has been done for you as a guide to the level of detail you should aim for. Once you have completed the description of the first Methods section, test and adjust your model by applying it to the Methods section in Section 2.3.1, and then to the Methods sections in your target articles.

A method to analyse levels of dissolved CO_2 in pristine groundwater

Method

1 *The current investigation involved collecting and analysing groundwater samples from six wells in the Mahomet Aquifer region to determine levels* *of dissolved CO_2. **2** This region is in the Midwestern United States, and since groundwater in this area contains virtually no modern contaminants [11] wells in this area have been frequently used to interpret groundwater evolution [2, 3, 7].*

***3** A total of 18 3 mL samples were collected for analysis; three from each well. **4** Prior to collection, stagnant water was pumped out of the wells using a Grundfos® Redi-Flo II electric submersible pump. **5** pH levels were monitored during pumping using a pH meter (Sartorius AG, Professional Meter PP-50, Gottingen, Germany) until stable pH readings were obtained, at which point the samples were taken. **6** The samples were transferred to amber glass bottles, which were sealed tightly and then stored under refrigeration at 5°C to prevent contamination until they could be analysed. **7** Samples were shipped directly to two separate laboratories at Imperial College London, where the amount of dissolved organic carbon was measured using a revised version of the method established by the Illinois Sustainable Technology Center [12]. **8** This method uses a carbon analyser with a detection limit of 0.050 mg L−1, which ensured highly sensitive detection of carbon residues. **9** All filters used were glass or stainless steel, and although two samples were at risk of CFC contamination as a result of brief contact with plastic and other anthropogenic materials at the source location, variation among samples was negligible.*

In Sentence 1, the writer	
In Sentence 2, the writer	
In Sentence 3, the writer	
In Sentence 4, the writer	**provides details of what was done/used, and details of the sequence of events.**
In Sentence 5, the writer	
In Sentence 6, the writer	
In Sentence 7, the writer	
In Sentence 8, the writer	
In Sentence 9, the writer	

2.2.2 Key

In Sentence 1 *The current investigation involved collecting and analysing groundwater samples from six wells in the Mahomet Aquifer region to determine levels of dissolved CO_2.* **the writer provides an overview of the method, including the aim of the investigation** *(to determine levels of dissolved CO_2)* **and the source of the sample** *(six wells in the Mahomet Aquifer region)***.**

If you just wrote that the writer *introduces the method* here, that won't help you when you come to write your own research article, because it doesn't tell you how to 'introduce' the method.

Can I just begin by describing the method?

Yes. Some writers begin immediately by describing the method, or the materials, or the source of the materials. This is appropriate where the research focus and/or the journal readership is narrow and those who are likely to read the research article are familiar with this type of method. If this is not the case, it is more reader-friendly to start with some introductory material.

One way to introduce the method is to start with a general statement about what was done and/or used, and then break it down to produce the details. This is more reader-friendly than beginning with highly specific details which the reader must put together to construct a coherent understanding of the method. This is not the reader's job. In addition, if the reader begins 'bottom-up' with the details rather than 'top-down' with a general overview, each reader may construct a slightly different understanding of the method. Beginning with general statements about what was done/used (*In all cases/Most sites*), ensures that you and your reader share the same framework and makes it easy for you to create a logical narrative flow from one sentence to the next. Remember: show your reader the wall before you start to talk about the bricks!

Here are three common ways to introduce the Methods:

- Offer a general overview by outlining the parameters of the work, for example the number of tests, the materials/equipment and perhaps the purpose of the investigation.

- Provide information about the source of the materials/equipment or background information such as the properties, characteristics of the materials/equipment.
- Refer back to something in the previous section, such as the aim of the project or the problem you are addressing.

In Sentence 2 *This region is in the Midwestern United States, and since groundwater in this area contains virtually no modern contaminants [11] wells in this area have been frequently used to interpret groundwater evolution. [2, 3, 7].* **the writer provides background information** *(is in the Midwestern United States)* **and justifies his/her choice via factual information** *(contains virtually no modern contaminants)* **and references to other studies** *(have been frequently used)***.**

How much background information do I need to give?

Consider your readership in terms of the following two questions: What can ALL potential readers be assumed to know about this method in general? What do they ALL need to know in order to understand your specific method? In this case, given the journal readership and the potential stakeholders who may want to access this study, the writer has decided that s/he cannot assume that the reader knows where *the Mahomet Aquifer region* is located. The only way to make these decisions is to pay attention to this when you are reading — what do other writers do in your target research articles? How much background information do they provide?

Do I need to state the reasons for the choices I made? Isn't it obvious?

In Sentence 2, the writer justifies the choice of location via **factual information** and **reference to previous studies.** Your reasons are obvious to you, but they are not always obvious to readers. If you don't provide justification for your choices, the reader may wonder why you did things in a particular way, or why you used a particular procedure. This has a negative effect: if you don't explain why you made certain choices then readers may not accept your method, and this will eventually affect the way they evaluate your study.

Many writers believe that this section is just an impersonal description of what was done or used; in fact, there is a strong communicative element in the Methods section. In this description of your materials and methods, you need to communicate not only **This is exactly what I did/used** but also **I had good reasons for making those decisions.** As stated earlier, the reader needs information *about* the method, and providing your reasons enables the reader to understand and accept the choices you made.

For example, your notes might read: *An Ag wire was attached to the anode layer with Ag paste and the cathode layer was sealed with wax*, but in the Methods section that you submit to a journal, you might add: *An Ag wire was attached to the anode layer with Ag paste* ***in order to form an electrical contact****, and the cathode layer was sealed with wax* ***to keep it from being exposed*** *to* ***the plating bath***. You may have chosen a particular material because of its properties; if so, say what those properties are. You may have chosen specific equipment or software because of what it can do; if so, say what it can do.

In Sentence 3 *A total of 18 3 mL samples were collected for analysis; three from each well.* **the writer makes a general statement about the procedure that was used.**

If I provided a general overview at the start of this subsection, do I need to make another general statement about the procedure?

Not necessarily; consult your target articles. As mentioned earlier (Section 1.5.4), a paragraph in academic writing often starts with a paragraph-entry sentence, i.e. a sentence which presents the focus or topic of the paragraph. The general statement in Sentence 3 is a paragraph-entry sentence, and like the one at the start of the Methods section, enables the writer to move in a 'top-down' direction by establishing a general framework into which details can be slotted. These sentences often start with phrases like *Most of the tests* or *In all cases* (see the list in Section 2.4.2).

How do I decide whether to use mL or ml?

As always, check the use of abbreviations and symbols in current editions of your target journal or the SI (Système International d'Unités). Many journals recommend using *mL* rather than *ml* to avoid possible confusion between *1, l* and *L*.

In Sentences 4 and 5 *Prior to collection, stagnant water was pumped out of the wells using a Grundfos® Redi-Flo II electric submersible pump. pH levels were monitored during pumping using a pH meter (Sartorius AG, Professional Meter PP-50, Gottingen, Germany) until stable pH readings were obtained, at which point the samples were taken.* **the writer provides details of what was done/used, and details of the sequence of events** *(prior to, until, at which point)***.**

How much detail do I need to provide?

One of the challenges of producing a successful Methods section is the need to have '*a reasonably accurate idea about what specific other people know'*[7]. By the time you write up your research you have repeated your experiments or simulations many times, and you have become very familiar with the quantities, equipment and software, the sequence or steps in the procedure, and the time needed for each step. In addition, most of your daily interaction is likely to be with colleagues who have become equally familiar with your project. However, the readers of your paper are not your colleagues, and what you can assume that other people know depends on the readership of the journal you are aiming for. In addition, the tendency of researchers to access research and data via search engines means that your readership may — now or in the future — be wider and more interdisciplinary than you think. For these reasons, it is better to give slightly too much information than too little.

Can I just use simple words like 'then' and 'next' instead of detailed sequence language (prior to, until, at which point)?

then and **next** communicate the order of events, but they may not give the reader enough information about the sequence to replicate it exactly. For a list of useful sequence language see pages 104–106.

In Sentence 6 *The samples were transferred to amber glass bottles, which were sealed tightly and then stored under refrigeration at 5°C to prevent contamination until they could be analysed.* **the writer continues to describe what was done in detail, using language which communicates that care was taken** *(tightly)***, and providing justification** *(to prevent contamination until they could be analysed)***.**

In this sentence, the writer uses *tightly* to demonstrate that the work was carried out carefully. Your aim is not only to report your work and communicate your conclusions, it is also to encourage your reader to accept those conclusions. To this end, it is important to present yourself as a competent and careful researcher whose conclusions are therefore likely to be reliable.

In Sentence 7 *Samples were shipped directly to two separate laboratories at Imperial College London, where the amount of dissolved organic carbon was measured using a revised version of the method established by the Illinois Sustainable Technology Center [12].* **the writer provides more details of what was done/used, referring to and citing existing methods.**

Note the language used to demonstrate that the authors were competent and careful. They could simply have written: *Samples were shipped to two laboratories at Imperial College London*, but including the words *directly* and *separate* communicates that they were careful and that the study is, therefore, reliable.

Why provide citation references for existing methods, especially if they are well known?

In most cases, part of your own method comes from, or is based on, a method developed by another researcher. If that part of the method is well known and the appropriate citation reference is provided, you don't need to describe it in full but you may still need to provide an appropriate reference. You will find vocabulary and sentence patterns for this in Section 2.4.2, Option 1 (page 109).

Check current usage in your field by inputting the method into a search engine such as Google Scholar. As a method becomes more and more established, the citation occurs less frequently, and the method eventually becomes part of the background information as described in Section 1.2.2 (pages 9–10). Once that has happened, a citation reference becomes unnecessary.

But if that part of my method is available in the literature and I also include the citation reference, why should I describe that part of the method at all? Why can't readers just find the reference and read it for themselves?

Readers do not have time to waste and it is unprofessional to require them to look up a reference if the information is necessary to understand the paper they are reading. Writers therefore often describe the procedures, equipment or materials that they used even if they are well known and/or identical to those in existing methods. This can be done in the following way: *The assay was carried out as in [1]. Briefly, samples were…,* followed by a basic description.

It is common to describe existing or standard methods in the **Present Simple**: *"...dissolved organic carbon was measured using a revised version of the method established by the Illinois Sustainable Technology Center [12]. This method **uses** a carbon analyser with a detection limit of 0.050 mg L−1, which ensured…"*.

Note that in this case, the method used by the writer is <u>not</u> identical to the cited method (*using a **revised** version of the method established by the Illinois Sustainable Technology Center*). Comparisons between your materials and methods and those of other researchers in the same field are an important topic for the Methods section. Your method may be identical to others you mention **(Option 1** on page 109**)**, similar **(Option 2)**, or significantly different. When yours is significantly different to existing methods, the difference may represent the key contribution of your study **(Option 3)**.

These comparisons form part of a central feature of all STEMM research writing: mapping a study onto existing literature and knowledge in order to identify its contribution. The literature in the field is a thread that runs through a research article from beginning to end. Starting in the Introduction by setting out the research background to the study, the thread is picked up in the Methods and Results sections by comparing your methods and results with others, and eventually, in the Discussion/Conclusion section, by identifying the contribution your study has made to the existing knowledge and literature on the topic.

Remember that citation references do not automatically go at the end of a sentence (see page 11). In the Methods section, you need to be particularly careful about the location of your citation references or you may accidentally credit someone with work they have not done — perhaps even with your own work. This is a surprisingly common error.

In Sentence 8 *This method uses a carbon analyser with a detection limit of 0.050 mg L−1, which ensured highly sensitive detection of carbon residues.* **the writer provides more information about the procedures that were used, and justifies the choice made using language that specifies the advantage** *(ensured highly sensitive)***.**

Justification is common throughout this section; as before, the aim is to pre-empt possible criticisms of your choices, to assure the reader that you had good reasons for those choices, and/or to provide those reasons.

In Sentence 9 *All filters used were glass or stainless steel, and although two samples were at risk of CFC contamination as a result of brief contact with plastic and other anthropogenic materials at the source location, variation among samples was negligible.* **the writer mentions a possible difficulty or problem in the method.**

Why would I mention problems in the method? Won't it make me look bad?

When you look at your first set of results, you may realise that you could have achieved better results by adjusting your simulation parameters or changing the experimental conditions. Should you delay writing the paper while you repeat the work and improve your method? What happens if you learn more next time too; should you delay again while you repeat the work again? And again? In this scenario, you may never actually write it up. Science does not truly exist until it is published[8], and delaying publication until the project is perfect is neither realistic nor advisable. You need to stop at a certain point and write the paper, including your subsequent awareness of potential limitations or difficulties.

There are two good reasons for mentioning problems or limitations. First, it is common to end a research article with suggestions for future work, and these are often linked to problems or limitations that were noted in the study being reported. These suggestions encourage other researchers to respond and their work places your study in the continuum of research on the topic. However, it is not a good idea to mention those problems or limitations for the first time right at the end of the research article, as this may affect the reader's confidence in your work. It is more effective to mention them first where they occur — in this case, in the Methods section — and then refer to them again at the end of the article. It's easy to imagine what kind of sentence might occur at the end of the paper we are looking at: *Future studies should further reduce the risk of CFC contamination by removing plastic and other anthropogenic materials from the source location prior to collecting samples*.

The second reason is that if you don't mention difficulties or problems that occurred, it appears as though you are unaware of them. This gives a poor impression of your competence. If you ignore or try to hide imperfections (such as a data set which was too small, or equipment that was not ideal), the reader may doubt your legitimacy as a researcher. By contrast, mentioning them demonstrates a high level of self-awareness, thereby enhancing the reliability of the study.

But how can I talk about problems in my work without looking like a failure?

Conventionally, writers use language that minimises the problem and its effects, minimises your responsibility, maximises the good aspects and/or suggests a solution. In the example above, the writer acknowledged that there was a problem and minimised it (*brief contact/negligible*). You can find examples of the language to refer to problems and difficulties in a conventional, professional way in the language list on pages 111–112.

2.2.3 A Methods model

Here are the sentence descriptions we have collected:

In Sentence 1, the writer	provides an overview of the method, including the aim of the investigation and the source of the sample.
In Sentence 2, the writer	provides background information and justifies his/her choice via factual information and references to other studies.

In Sentence 3, the writer	makes a general statement about the procedure that was used.
In Sentences 4 and 5, the writer	provides details of what was done, and details of the sequence of events.
In Sentence 6, the writer	continues to describe what was done in detail, using language which communicates that care was taken, and providing justification.
In Sentence 7, the writer	provides more details of what was done/used, referring to and citing existing methods.
In Sentence 8, the writer	provides more information about the procedures that were used, and justifies the choice made using language that specifies the advantage.
In Sentence 9, the writer	mentions a possible difficulty or problem in the method.

We can streamline these so that our Methods model has SIX basic components. Unlike the Introduction model, in which most of the components are likely to be used, in the Methods section the model should be considered as a 'menu': select the items which are appropriate to your research topic and which reflect the norms in the journal you are submitting to. If you did not encounter any problems or issues, for example, you won't use the sixth component. In some cases, the Methods section also includes graphics such as figures, maps, photographs or tables, so this has been added to the model.

GENERIC METHODS MODEL	
1	PROVIDE AN OVERVIEW OF/STATEMENT ABOUT THE METHODS RESTATE THE AIM/GAP FROM THE INTRODUCTION DESCRIBE/GIVE THE SOURCE OF MATERIALS/EQUIPMENT USED
2	PROVIDE DETAILS OF THE MATERIALS/METHODS e.g. temperature, sequence • ± justify choices • ± indicate that you took appropriate care
3	DESCRIBE/DISCUSS THE CONTENT OF A FIGURE/TABLE
4	REFER TO MATERIALS/METHODS IN OTHER STUDIES • to compare • to justify your choices
5	PROVIDE BACKGROUND INFORMATION IN THE PRESENT SIMPLE TENSE • to support the reader • to justify your choices
6	INDICATE ISSUES OR PROBLEMS

2.3. Testing and Adjusting the Model

2.3.1 A demonstration of the model

Language that exemplifies these six model components is in **bold** type in the Methods section below.

Identification and characterisation of the early differentiating cells in neural differentiation of human embryonic stem cells[c]

Materials and methods

Flow cytometry analysis and cell sorting

Cells **were detached** into single cells by trypsin/EDTA, **incubated** with antibody **directly** (for surface antigens) or **following** fixation with 4% paraformaldehyde (for 15 min) and permeation with 100% ethanol (2 min) (for nuclear proteins). Cells **were analysed** using a BD FACSCalibur and CELLQUEST software. Fluorescence-activated cell sorting (FACS) **was carried out** with BD FACSAria II **after** staining live cells with antibodies against cell surface antigens. Magnetic-activated cell sorting **was performed with** Dynal magnetic beads (Invitrogen) **following the manufacturer's instructions**. **Briefly**, 25 ml (25 µl (1×10^7)) Dynabeads **were pre-coated** with 1 µg primary antibody by incubation at 4°C for 30 minutes in 1 ml buffer 1. Pre-coated beads were **then** incubated with cells (0.5 ml) at 4°C for 30 minutes with **gentle** tilting and rotation. 2 ml buffer 1 **was added** into the tube **to limit** trapping of unbound cells **before** placing the tube onto the magnet for 2 minutes. For negative selection, the supernatant, containing the unbound cells, **was transferred** to a **fresh** tube for further experiments. For positive isolation, the bead-bound cells **were gently washed** with buffer 1 and **collected** in **appropriate** solution/medium for further experiments.

Gene expression analysis by quantitative RT-PCR (qRTPCR)

Total RNA **was extracted** using TRI reagent solution (Sigma) following the manufacturer's instructions. Remaining traces of DNA **were removed** by DNase I treatment (Invitrogen). Reverse transcription and qPCR **were performed as described previously [45]**. RNA without reverse transcription **was used** as a negative control. The relative gene expression levels **were calculated** by calibrating their Ct values with those of housekeeping genes, HPRT and GAPDH, and **then normalized** to undifferentiated hESCs. The standard deviation **was calculated** from **at least** four qPCRs from three **independent** experiments.

2.3.2 EXERCISE 2a: Identifying the model components

Here are three Methods sections from research articles in different disciplines. They have been edited for length, and ellipses are marked as [...]. The words/phrases in **bold** type will help you identify the model components. Pay attention to the verb tenses, and think about why each verb is in that particular tense.

1 Influence of electrodes on the photon energy deposition in CVD-diamond dosimeters studied with the Monte Carlo code PENELOPE[j]

Materials and methods

The MC code system PENELOPE 2003 **(Salvat *et al*. 2003)** and the main program PENCYL **were used** to calculate the absorbed dose in the detector and surrounding water phantom. **In order to** minimize the time of the simulations, the geometry of the diamond layer and electrodes **was simplified** by adopting an infinite-slab geometry [...] **Since the present study focuses on** the metal/diamond/metal interface phenomena, the housing of the detector **was regarded** as water equivalent and **thus replaced** by water. The influence of metallic electrodes of different thicknesses on the absorbed dose to the diamond **was investigated**. Electrodes made of silver **were simulated** first. Silver **is** a common material because it **has** a high electrical conductivity, **forms** ohmic contact with diamond and the technology of its thermal deposition as well as contacting the detector with silver epoxy glue **is well established**. [...]

A **careful** selection of simulation parameters **was needed in order to** preserve accuracy while completing the calculations within reasonable CPU times. **In the course of** the simulations, each particle (a primary or secondary photon, electron or positron) **was transported until** its energy fell below the corresponding pre-selected absorption energy, E_{abs}; **when this happened,** its energy **was deposited** locally and simulation of the particle **was discontinued.** The mixed algorithm implemented in PENELOPE for the tracking of electrons and positrons **is governed** by specific simulation parameters, namely C_1, C_2, W_{cc} and W_{cr}, whose definitions and role **are explained at length in Salvat *et al.* (2003)**. **For the sake of brevity**, **here we** just **enumerate** them and **quote** the adopted values. [...]. **We found it convenient to use** different simulation parameters depending on the distance of the particles to the active layer and electrodes. **To this end**, **we considered** that the detector, where the most 'conservative' simulation parameters **were selected**, was surrounded by three 'shells' of water with successively increasing thickness and values of E_{abs}. [...]. **In this way**, charged particles which were far away from the detector and did not have sufficient energy to reach it were absorbed and no longer simulated. [...] **This procedure substantially reduced** the simulation time. In fact **this approach is equivalent to** the variance-reduction technique called range rejection, but **did not require** any changes in the main program and **could be implemented straightforwardly** through the input file.

2 The effect of particle size distribution on froth stability in flotation[k]

2. Methodology

2.1. Experimental system

The experimental system **is** a 4 L closed loop, continuously overflowing bench-scale flotation cell. The continuous recycle of concentrate as feed to the cell **allows for** steady state conditions to be established. The design of the cell **is based upon the standard mixing tank by Costes and Couderc [7]**.

The cell **is** cylindrical and **has** an internal diameter of 180 mm. It **is** of equal width and height, stirred by a six bladed Rushton impeller connected via a 2:1 rpm ratio stepped gearbox (**supplied by** Automation International Ltd) to the motor, supplied by Marelli Motori. Four baffles **are installed** to a height of 120 mm at 90° intervals. At the base **is** an air reservoir, separated from the cell by a frit (manufactured by Carbis Filtration Ltd), 110 mm in diameter and 1.3 mm in thickness, centred below the impeller. The frit **has** a mesh hole-size of 20 μm, fabricated from multiple sintered layers. Attached to the exterior of the cell **is** a launder, angled at 10° from back to front that **has** a width of 60 mm. The experimental system **is** shown in Fig. 1.

A single species system **is described in this paper**; **this can be used to** determine the effects of changing operating variables, for example air rate, into the flotation cell. Spherical silica ballotini for the experiments **were supplied by** Sigmund Lindner. Pre-sized distributions **were sourced** with ranges from 40–70 μm, 70–110 μm and 90–150 μm. Three particle sets **were created** by mixing the pre-sized material, obtaining the particle size distributions **presented in Fig. 2**. Representative diameters for the three particle sets **are shown in Table 1**, where **it can be seen that** particle set A **has** the coarsest particles and the broadest size distribution while particle set C **is** the finest of the three. **This allows** investigation into the effects of relatively small variation in particle size distribution on air recovery and flotation performance.

For each experiment, 900 g of ballotini **were used**. The ballotini **were initially prepared by** mixing with 2 L of 5×10^{-4} M sodium hydroxide solution, **based on a similar preparation procedure as set out by Ata *et al*. [3]**. **This was undertaken to** strip the ballotini surfaces of impurities. The ballotini **were washed with** deionized water and **then mixed with** 2.9 L of deionized water to form a slurry with a pulp pH of 7.9 in suspension. The collector, Tetradecyltrimethylammonium bromide (TTAB), **was added** at a concentration of 278.4 ppb. The slurry **was then allowed to** mix at 915 Hz for 30 min. Methyl isobutyl carbinol (MIBC) **was then added** at 352 ppm, and the slurry **allowed to** mix for a further 5 min.

Air rates for the experiments **were selected from** a range between 10 and 30 lpm (litres per minute) **as shown in Table 2**. This range **corresponds to** superficial gas velocities of 0.66–1.97 cm s^{-1}. A further 15 min of conditioning **was then allowed** with the froth overflowing **before** the first air rate **was selected**. **At this time**, dosing **started** with additional MIBC at a rate of 4.2 ml h^{-1} of 102 ppm MIBC solution **to maintain** froth stability. Froth depth (from cell lip to pulp-froth interface) **was maintained** at 7.5 cm by adjusting the recycle pump as required.

2.2. Measurement

For each air rate, 5 min of conditioning **was allowed, before** 5 min of on-line data collection. The height of the overflowing froth above the lip of the cell **was measured via** an on-line laser (0D1300, supplied by ifm electronic) and the data **recorded** through LabVIEW [24]. The velocity of the overflowing froth **was measured** using a camcorder (Panasonic Video NVGS37) through FrothTracker, a block-matching image analysis program **developed in-house**. The output values **were then used** to calculate air recovery using Eq. (1).

In order to sample the concentrate, a scoop **was fitted to** the lip of the flotation cell for 20 s **at the end** of each measurement period. The sample **was weighed**, and the mass of the solid and liquid phases **determined** by decanting the liquid into a measuring cylinder. The sample **was then returned** to the launder. **Only one** sample **was taken** for each air rate tested, **as** removing too much of the concentrate **leads** to a destabilisation of the experimental system.

3 Effect of muscle compensation on knee instability during ACL-deficient gait[l]

Methods

A three-step approach **was used to determine** the muscle forces needed to restore ATT in the ACLd knee. **First**, joint motion, ground-reaction forces, and muscle forces for normal walking **were obtained** from a forward dynamic simulation **(1)**. **Second**, these data **were input** into a model of the lower limb that included a detailed 3D model of the knee. A static equilibrium problem **was then solved** at 23 points of the gait cycle **to determine** ATT over the full gait cycle for both an intact and ACLd knee **(24, 25)**. **Third**, using the muscle forces obtained for normal gait as a baseline, two further static equilibrium problems **were solved** over the whole gait cycle **to determine the** quadriceps and hamstrings forces needed to restore ATT in the ACLd knee to first the intact level and then the maximum allowable level. Intact ATT **was defined** as the amount of ATT calculated for normal walking in the intact knee **(24)**.

Maximum allowable ATT **was defined** as the amount of ATT calculated for maximum isometric contractions of the quadriceps (i.e., maximum isometric knee extension) in the intact knee **(23)**. Maximum allowable ATT **was used** as the upper limit of knee instability **because some researchers have shown that** ACLd subjects often **perform** activities with ATT levels above those observed in the healthy knee **(10, 32)**. **Thus**, maximum allowable ATT **represents** the limit of ATT that a healthy knee might comfortably achieve **(33)**. Maximum allowable ATT **was calculated** with the lower extremity model (see below) by simulating a seated maximum isometric knee extension. In these simulations, the model knee **was placed** at joint angles corresponding to those found in walking, the quadriceps muscles **were** maximally **activated**, and a constraint **was applied** at the level of the ankle **to prevent** the knee from extending **(23)**.

A 3D model of the body **was used** to determine lower limb muscle forces during normal walking. The skeleton **was modeled** as a 10-segment, 23-*df* articulated chain. Each hip **was represented** as a 3-*df* ideal ball-and-socket joint, each knee as a 1-*df* hinge joint, each ankle as a 2-*df* universal joint, and each metatarsal joint as a 1-*df* hinge (1). The model **was actuated** by 54 musculotendinous units, each unit **represented** as a three-element muscle in series with tendon. The dynamic optimization problem **was** to find the muscle excitation histories, muscle forces, and body motions subject to minimum metabolic energy consumed per unit of distance moved. The joint angles, ground reaction forces, and muscle activation patterns obtained from the simulation **were similar to** the same measures obtained from healthy subjects who walked at their preferred speeds **(1, 2)**. Details concerning the walking model and dynamic optimization solution obtained for normal gait **are reported by Anderson and Pandy (1, 2)**.

Anterior tibial translation of the intact and ACLd knee **was calculated** using another model of the lower limb that included a **detailed** 3D model of the knee (the lower-limb model). Five segments **were used** to represent the lower limb in this model: thigh, shank, patella, hindfoot, and toes. These segments **were connected** together by five joints: hip, tibiofemoral joint, patellofemoral joint, ankle, and metatarsal joint (Fig. 1). The hip, ankle, and metatarsal joints **were represented** in **exactly the same** way as in the walking model. At the knee, six generalized coordinates **described** the movements of the tibia relative to the femur, and another six coordinates described the movements of the patella relative to the femur. **A complete description of the model can be found in Shelburne *et al*. (24)**.

The geometry of the distal femur, proximal tibia, and patella **was based on** parasagittal sections of the bones obtained from 23 cadaveric knees. The contacting surfaces of the femur and tibia **were modeled** as deformable **(19)**. The model of patellofemoral mechanics **was based on** the assumptions that the patellar tendon was inextensible and that interpenetration between the facets of the patella and the patellar surfaces of the femur can be neglected. The geometry of the cruciate and collateral ligaments, posterior capsule, and anterolateral structures of the knee **was modeled** using 13 elastic elements (Fig. 1B). Thirteen muscles **were represented** in the lower-limb model (Fig. 1A). The paths of all muscles, except vasti, hamstrings, and gastrocnemius, **were identical with** those incorporated in the walking model. Whereas vasti, hamstrings, and gastrocnemius **were each represented as** one muscle in the walking model, the separate portions of each of these muscles **were included** in the lower-limb model (18, 19).

The relative positions of the femur, tibia, and patella in the intact knee **were found** by assuming the lower limb was in static equilibrium at each instant during the simulated gait cycle; **thus**, the inertial contributions of the shank, patella, hindfoot, and toe segments **were neglected** in these calculations. Specifically, muscle forces, ground reaction forces, joint angles of the hip, ankle, and metatarsals, and the flexion-extension angle of the knee obtained from the walking simulation **were used** as inputs to the model. The unknown translations and rotations of the bones at the knee **were found** by performing a forward integration of the equations of motion at each time step of the walking simulation **until** the accelerations and velocities of all the joints approached zero **(24)**. These calculations **were repeated** with the ACL removed from the model **to estimate** the amount of ATT during ACLd gait **(25)**.

Four simulations of ACL-deficient walking **were performed**. The model of the lower limb **was used** for these calculations. In each simulation a static equilibrium problem **was solved** at 23 points of the gait cycle (**as described above** for the intact and ACL-deficient knee) subject to the following conditions. In the first two simulations, quadriceps force **was decreased to determine** whether this change alone could reduce ATT in the ACLd knee first to the amount calculated for the intact knee (intact ATT; simulation 1), and second, to the amount calculated for maximum isometric knee extension (maximum allowable ATT; simulation 2). In each of these simulations, quadriceps force **was decreased** by decreasing the force in each of the three vasti (medialis, intermedius, and lateralis) as a percentage of its peak isometric strength. The forces in all three muscles **were decreased** by the same percentage each time. The output of simulations 1 and 2 were a decrease in quadriceps force and the resultant change in extensor moment. In the next two simulations, hamstrings force **was increased to determine whether this change alone** could restore ATT in the ACLd knee first to the amount calculated for the intact knee (simulation 3), and second, to the amount calculated for maximum isometric knee extension (simulation 4). In each of these simulations, hamstrings force **was increased** by increasing the force in each of three hamstrings (biceps femoris long head, semimembranosus, and semitendinosus) as a percentage of its peak isometric strength. The forces in all three muscles **were increased** by the same percentage each time. **Experimental evidence suggests that** a hamstrings facilitation strategy **is characterized by** increased activity of both the medial and lateral hamstring muscles **(14)**. […]

2.3.3 EXERCISE 2b: Identifying the model components

Here is another extract from a Methods section. This time, identify the model components yourself.

Pore-scale contact angle measurements at reservoir conditions using X-ray microtomography[m]

2. Method

2.3. Image processing

After acquisition the images were filtered using a non-local means edge preserving filter [30,31]. They were then corrected for any beam hardening or softening artefacts created during image reconstruction by modelling these artefacts as radially symmetric Gaussian functions. The centre of this function was allowed to take any point in the x and y dimensions, but was assumed to be uniform in the z direction. As segmentation of images containing a partial saturation of multiple fluids is significantly more difficult than the segmentation of dry images [32], the use of simple grey-scale segmentation was insufficient. Instead a seeded watershed algorithm was used, with the seed generated by the use of a 2D histogram [33]. This segmented image was then analysed in 3D to identify each unique disconnected ganglion, which was then labelled.

A subvolume was then extracted around each unique ganglion and resegmented using the same 2D histogram-based watershed method detailed above, as the beam hardening and softening correction may not remove all lateral variations in grey-scale value across the image. Local segmentation was therefore likely to be more accurate than the primary global segmentation.

The edges of each phase were found on this new segmented image using a 3D Sobel filter [13]. The intersection of the edges of all three phases ($scCO_2$, brine and solid) was labelled as the contact line which could be traced in 3D. Finally a bilinear filter was applied to the resampled slice to eliminate possible angular quantisation due to the voxelized nature of the image. The contact angle was then measured by resampling the data onto a plane with a normal parallel to the contact line at a specific point (Fig. 2). The measurement was taken according to the best interpretation of the tangential direction of the relevant surfaces at the contact line and no effort to “smooth” the surfaces was made. This can be seen in Fig. 3F, where the tangential direction on the grain surface at the contact point is seen to be at a significant angle to the larger scale attitude of the grain surface. The resulting variation in contact angle was reported as part of the distribution shown in Fig. 4.

Contact angles were measured manually on the unsegmented data by tracing two vectors tangential to the $scCO_2$–brine interface and the rock surface. The angle between these lines was then measured through the non-wetting phase with a 3D angle measurement tool (Fig. 3). Measurements were performed at 300 points randomly selected along the $scCO_2$–brine–rock contact lines of different ganglia. The contact angle was not measured on the segmented data, as the angle measured was highly sensitive to the detail of segmentation close to the contact line, where we would expect the segmentation to be least accurate. In contrast, tracing the interface between the $scCO_2$ and the brine visually was relatively simple, making angle measurement more accurate and robust. All image processing was conducted within the Avizo Fire 8.0 (Visual Sciences Group, www.vsg3d.com) and imageJ programs.

EXERCISE 3 Analyse and model the Methods sections in your target research articles. Instead of reading for content, pay attention to how that content is delivered. You will start to see the scaffold that holds the information, and this will develop into a lifelong reading and writing tool that updates automatically every time you read a review article or a research paper.

2.4. Useful Words and Phrases

2.4.1 Language task

EXERCISE 4 Look through the Methods sections in this Unit and in your target research articles. Underline or highlight all the words or phrases that you think could be used in the four areas below, and then compare your suggestions with the words and phrases listed in Section 2.4.2. For example:

1 DESCRIBE/GIVE THE SOURCE OF MATERIALS/EQUIPMENT USED
Look for words and phrases such as *were obtained from.*

2 PROVIDE DETAILS ABOUT MATERIALS AND METHODS
± JUSTIFICATION
± INDICATE THAT YOU TOOK APPROPRIATE CARE
Look for verbs that communicate what the writers did, such as *design, formulate, install, measure, transfer.*
Look for language that describes sequences accurately, such as *prior to, subsequently, at that point.*
Look for language that communicates reasons for choices or advantages of choices, such as *in order to, with the aim of, accurate, to ensure.*
Look for language that communicates that care was taken, such as *gently, precisely, immediately.*

3 COMPARE WITH MATERIALS/METHODS IN OTHER STUDIES
Look for language that communicates the similarities or differences between your method and other methods, for example: *adapted from, similar to, instead of.*

4 INDICATE ISSUES OR PROBLEMS
Look for language such as *slightly problematic, unavoidable, challenging.*

2.4.2 Language for the Methods section

This section lists words and phrases for the Methods section from analysis of over 2,500 published research articles in different disciplines. The list only includes words and phrases which appear frequently and are therefore considered normal and acceptable by writers and editors.

The list will also keep the flow of writing moving. Underneath each list there are examples of how the words and phrases are used in sentences, so look at the sentence examples as well as the list when you are feeling stuck and can't think of what to write or how to continue.

GIVE THE SOURCE OF THE MATERIALS/SAMPLES/EQUIPMENT USED

is commercially available	was collected	was performed (by/in)
was a kind gift (from)	was devised	was provided (by)
was acquired	was/were found (in)	was purchased (from)
was carried out	was generated	was supplied (by)
was chosen	was modified	was used as received
was conducted	was obtained	was used as supplied

Here are some examples of how these are used:

- **A three-step approach was used** to determine the muscle force.
- The extracts **were obtained by using** two different methods.
- The fetal bovine serum used in this study **was provided by** Gibco, UK.
- Dextran standard 5000 **was purchased from** Sigma Aldrich.
- A laboratory-scale fixed-bed reactor **was used in this study**.
- The cell lines **were a kind gift from** Dr David Louis (Massachusetts General Hospital, MA, USA).
- The inclusion criteria used here are **a modified version of** those in a previous study[22].
- **All** volumetric lung images **were acquired from** healthy asthmatic subjects.
- **In the majority of the tests,** the chickens were kept in a temperature test chamber.

SUPPLY ESSENTIAL BACKGROUND INFORMATION and/or DESCRIBE MATERIALS/SAMPLES/EQUIPMENT USED

You may need to give a detailed description of the equipment/apparatus or instrument you used or constructed, or describe a photograph or diagram so that the reader can visualise it. To do this accurately, you need a range of language to describe spatial relationships, positions and locations, such as:

<table>
<tr><td>above</td><td>over</td><td>on top (of)</td><td rowspan="20">Verbs

align
arrange
assemble
attach to
bisect
connect
converge
couple
embed
encase
enclose
fasten
fit
fix
install
intersect
join
locate
mount
orient
place
position
situate
space
surround</td></tr>
<tr><td>adjacent</td><td>adjoining</td><td></td></tr>
<tr><td>across</td><td>along</td><td>against</td></tr>
<tr><td>at the front</td><td>on the front</td><td>in the front</td></tr>
<tr><td>below</td><td>under</td><td>underneath</td></tr>
<tr><td>beside</td><td>alongside</td><td></td></tr>
<tr><td>boundary</td><td>edge</td><td>border</td></tr>
<tr><td>circular</td><td>rectangular</td><td>conical</td></tr>
<tr><td>downstream</td><td>upstream (of)</td><td></td></tr>
<tr><td>equidistant</td><td>equally spaced</td><td></td></tr>
<tr><td>exterior</td><td>interior</td><td></td></tr>
<tr><td>in the vicinity</td><td>in close proximity</td><td>nearby</td></tr>
<tr><td>inside</td><td>within</td><td></td></tr>
<tr><td>lateral</td><td>sideways</td><td>horizontal</td></tr>
<tr><td>on each side</td><td>on either side</td><td>on both sides</td></tr>
<tr><td>on the right/left</td><td>to the right/left</td><td></td></tr>
<tr><td>opposite</td><td>facing</td><td></td></tr>
<tr><td>out of range</td><td>within range</td><td></td></tr>
<tr><td>parallel (to/with)</td><td>perpendicular (to)</td><td></td></tr>
<tr><td>symmetrical</td><td>asymmetrical</td><td></td></tr>
</table>

Here are some examples of how these are used:

- In the experiment, source and detector **were positioned** on opposite sides.
- The apparatus consists of **a circular tube fitted with** rectangular-winglet tape (RWT) vortex generators.
- The compression axis **is aligned with** the rolling direction…

- The source light is polarised **horizontally** and the sample beam can be scanned **laterally**.
- The microtubules that **were embedded in** collagen gel were **oriented perpendicular to** the direction of the magnetic field.
- Measuring stations **were spaced** 20 cm apart, starting 2 cm **downstream of** the pipe entrance.
- A scanner **was mounted on top of a** metal structure, while pots were placed **underneath, over** a cart moving at constant speed **in the direction perpendicular to** the line of acquisition.

In which sentence/s below was the table placed closest to the wall?

The table was placed	against the wall.
The table was placed	alongside the wall.
The table was placed	beside the wall.
The table was placed	flush with the wall.
The table was placed	in contact with the wall.
The table was placed	next to the wall.
The table was placed	right against the wall.

In which sentence/s below was the clock positioned closest to the door?

The clock was positioned	just above the door.
The clock was positioned	slightly above the door.
The clock was positioned	immediately above the door.
The clock was positioned	directly above the door.
The clock was positioned	right above the door.

LANGUAGE TO PROVIDE SPECIFIC AND PRECISE DETAILS OF MATERIALS AND METHODS

(i) VERBS

Verbs in the Methods section fall into three categories. The first contains general academic research verbs such as *attempt, consider, conduct, determine, investigate, report, verify*. These can be found in Appendix B: Research Verbs. The second category contains verbs which are highly specific to a particular discipline, for example *anneal, clone, dissect, ionise, infuse.* These are not included in the list because they are not useful in other disciplines. The list below contains examples of the third category: technical verbs used in a wide range of disciplines to specify what was done or used.

was adapted	was divided	was operated
was added	was eliminated	was optimised
was administered	was employed	was performed
was adopted	was estimated	was placed
was adjusted	was evaluated	was plotted
was altered	was examined	was positioned
was analysed	was excluded	was prepared
was applied	was exposed	was processed
was arranged	was extracted	was produced
was assembled	was fabricated	was quantified
was assessed	was filtered	was recorded
was assumed	was formulated	was recovered
was attached	was generated	was regulated
was calculated	was immersed	was removed
was calibrated	was implemented	was repeated
was carried out	was included	was represented
was characterised	was incorporated	was restricted
was collected	was initiated	was retained
was combined	was input	was retrieved
was compared	was inserted	was sampled
was computed	was installed	was scored
was conducted	was inverted	was selected
was connected	was isolated	was separated
was constructed	was located	was simulated
was controlled	was maintained	was solved
was converted	was maximised	was stabilised
was created	was measured	was substituted
was defined	was minimised	was synthesised
was derived	was modelled	was tracked
was designed	was modified	was transferred
was determined	was monitored	was treated
was discarded	was normalised	was varied
was distributed	was obtained	was utilised

(ii) SEQUENCE LANGUAGE

A precise description of the timing and order of each step in a procedure is essential to enable readers and peer reviewers to visualise it and, if they want, to repeat the procedure and compare their results with yours. Words like *then* or *next* describe the order of events, but they don't provide information about how long each step took or how soon the next step occurred. To do this you need a more precise sequence vocabulary. This sequence language is equally important when describing the results.

The words and phrases that communicate sequence in STEMM writing can be divided into eight groups, as follows:

Group 1 contains words/phrases referring to events that occurred before beginning the experiment/simulation, or before you began observing your results:
It was apparent beforehand that a reduction in temperature would be a desirable outcome.

Group 2 marks the beginning of the experiment/simulation, or the first step/result you are describing:
At the beginning the temperature was stable, as predicted.

Group 3 contains words/phrases which tell you the order in which events occurred, but don't give information about the timing of the sequence:
The temperature was increased to 49°C and then reduced to 30°C.
The drop in temperature may have occurred soon after the temperature reached 49°C or it may have occurred a long time after; the word *then* only tells the reader the order of events.

Group 4 is used to communicate that there was (only) a short period of time between two events, or that an event occurred after a short waiting period:
The temperature increased to 49°C but soon dropped to 30°C.

Group 5 communicates that the period of time between the events was long, or that the event being described occurred near the end of the sequence:
The temperature was increased to 49°C and later reduced to 30°C.

Group 6 is extremely useful and important. It contains words and phrases which communicate that two or more events occurred at the same time/during the same period, or that one event began at exactly the same moment

as another ended, i.e. that the two events interfaced. Items in this group are sometimes used to communicate a possible causal relationship or a correlation between the events:
The temperature dropped sharply when we reduced the pressure.

Group 7 marks the end of a sequence:
At the end there was a noticeable drop in temperature.

Group 8 refers to events that occurred after you finished your experiment/simulation or after you finished observing the results:
At the end there was a noticeable drop in temperature but it was decided afterwards to omit this from the input data.

Put each word/phrase below in the correct group.

after	earlier	in time	secondly
afterwards	eventually	initially	shortly after
as	finally	instantly	simultaneously
as soon as	firstly	lastly	soon
at once	followed by	later	straight away
at first	following	later on	subsequently
at that point	formerly	meanwhile	then
at the beginning	immediately	next	to begin with
at the end	in advance	once	to start with
at the same time	in due course	originally	towards the end
at the start	in the beginning	previously	until
beforehand	in the end	prior to	when
directly	in the meantime	quickly	while

KEY

Group 1: *before the beginning*

beforehand	formerly	originally	prior to
earlier	in advance	previously	initially

Group 2: *at the beginning/first step*

at first	at the start	in the beginning	to begin with
at the beginning	firstly	initially	to start with

***Group 3:** steps/order*

after afterwards earlier	followed by following formerly	next previously prior to	secondly (etc.) subsequently then

***Group 4:** after a short while*

quickly	shortly after	soon

***Group 5:** at a late or later stage; after a while/ longer waiting period*

eventually in due course	in time later later on	subsequently towards the end

***Group 6:** one point/period occurring almost or exactly at the same time as another*

as as soon as at once at that point at the same time directly	immediately instantly in the meantime meanwhile once	simultaneously straight away until when while

***Group 7:** at the end/last step*

at the end eventually	finally in the end lastly

***Group 8:** after the end*

afterwards eventually	later later on subsequently

JUSTIFY CHOICES

This includes phrases that introduce the reasons for the methodological or procedural choices you made, such as *in order to*, and a list of 'happy' words and verbs that communicate the advantage/s of those choices.

by doing..., we were able to chosen for/to designed for/to for brevity for convenience for maximum effect for (the sake of) simplicity for the following reasons: in an attempt to in order to offer a means of our aim was to provide a way of/to selected on the basis of so as to so/such that the advantage of the reason for thereby thus to take advantage of to this end which/this allowed which/this permitted which meant that with the aim of	**'happy' words** ☺ accurate consistent direct easy excellent important precise relevant robust satisfactory simple suitable useful **CAUSE and RESULT signalling connectors** (See pages 59–60)	**Verbs** achieve allow avoid compensate (for) confirm determine enable enhance ensure establish facilitate guarantee improve include increase limit minimise obtain overcome permit prevent provide reduce remove simplify validate

Here are some examples of how these are used:

- **For brevity**, these equations are not included in this paper.
- **To** make the problem tractable, we reduced the number of possible scenarios.
- Zinc oxide was drawn into the laminate **with the intention of enhancing** delaminations and cracks.
- A highly conductive filler is added to the matrix **in order to ensure** electrical conductivity above the required level.

- **The advantage of** using three-dimensional analysis was that the out-of-plane stress field could be obtained.
- By partitioning the array, **we were able to** identify all the multipaths.
- **For simplicity**, only a single value was analysed.
- The samples were dried before being weighed**, so allowing** accurate calculation of the ratio of soil to stones.
- **For verification purposes**, tests were repeated for 9 different combinations of temperature and strain rate.
- The survey was administered during the spring, **which avoided problems of** low activity during the summer months.
- Our control drug was given to all patients, **therefore we were able to** separate the effects of increased pH from other factors.

INDICATE THAT APPROPRIATE CARE WAS TAKEN

Most of the items in the box below are in adverb form (*accurately*), but they can also occur in adjective form (*accurate*).

accurately	entirely	immediately	rigorously
always	every/each	independently	separately
appropriately	exactly	individually	smoothly
at least	firmly	never	strictly
both/all	frequently	only	successfully
carefully	freshly	precisely	suitably
completely	fully	randomly	tightly
constantly	gently	rapidly	thoroughly
correctly	good	reliably	uniformly
directly	identical	repeatedly	vigorously

Here are some examples of how these are used:

- Care was taken to maintain **strict** anaerobic conditions during extract preparation.
- These cells were then washed **thoroughly at least** three times.
- To prevent an emulsion from forming, only **gentle, repeated** inversion was used.
- The specimen was monitored **constantly** for 24 hours.

- **Frequent** readings were taken to update the stress conditions **smoothly**.
- The specimen was **tightly** clamped at two corners to minimize any unexpected gaps.
- After irradiation, the reaction mixture **was carefully** condensed.
- 6 **pristine** specimens **were handpicked** under a microscope.
- We used a **reliable** analytical method based on high-performance liquid chromatography.

COMPARE WITH or REFER TO MATERIALS/METHODS IN OTHER STUDIES

Option 1: The material/method you used is **exactly the same** as the one you cite.

according to as described by/in* as detailed by/in as explained by/in as in as proposed by/in	as reported by/in as reported previously as suggested by/in can be found in described elsewhere details are given in following x *et al*.	given by/in identical to in accordance with previously shown in/by the same as that of*/in using the method of/in

Note*: **by and **of** are usually followed by the name of the researcher or research team (*as described by Ross* or *using the method of Ross et al.*) whereas **in** is usually followed by the work (*as described in Ross et al. [2020]).*

Another way to do this is simply to provide the relevant research reference at the appropriate place in the sentence: *We used the Shapiro-Wilk test*[11] *to determine whether a given sample was from a normal population.*

Option 2: The material/method you used is **similar to** the one you cite.

a (modified) version of adapted from almost the same as based on essentially identical essentially the same except for/that	largely the same more or less identical partly based on practically the same similar (to) slightly modified virtually the same	(to) adapt (to) adjust (to) alter (to) change (to) modify (to) refine (to) resemble

following x *et al.* in essence in line with in principle	with some adjustments with some alterations with some changes with some modifications	(to) revise (to) vary

Option 3: The material/method you used is **significantly different from** the one you cite.

a novel step was… adapted from although in many ways similar although in some ways similar although similar to based on except for/that instead (of) loosely based on partly based on unlike with the following modifications:	**CONTRAST signalling connectors, e.g.:** however whereas by contrast	(to) adapt (to) adjust (to) alter (to) change (to) modify (to) refine (to) resemble (to) revise (to) vary

Note: As you see, most of these can be used in Option 2 as well as Option 3. When you use them in Option 2 you may not need to state the differences between the procedure/material you used and the one you cite. In Option 3 those differences are significant and you should say exactly what they were, **particularly if they improved the method**.

Here are some examples of how these are used:

- The method was **essentially the same as** that previously described elsewhere[5] for use in *X. tropicalis*.
- **We follow** Sobral *et al*. (2013) and apply one magnitude of dust extinction to all of our HAEs.
- The analytical method **was adapted from** British Pharmacopeia[7].
- The method used was **identical to** that previously reported in ref. 17.
- Activated calf thymus DNA was prepared **as decribed by** Pedrali-Noy and Weissbach (17).
- We **modified** the Du and Parker filter to address these shortcomings and we refer to this modified filter as the MaxCurve filter.

- Data were collected using **a revised version** of the Portrait Values Questionnaire (9).
- However, **in this study**, **instead of using** a coil around the membrane cell, we placed the coil on top of the cell.

INDICATE WHERE PROBLEMS OCCURRED

minimise problem ***(no big deal)***	**minimise responsibility** ***(not my fault)***	**maximise good aspects**
did not align precisely	as far as possible	acceptable
immaterial	impossible	fairly well
it is recognised that	impractical	quite good
less than ideal	inevitably	reasonably robust
minimal	(it was) difficult to	
minor deficit	(it was) hard to	
negligible	limited by	
not identical	necessarily	**refer to a possible**
not perfect	not possible	**solution:**
not significant	problematic	Future work should…*
only approximate	unavoidable	Future work will…*
rather time-consuming	unworkable	
slightly disappointing		
slightly problematic		
unimportant		
(very) small		

**Note*: There is an important difference between *future work should* and *future work will*. *Future work should* suggests a direction for future work, and invites the research community to take up the challenge and produce the research, whereas *future work will* communicates the writer's own plans, intentions or work currently underway.

Here are some examples of how these are used:

- Despite our routine of monthly examinations, follow-up **was not perfect**.
- It **was slightly difficult to** deposit a uniform film of the liquid, probably owing to its low viscosity.

- Although some duplication **was unavoidable**, this was **minimized by** the frequent use of cross references.
- The probability is **very small**, and hence we believe such contaminants have **only a negligible effect on** this study.
- Varying the diameter required the machine to be recalibrated, which **was rather time-consuming**.
- Although centrifugation did not remove all the excess solid drug, the amount remaining was **negligible**.
- Due to the lack of multiwavelength data it was **not possible** to apply additional broad-band selections.
- **Inevitably**, considerable computation was involved.
- This procedure **was slightly problematic** in that the program reported successful setup even if a nonexistent file was specified.

2.5. Language and Writing Skills

This section deals with three language areas which are important in the Methods section:

OWNERSHIP: VERB TENSE AND THE AGENTLESS PASSIVE
PREPOSITIONS
USING **A** AND **THE**

2.5.1 Verb tense and the agentless passive

Before you write the Methods section, look at your target articles and the Guide for Authors in your target journal to find out whether it is written mainly in the passive or the active. Although active verbs (*we investigated/ we conclude*) are common in research writing, some processes may still normally be expressed in the passive in the Methods section.

Science writers generally use an agentless passive verb (*was/is found*), rather than passive + agent (*was/is found* ***by us***), so in most cases those who actually performed the verb are not mentioned. This creates a high risk of ambiguity because the agentless passive looks identical whether it is describing your own work (*samples were collected using a sterile swab*) or the work of another researcher (*samples were collected using a sterile swab*). This type of ambiguity is highly detrimental to the success of your research paper as it risks you losing ownership of your contribution and unknowingly crediting another researcher with all or part of your work.

A second potential ambiguity comes from the use of verb tense in the Methods section. The Past Simple tense is usually used to report what you did, whereas the Present Simple tense is used to describe standard procedures or equipment. A mistake in verb tense in the passive may therefore change the meaning of the information; for example, your own work may become confused with a standard procedure you are describing:

Reporting what you did (Past Simple agentless passive):
A flexible section ***was*** *inserted in the pipe.*

Describing a standard procedure (Present Simple agentless passive):
A flexible section ***is*** *inserted in the pipe.*

It is essential to meticulously detect and resolve this type of ambiguity. If not, it will be difficult or impossible for the reader or reviewer to work out when you are referring to your own work and when you are referring to the work of other researchers or to standard procedures. This is highly detrimental to the success of your research paper. Unfortunately, your familiarity with the project makes it harder to see where there might be ambiguity: the meaning of what you have written always seems obvious to you, but that doesn't mean that it is obvious to the reader.

Remember that one of the key messages at the start of the book was that **THE AIM IS NOT SIMPLY TO MAKE IT POSSIBLE FOR THE READER TO UNDERSTAND; THE AIM IS TO MAKE IT IMPOSSIBLE FOR THE READER NOT TO UNDERSTAND**. One way to make sure that your own contribution is clear and easy to identify is by marking it with language like *In this study*. Here are five possible uses of the agentless passive that you might need in the Methods section, and suggestions for ways to make your meaning clear:

	What do you mean?	How can you make it clear?
1	X was (collected/ modified) **by me in the procedure or work that I carried out**.	• Move to the active: *We collected/ modified X*. • Add words or phrases such as *here/in this work/in our model.* • Use a 'dummy' grammatical subject such as *This experiment/The procedure described above.*
2	X was (collected/ modified) **by the person whose procedure or work I am using as a basis for mine or comparing with mine**.	• Give a citation reference. • Add words/phrases such as *in their work/ in that model.* • Use a 'dummy' grammatical subject such as *That experiment/The probe used in their study.*
3	X is (collected/ modified) **normally, i.e. as part of an established or standard procedure**.	• You may need a citation reference even if it is a standard procedure, depending on how well known the procedure is. • Use phrases such as *using standard procedures/as in [5].*

4	X is (collected/ modified) **as you can see in Fig. 1, and it was collected/ modified by me**.	• Explicitly identify the content of the Figure as your own work: *The experimental setup used here is shown in Fig. 3.* • Move to the active: *We collect/modify X.*
5	X was (collected/ modified) **by me, but in my field/this journal the Present Simple tense is used**.	• Move to the active: *We collect/modify X.* • Add words or phrases such as *here/in this work/in our model.* • Use a 'dummy' subject such as *This equation/The model.*

Owning your own work and separating it from existing work is of paramount importance. When you have finished writing your Methods section, check **every single sentence** to ensure that the verb is in the right tense, i.e. that it is communicating the function/meaning you want, and that you are not simply assuming that it will be obvious to the reader.

2.5.2 Prepositions

Prepositions have an impact on meaning. *Evidence of* something is a measurable sign that it is there or that it exists, whereas *evidence for* something is a sign that it might be there, or that it might exist. Some verbs depend entirely on the preposition for their meaning: *X was substituted* ***for*** *Y* means that *X replaced Y*, whereas *X was substituted* ***with*** *Y* means that *Y replaced X*.

Even if English is your first language, you are writing for a global audience, some of whom may have difficulty understanding preposition meanings, so it pays to be careful. Here are FIVE useful strategies for improving your preposition use:

1 Start by paying more attention to prepositions

How many of the following prepositions: *of for with on in through at over from about* can you find in these edited extracts? The answer is given in brackets after each extract.

- A helium-neon laser beam, having a wavelength of 633 nm, was directed onto the sample, through a chopping wheel, at an angle 59° from the normal. The specularly reflected beam was absorbed onto a black card, and the scattered light was collected at normal incidence to the sample using an X10 microscope objective. *(8)*

- The solutions were placed in the refluxing bath immediately after mixing, and the temperature of the bath was increased to 70°C in 15 min and kept there for 2 h. The solutions were then aged for 24 h at room temperature, before being diluted with an equal volume of EtOH and stirred for 10 min, to give the solution used for spin coating. *(11)*
- The film is placed in a sealed chamber on the sample stage of the ellipsometer; first dry N2 gas is passed through the chamber to empty the pores, and after N2 has been bubbled through, the liquid adsorbate is passed over the sample to fill the pores. By assuming that all the accessible pores are completely empty or filled with adsorbate, the pore volume and index of the solid skeleton can be determined. Measurement of *nf* for both the dry and saturated films allows both *vp* and *ns* to be determined with the assumption that *np* has the same value as that of the bulk adsorbate in the saturated case, and of air (*np = 1*) in the dry case. *(15)*
- The IR camera that we used in the setup is a Raytheon Radiance HS, and operates in the 3–5 μm spectral region. It is sensitive (with a 1 ms integration time) to surface temperature changes of ~0.03°C, and can be operated at full frame rates of 140 Hz with that sensitivity. We have also observed the effects reported here with a microbolometer focal plane array camera, operating in the long wavelength of the IR. *(11)*
- Hexagonally packed intermediate (HPI) layer from Deinococcus radiodurans, a kind gift of Dr. W. Baumeister, was extracted from whole cells (strain SARK) with lithium dodecyl sulfate, and purified on a Percoll density gradient. A stock solution (1 mg/ml protein) was stored in distilled water at 4°C. Porin OmpF trimers from E. coli strain BZ 1 10/PMY222 (Hoenger *et al*., 1993) solubilized in octyl-polyoxyethylene were mixed with solubilised dimyristoyl phosphatidylcholine (Sigma Chemical Co., St. Louis, MO) at a ratio (w/w) of 0.2 and a protein concentration of 1 mg/ml. 1,2-Dipalmitoyl-phosphatidylethanolamine (DPPE) from Sigma was solubilized in chloroform:hexane (1:1) to a concentration of 1 mg/ml. The resulting solution was diluted in buffer solution (150 mM KCl, 10 mM Tris, pH 8.4) to a concentration of 100 μg/ml. *(20)*

2 Pay attention to the verb + preposition clusters used to describe processes in your target research articles

Here is an edited extract from the Methods section on pages 90–91. Some of the prepositions are obvious, others less so. Would you have chosen these prepositions?

Materials and methods

The MC code system PENELOPE 2003 (Salvat et al. 2003) and the main program PENCYL were used to calculate the absorbed dose **in** the detector and surrounding water phantom. In order to minimize the time **of** the simulations, the geometry **of** the diamond layer and electrodes was simplified **by** adopting an infinite-slab geometry […] Since the present study focuses **on** the metal/diamond/metal interface phenomena, the housing **of** the detector was regarded **as** water equivalent and thus replaced **by** water. The influence **of** metallic electrodes of different thicknesses **on** the absorbed dose **to** the diamond was investigated. Electrodes made **of** silver were simulated first. Silver is a common material because it has a high electrical conductivity, forms ohmic contact **with** diamond and the technology **of** its thermal deposition as well as contacting the detector **with** silver epoxy glue is well established. […]

A careful selection **of** simulation parameters was needed in order to preserve accuracy while completing the calculations **within** reasonable CPU. **In** the course of the simulations, each particle (a primary or secondary photon, electron or positron) was transported until its energy fell **below** the corresponding pre-selected absorption energy, E_{abs}; when this happened, its energy was deposited locally and simulation **of** the particle was discontinued. The mixed algorithm implemented **in** PENELOPE **for** the tracking **of** electrons and positrons is governed **by** specific simulation parameters, namely C_1, C_2, W_{cc} and W_{cr}, whose definitions and role are explained at length **in** Salvat et al. (2003). For the sake of brevity, here we just enumerate them and quote the adopted values. […]. We found it convenient to use different simulation parameters depending **on** the distance **of** the particles **to** the active layer and electrodes. To this end, we considered that the detector, where the most ‘conservative’ simulation parameters were selected, was surrounded **by** three ‘shells’ of water **with** successively increasing thickness and values **of** E_{abs}. […].

Here are some examples of verb + preposition clusters. Add to this list by mining your target articles.

was applied across all cohorts	was infused within 5 minutes
was calcinated at 450°c	was input into a model
was calcined in static air	was labelled with a dye
was calibrated against real-world data	was maintained in this condition
was considered for analysis	was manufactured in mild steel
was converted into fatty acids	was manufactured with steel pins
was cultured on coated plates	was mapped against the reference genome
was cured in an autoclave	was normalised for exon length
was degassed in a vacuum oven	was performed at quasi-static rates
was degassed with argon	was performed on tissue samples
was degreased in acetone	was placed under vacuum
was divided into rectangular cells	was precipitated with isopropanol
was exposed to heat	was propagated in 1:3 ratio
was extracted from frozen samples	was propagated with Invitrogen
was extracted with a Hilbert transform	was replaced with feed gas
was fitted with a plastic tube	was retrieved from the database
was grit-blasted with grade 60 grit	was spread onto the surface
was ground with a mortar and pestle	was subjected to impact
was grown on a mineral medium	was transferred into a well plate
was incubated for 2 h	was treated with primary antibodies

3 Consider replacing prepositions with words that make the meaning clear

This is particularly important at the start of a sentence, because as noted earlier (Section 1.5.2), the way that a sentence starts is central to its success.

Instead of:

> ***From*** *this estimation, we ranked the search results obtained and then classified them according to size.*

Consider writing:

> ***Using*** *this estimation, we ranked the search results and then classified them according to size.*

When you write:

> ***With*** *the increase in computer processing speeds, the time taken for simulations has reduced.*

Do you mean **as a result of** the increase or **at the same time as** the increase?

When you write:

> ***With*** *many attempts, we were able to position the probe in the centre of the tissue.*

Do you mean **after many (failed) attempts** or **in several cases**?

The preposition **with** is particularly problematic. *Look at that dog **with one eye*** can either mean *USING one eye* (close one of your eyes when you look) or *HAVING one eye* (the dog only has one eye). In addition, **with** can communicate intention in some contexts, whereas **by** suggests lack of intention: being hit **with** a metal bar is intentional, whereas being hit **by** a metal bar suggests lack of intention. In another example, if *X was coated **with** Y*, that probably means Y was the *material used* to coat X. To indicate the process used to coat X, it is clearer to write *X was coated **by** (doing) Y*.

4 Look for patterns in preposition use

When you look at your target research articles, you may notice that *using* occurs more often than *with*, and that *by* often comes before a process description ending with the suffix *-ing*. Here are some examples:

was analysed USING a computing cluster	was generated USING clinical covariates
was assessed USING an Instron 4507	was improved USING a shielding gas mix
was calculated USING another	was modeled USING 13 elastic elements
was carried out USING a Ministat 251	was mounted USING adhesive tape
was computed USING a flow algorithm	was optimised USING Bayesian criteria
was conducted USING an optical microscope	was performed USING an X-ray diffractometer
was controlled USING an automatic system	was performed USING a mapping algorithm
was designed USING an eArray platform	was quantified USING the phase-locking factor
was developed USING a laser	was removed USING a grinder
was evaluated USING an analog scale	was reported USING the HGVS nomenclature
was evaporated USING a rotary evaporator	was selected USING a filter
was extracted USING a reagent solution	was solved USING the penalty method
was filtered USING a Butterworth filter	was sonicated USING a Branson Sonificator

was achieved BY electroplating	was extracted BY applying a filter
was assessed BY analysing…	was formed BY incorporating…
was assessed BY angiography	was initiated BY administering a drug
was calculated BY dividing…	was precipitated BY adding…
was confirmed BY immunostaining	was prepared BY chemical vapour deposition
was determined BY measuring ATP levels	was prepared BY dissolving…
was differentiated BY withdrawal of bFGF	was replaced BY bFGF

5 Avoid strings of prepositional phrases

Linked prepositional phrases tend to 'infect' each other, resulting in muddled sentences. In a sentence such as: *He gave a lecture about liver cancer at the hospital last January*, it's not clear whether the lecture or the liver cancer occurred at the hospital, or whether the lecture or the cancer cases occurred in January. Consider reformulating it as:

> *Last January he gave a lecture at the hospital; the subject was liver cancer*.

A sentence with multiple prepositional phrases, like the one below, is even more difficult for the reader to process:

> *The tray* ***with*** *the samples was placed* ***in*** *the oven* ***at*** *250°C* ***with*** *protective gloves to avoid injury* ***for*** *one hour.*

Were the gloves in the oven too? Was the aim to avoid injury only for an hour? Consider reformulating it as:

> *The tray* ***containing*** *the samples was placed in the oven for one hour* ***at*** *250°C. Protective gloves were worn to avoid injury.*

Similarly, the precise novelty is difficult to identify in sentences such as:

> *This is the first study to use X-ray imaging* ***over*** *a period of five years to measure contact angles* ***within*** *oil-bearing rocks* ***at*** *reservoir conditions.*

Was this the first study to use *X-ray imaging*? The first to use *X-ray imaging over a period of five years*? The first to use it *to measure contact angles within oil-bearing rocks*? The first to do all this *at reservoir conditions*? Your meaning is always clear to you, but that doesn't mean it's clear to every reader.

2.5.3 Using A/AN (indefinite article), Ø (zero article), and THE (definite article)

Article use is not determined by grammar alone; articles have a profound communicative function and writers often need to choose between grammatically correct articles in order to communicate clearly. A sentence may be grammatically correct whether the writer uses **the** or **a**, but it will not mean exactly the same thing. Therefore, while there are grammar rules underlying article use, context often plays a significant role in deciding whether to use **a/an**, **Ø**, or **the**. This is particularly relevant in the communication of highly technical and complex information, where article choice sometimes depends on what the writer wants to communicate, or on the assumed level of shared knowledge between reader and writer.

A good starting point is the rule that singular countable nouns must take an article, such as **a** or **the**, but like many grammar rules, applying it is not straightforward. In the first place, it is by no means clear which nouns are countable — and even when you know that a noun is countable, how do you decide between **a** and **the**?

This section will consider the following three questions:

1. *What exactly is a countable noun?*
2. *Should I use **a/an, Ø,** or **the**?*
3. *Where **a/an** and **the** are both possible, is there a difference in meaning?*

Question 1: What exactly is a countable noun?

A countable noun is a noun that can form a plural. Some nouns are countable, some are uncountable, and some can be countable or uncountable depending on how they are used. For example, many so-called uncountable nouns like *death* or *childhood* can also form plurals:

*There have been three **deaths** this year from pneumonia.*
*Our **childhoods** were very different; I grew up in France and she grew up in China.*

and so can nouns like *industry*:

*Many **industries** rely on fossil fuels.*

So when you use a noun like *industry*, stop and think — do you mean industry in general (uncountable) or particular industries (countable)? In addition, materials such as *concrete* and *steel,* which are normally considered uncountable, can be used countably when they are used by those who are experts in that material:

> *We have developed **steels** containing only elements that produce certain radioactive isotopes.*

Here is a list of uncountable nouns that are useful in a STEMM context. Try and identify those which can also form plurals, and then check your answers in the Key.

absence	earth	industry	protection
advice	economy	information	purity
age	education	insurance	quantity
agriculture	electricity	intelligence	reality
aid	energy	knowledge	research
air	environment	life	risk
analysis	equipment	light	safety
atmosphere	evidence	loss	salt
behaviour	existence	machinery	sand
blood	experience	noise	science
business	failure	nutrition	strength
calculation	fear	oil	stuff
cancer	fire	organisation	technology
capacity	food	oxygen	temperature
childhood	fuel	paper	transport
concrete	harm	philosophy	treatment
danger	health	physics	trouble
death	heat	policy	truth
democracy	height	pollution	velocity
design	help	power	vision
disease	history	pressure	waste
distribution	independence	progress	water

KEY

Nouns which CANNOT be used countably, i.e. do not have a plural form, are in **bold** type. To use these nouns in the plural, add another noun: *items* of equipment/*methods* of transport/*types* of evidence.

absence	**earth**	industry	**protection**
advice	economy	**information**	purity
age	education	**insurance**	quantity
agriculture	**electricity**	**intelligence**	reality
aid	energy	**knowledge**	**research**
air	environment	life	risk
analysis	**equipment**	light	**safety**
atmosphere	**evidence**	loss	salt
behaviour	existence	**machinery**	sand
blood	experience	noise	science
business	failure	**nutrition**	strength
calculation	fear	oil	**stuff**
cancer	fire	organisation	technology
capacity	food	**oxygen**	temperature
childhood	fuel	paper	**transport**
concrete	**harm**	philosophy	treatment
danger	**health**	**physics**	trouble
death	**heat**	policy	truth
democracy	height	**pollution**	velocity
design	**help**	power	vision
disease	history	pressure	waste
distribution	**independence**	**progress**	water

*Question 2: Should I use **a/an, Ø,** or **the**?*

You may have read that **a/an** is used for general reference and **the** is used for specific reference, but in the sentence:

> *There is **a** book on the shelf above my desk*.

***a** book* clearly refers to a specific book, in fact the aim of the sentence is to specify or identify that book. So if the general/specific criterion doesn't help you to select **a/an** or **the**, how do you choose?

Using **a/an**

(i) Use a/an when you mention a singular countable noun for the first time:

*I bought **a** cheese sandwich and **an** apple. **The** sandwich was OK but **the** apple had **a** little worm in it*.

Although both sentences refer to the same (specific) cheese sandwich and apple, the first uses **a** and the second uses **the**. This is because the first time the writer mentions the cheese sandwich or the apple, only s/he knows about them — but the second time, both the writer and the reader share that knowledge. The switch to **the** is therefore not grammar-based; it is context-based and reflects the fact that knowledge is shared by both reader and writer. This concept of shared knowledge is highly relevant to research writing.

(ii) Use a/an when it doesn't matter, or you don't know, or the reader doesn't know which thing/person you mean:

*Bring me **a** pen please.* (It doesn't matter which pen)

*She works in **a** bank*. (I/you don't know which bank)

*The subject spoke to **an** interviewer*. (I know which one but you don't)

(iii) Use a/an to make a general statement about a countable noun in the singular:

***A** semiconductor can conduct electricity under certain conditions.*

Using **Ø**

(i) Use Ø to make a general statement about a countable noun in the plural:

***Ø** Semiconductors can conduct electricity under certain conditions.*

(ii) Use Ø to make a general statement about an uncountable noun:

***Ø** Pollution is generally the result of human activity.*

(iii) Use Ø when you mention a plural countable noun for the first time:

*We conducted **Ø** DNA arrays on **Ø** silicon chips.*

(iv) Use Ø for a fully uncountable noun, or a noun in its uncountable meaning:

*These acids may undergo **Ø** oxidation.*

*We found many applications in **Ø** industry.*

Using **the**

(i) Use *the* when there is really only one possibility:

*The opening was located in **the** centre of each mesh.*

*We report the discovery of **the** smallest possible carbon nanotube.*

(ii) Use *the* when it is definitely known to the reader:

*They arranged to meet in **the** café.* (The café where they usually meet)

*Did she get **the** job?* (The job we both know she wanted)

***The** cheese sandwich was very good*. (The cheese sandwich I mentioned earlier)

(iii) Use *the* when it is obvious to the reader, even if the thing or person has not been mentioned:

*I bought a new computer but **the** keyboard was faulty*.

This is where the concept of shared knowledge becomes important. As soon as *computer* is mentioned, the reader and writer can be safely assumed to 'share' *keyboard*. Accurately and sensitively determining what you can safely assume to be shared knowledge is central to the success of your text.

*Question 3: If **a/an** and **the** are both possible, is there a difference in meaning?*

In some cases there is a real difference in meaning. For example:

1. *The nodes should be attached to **Ø** two receptor sites.*
2. *The nodes should be attached to **the** two receptor sites.*

In sentence 1 there are **many** receptor sites, whereas in sentence 2 there are **only two** OR **two previously identified** receptor sites. This is similar to the difference between *X is **a** cause of Y* (one of many causes) *and X is **the** cause of Y* (the only cause). Here is a similar example:

1. *This effect may hide **a** connection between A and B.*
2. *This effect may hide **the** connection between A and B.*

In sentence 1 **there may be** a connection between A and B, whereas in sentence 2 **there is** a known connection between A and B.

In other cases there is no difference in meaning but the choice reflects the assumed knowledge of the reader. For example:

1. ***Ø*** *Improvements in virus-detecting software have recently become very important*.
2. ***The*** *improvements in virus-detecting software have recently become very important*.

Sentence 1 could be in a national newspaper, whose readers may not be aware of the improvements. Sentence 2 could be in a computing journal, whose readers are assumed to have a high level of shared knowledge with the writer, and who would therefore be familiar with these *improvements*.

To illustrate the role of shared knowledge, consider whether you would use **a** or **the** in the sentence below if:

a) you were booking a plane ticket on the telephone.
b) you were booking a plane ticket while sitting in the travel agent's office.

I'm going to have ______ baby next month, so I would like a very comfortable seat.

The concept of **shared knowledge** has important implications for journal publishing, and for interdisciplinary access to the content of your research article. If you are submitting the article to a journal which has a wide readership, you cannot assume that your key terms and concepts will be known to all readers, so you may need to use **a/an** when you first mention them, and you may also need to define or explain them. On the other hand, if your field is very narrow and you are certain that all readers will be familiar with your key terms and concepts, it may be acceptable to use **the.**

Now look at some of the sentences in your target research articles and using all the information above, work out why the writer has chosen in each case to use **the**, **a** or **Ø**.

2.6. Writing a Methods Section

This Unit presents a generic model of the Methods section and the language that is conventionally used to generate a readable, effective text. In this task, you will write a Methods section by bringing together everything in this Unit: the model, the language and writing skills, and the vocabulary.

2.6.1 Write a Methods section

The aim of this task is for you to learn how to describe what you did and used so that any reader can repeat exactly what you did, understand why, and obtain similar results. This requires a clear understanding of the difference between your own familiarity with the method and that of a potential reader. This familiarity also makes it hard to see potential grammar-related ambiguity, such as the use of agentless passives.

To complete the task, imagine that you are writing up a research project which has carried out the first-ever attempt to cook chicken. Imagine that until now, everyone ate it raw. The task is to write a recipe for cooking chicken as if it were the Methods section of a research article. As an example, instead of starting by writing something like *Cut the chicken into four pieces*, you could perhaps start with an overview of the entire procedure, or by giving the source of your chicken. Did you obtain it from a supermarket? Was it supplied by a laboratory facility? You will need to say what you used to cut the chicken up; using an axe gives a very different result from using a 4 cm Sabatier steel knife! Instead of writing *Now put the chicken pieces in a hot oven for about an hour and a half*, you should write something like: *Each sample was then placed on a 300 x 600 mm stainless steel sheet and heated in a Panasonic E458X 500 w standard fan-assisted oven for 94 minutes at 350°C*.

The title of the research article in which you report the new process is **An approach to the preparation of chicken using heat and flavouring**. Here is the Introduction:

Introduction

Chicken preparation techniques are used in a range of applications both in homes and in restaurants. Chicken is easily available and *can be locally produced in most areas; in addition, it is easily digested and low in calories[1].*

Since Dundee's pioneering work reporting the natural method of chicken preparation (Dundee et al., 2008) in which the chicken was killed and then eaten raw with salt, there have been significant innovations. Much work has been carried out in France in relation to improving the method of slaughtering chickens[2], whereas in the USA researchers have concentrated on improving the size of the bird[3,4]. The natural method is widely used since the time required for the process is extremely short; however, some problems remain unsolved. The flavour of chicken prepared using the Dundee method is often considered unpleasant[5] and there is a well-documented risk of bacterial infection resulting from the consumption of raw meat[6,9,11].

The aim of this study was to develop a preparation method that would address these two problems. In this report, we describe the new method, which uses seasoning to improve the flavour while heating the chicken in order to kill bacteria prior to eating.

Now write the Methods section. If you get stuck and don't know what to write next, use the model and the language list to help you move forward. Don't look at the sample answer in the Key below until you have finished writing.

2.6.2 Key

Note which part of the model is represented in each sentence.

An approach to the preparation of chicken using heat and flavouring

Method

Two chicken samples were tested to determine the impact of seasoning and heating on flavour and bacterial levels. Flavour was assessed by a testing group selected from those in a previous study[6]. Bacterial counts were determined before and after the heating process using an immunoassay system (Saliva-Check MUTANS) based on monoclonal antibody technology[11].

Two 4.5 kg frozen organic chickens were purchased from Buyrite Supermarket. Buyrite only sells grade A chickens approved by the Organic Farmers Association, thus ensuring the homogeneity of the samples. Two seasoning mixtures, Tri-8-00 and Tri-8-001, were obtained from SeasonInc® and used as supplied.

The chickens were defrosted in a sealed container at room temperature for 5 h. They were then cleaned according to the Hanks method[7], in which chickens are immersed in boiled water cooled to a temperature of 20°C, and subsequently rinsed thoroughly in an isotonic salt solution. In order to obtain two samples of equal size and weight for testing, the chickens were first skinned using a standard BS1709 Skin-o-matic. This made selecting suitable sample locations visually simpler, and enabled precise measurement of the samples prior to cutting. A 3 cm cube weighing 100 g was cut from the identical location on each chicken, using a 4 cm steel Sabatier knife[8] at a pressure of 2 psi.

The two cubes thus obtained were placed in a Phillips R2D2 Dehydrator for 10 minutes to evaporate the remaining salt solution. Immediately after removing the cubes from the dehydrator each cube was completely spray-coated with 15 g of one of the seasoning mixtures, using an application technique similar to that described in Duck *et al*.[9]. The samples were left to stand on a glass plate for 30 minutes at room temperature (16°C) to enhance absorption of the seasoning prior to heating. It should be noted that the seasoning quantities were measured using standard domestic kitchen scales, and are therefore only approximate.

Each cube was then placed on an ovenproof dish and transferred to a pre-heated Panasonic Model 33KY standard electric fan-assisted oven at 150°C for 10 minutes. The samples were then removed from the oven and allowed to come to equilibrium, after which they were assessed using the Bacteriometer test developed by Vira[9]. Flavour was assessed by the testing group using the scale described in Buds *et al*.[6].

EXERCISE 5 Summary exercise. In the extracts, underline or highlight the following: model components; useful prepositions; interesting verb tenses and sequence language. A Key follows.

Nanoparticle scaffolds for syngas-fed solid oxide fuel cells[n]

Experimental

Fig. 1 summarises schematically the formulation and fabrication procedures used in the paper. Inks were formulated from a mixture of commercial gadolinia-doped ceria ($Ce_{0.9}Gd_{0.1}O_{1.97}$, CGO, particle size = 0.5 μm) from Praxair, nanoparticle CGO ($Ce_{0.9}Gd_{0.1}O_{1.97}$, particle size = 5 nm from TEM) produced by continuous hydrothermal flow synthesis (CHFS), polymer microbeads (6 μm, Microbeads AS, Spheromers CA6), terpineol as a solvent, Hypermer KD15 as a dispersant and an ethylcellulose binder (Hercules EC N-7). The CGO nanopowders were produced by continuous hydrothermal flow synthesis using a pilot plant at University College London as described elsewhere.[17] CHFS is an emerging and scalable method of preparing nanoparticles and has previously been used to make samaria-doped ceria,[3] ceria-zirconia solid solutions,[18,19] an entire phase diagram of 66 ceria–zirconia–yttria samples[20] and a range of other metal oxides[21,22] and phosphates[23] with typically sub 50 nm diameter. In CHFS, an aqueous mixture of cerium ammonium nitrate and gadolinium nitrate solution was continuously mixed with a stream of superheated water at 450 °C and 22.1 MPa in a patented confined jet mixer.[24] Particles were then cooled (*via* a pipe cooler) and then collected as an aqueous slurry at the exit of the back-pressure regulator. The particles were recovered by centrifugation and washing (three times) in an equal volume of water until the final solid sludge was obtained. The nanopowder was recovered by freeze drying.

For preparation of scaffolds, the solvent (0.653 g), dispersant (0.265 g) and binder (0.040 g) were mixed together until the binder had fully dissolved. Next, with stirring in an ultrasonic bath, each solid component was added sequentially in two or three aliquots, starting with the dried CGO nanoparticles (0.751 g), followed by the commercial CGO (1.047 g), and finally the polymer microbeads (0.153 g). The ultrasonication and stirring is effective in suspending the nanoparticles. This gave an ink with *ca.* 26 vol% solids content, which was an acceptable level for a screen printing ink.[11] In formulating the ink, two conditions were sought: high total solid content and high nanoparticle content. The order of addition was important to ensure that the nanoparticles were fully incorporated and homogenised, and the large differences in particle size between the different components helped to maintain an appropriate viscosity at high solid loadings.

The inks were screen printed onto 200 μm thick yttria-stabilised zirconia (YSZ) electrolytes. In the case of fuel cells, the procedure differed slightly between cells with different sintering temperatures for the anode, as shown schematically in Fig. 1. In the cells with scaffolds sintered at 1300 °C, one side was printed with the scaffold ink, while the other was printed with a thin layer of a CGO ink (this is to prevent reactions between the cathode material and the YSZ electrolyte). The printed pellets were then heat-treated at 1300 °C for one hour, with a 1 °C min^{-1} ramp rate during heating and cooling. The LSCF-CGO cathode (ink purchased from Fuel Cell Materials, Columbus, OH, USA) was then screen-printed, and the cell heat-treated at 1100 °C for three hours with a 5 °C min^{-1} ramp rate during heating and cooling. The process for the cells with scaffolds heat-treated at 1000 °C was identical except the order of printing and sintering was a protective CGO layer first, followed by cathode and finally by the CGO scaffold. Cells with one, two or three layers of CGO scaffold were produced. The scaffold was dried in an oven at ~80 °C in between each printing cycle.

Next, the CGO scaffolds were impregnated with a nickel salt, again shown schematically in Fig. 1. The impregnation solution was prepared from 0.125 g of nickel nitrate hexahydrate in 200 μL of absolute ethanol. The solution was dropped onto the scaffold using a 1–20 μL pipette, with the volumes used determined empirically by visually observing whether the drop spread beyond the edge of the scaffold. If it did, then the volume of the following impregnation was reduced. The first volume used was determined by dropping pure ethanol onto the scaffold. In between each impregnation, the pellets were placed into a furnace directly at 500 °C for 5 min. This cycle was then repeated ten times. After the final impregnation, the pellets were placed into this furnace, and the temperature was increased to 800 °C at 5 °C min^{-1} and held for eight hours before cooling at 5 °C min^{-1}. The NiO loading was determined by weighing.

Four symmetrical cells were produced: a single layer cell heat-treated at 1300 °C; a single layer cell heat-treated at 1000 °C; a double layer cell heat-treated at 1000 °C and a triple layer cell heat-treated at 1000 °C. In addition, four button cells for fuel cell testing were produced from single and double layer CGO scaffolds heat-treated at 1000 °C, and the same heat-treated at 1300 °C.

The scaffolds were studied by Ultra Small Angle X-ray Scattering (USAXS) to obtain information about the pore structure, while the *in situ* measurements allowed us to monitor the development of the microstructure with temperature.[25] For the USAXS measurements, single layered samples were printed onto MgO substrates (used instead of YSZ as it is less absorbing of X-rays) for analysis by USAXS, and heat-treated at either 1000 or 1300 °C. These samples were compared to a scaffold made from a "control" ink in which the nanoparticle component was replaced by extra commercial CGO. One sample printed on MgO was heat-treated *in situ*. The USAXS data were taken at sector 15, Advanced Photon Source, Argonne National Laboratory. Briefly, small angle scattering intensities around the direct beam was measured using channel cut Si crystal monochrometers in a Bonse–Hart configuration. The X-ray energy was 16.8 keV and the beam size was 1.5×0.4 mm. The sample was mounted in a LinkAm heater for the *in situ* USAXS measurements. The USAXS intensity is plotted as a function of the scattering vector $q = 4\ \sin(\vartheta)/\lambda$ where λ is the X-ray wavelength and ϑ is the scattering angle. The USAXS spectra can be viewed as the autocorrelation of the electron density fluctuations inside the sample, resulting from contrast between the pores and the powders. The USAXS is normally plotted in a log–log plot, and at low q Guinier approximation is valid so the USAXS intensity shows an inflection proportional to $-\exp(q^2R_g^{\ 2}/3)$ where R_g is the radius of gyration. At higher q values, the USAXS intensity follows a power law slope with an exponent of −3, as expected from Porod's law from slit-smeared USAXS. Our USAXS could not resolve the Guinier inflection from the large pores made by polymer microbeads, so we used a combination of a powder law slope and a log-normal size distribution of spherical pores to model the USAXS intensity for non-linear least squares fitting.

The scaffolds and impregnated anodes were imaged by FEG-SEM (LEO Gemini 1525).

Electrochemical measurements were carried out with an Autolab PGSTAT. Symmetrical cell tests were carried out under humidified hydrogen in nitrogen, while fuel cell tests were carried out under humidified hydrogen in nitrogen and humidified syngas in nitrogen (15% H_2, 25% CO, 60% N_2). The exact syngas composition with a high content of nitrogen was chosen so that some of the nitrogen can be replaced with other components (*e.g.* CO_2, larger quantities of steam, tars or H_2S) in later studies. For the syngas tests the cells were put under load in 50% H_2 in N_2 before switching to syngas and carrying out the measurements. This avoids the carbon deposition caused by direct exposure to syngas at OCV. In all cases the same procedure for reducing the anode was employed; the cells were heated under dry nitrogen to 765 °C at 5 °C min^{-1} before switching to humidified 10% hydrogen in nitrogen for one hour before cooling to the operating temperature. In all cases in this report, the humidification was carried out at 20 °C, giving a humidity of 2.3%, while the gas compositions given refer to the gas compositions prior to humidification. […]

Key to EXERCISE 5

Nanoparticle scaffolds for syngas-fed solid oxide fuel cells[n]

Experimental

Fig. 1 **summarises** schematically the formulation and fabrication procedures **used in the paper**. Inks **were formulated from** a mixture of commercial gadolinia-doped ceria ($Ce_{0.9}Gd_{0.1}O_{1.97}$, CGO, particle size = 0.5 μm) **from** Praxair, nanoparticle CGO ($Ce_{0.9}Gd_{0.1}O_{1.97}$, particle size = 5 nm **from** TEM) **produced by** continuous hydrothermal flow synthesis (CHFS), polymer microbeads (6 μm, Microbeads AS, Spheromers CA6), terpineol as a solvent, Hypermer KD15 as a dispersant and an ethylcellulose binder (Hercules EC N-7). The CGO nanopowders **were produced by** continuous hydrothermal flow synthesis **using** a pilot plant **at** University College London **as described elsewhere**.[17] CHFS **is an emerging and scalable method of** preparing nanoparticles and **has previously been used** to make samaria-doped ceria**,**[3] ceria-zirconia solid solutions,[18,19] an entire phase diagram of 66 ceria–zirconia–yttria samples[20] and a range of other metal oxides[21,22] and phosphates[23] **with** typically sub 50 nm diameter. **In** CHFS, an aqueous mixture of cerium ammonium nitrate and gadolinium nitrate solution **was continuously mixed with** a stream of superheated water **at** 450 °C and 22.1 MPa **in** a patented confined jet mixer.[24] Particles **were then cooled** (***via*** a pipe cooler) and **then collected as** an aqueous slurry **at** the exit **of** the back-pressure regulator. The particles **were recovered by** centrifugation and washing **(three times) in** an equal volume of water **until** the final solid sludge **was obtained**. **The** nanopowder **was recovered** by freeze drying.

For preparation of scaffolds, the solvent (0.653 g), dispersant (0.265 g) and binder (0.040 g) **were mixed** together **until** the binder had **fully** dissolved. **Next**, **with** stirring **in** an ultrasonic bath, **each** solid component **was added** sequentially **in** two or three aliquots, **starting with** the dried CGO nanoparticles (0.751 g), **followed by** the commercial CGO (1.047 g), and **finally** the polymer microbeads (0.153 g). The ultrasonication and stirring **is effective in** suspending the nanoparticles. This **gave** an ink **with** *ca.* 26 vol% solids content, **which was an acceptable level for** a screen printing ink.[11] **In** formulating the ink, two conditions **were sought**: high total solid content and high nanoparticle content. The order of addition **was important to ensure that** the nanoparticles were **fully** incorporated and homogenised, and the large differences **in** particle size **between** the different components **helped to maintain** an **appropriate** viscosity **at** high solid loadings.

The inks **were screen printed onto** 200 μm thick yttria-stabilised zirconia (YSZ) electrolytes. In the case of fuel cells, the procedure **differed** slightly **between** cells **with** different sintering temperatures **for** the anode, as shown schematically in Fig. 1. **In** the cells **with** scaffolds sintered **at** 1300 °C, one side **was printed with** the scaffold ink, while the other **was printed with** a thin layer of a CGO ink **(this is to prevent** reactions **between** the cathode material and the YSZ electrolyte). The printed pellets **were then heat-treated at** 1300 °C **for** one hour, **with** a 1 °C min^{-1} ramp rate during heating and cooling. The LSCF-CGO cathode (ink **purchased from** Fuel Cell Materials, Columbus, OH, USA) **was then screen-printed**, and the cell **heat-treated at** 1100 °C **for** three hours **with** a 5 °C min^{-1} ramp rate during heating and cooling. The process **for** the cells **with** scaffolds heat-treated **at** 1000 °C **was identical except** the order of printing and sintering **was** a protective CGO layer **first, followed by** cathode and **finally** by the CGO scaffold. Cells **with** one, two or three layers **of** CGO scaffold **were produced**. The scaffold **was dried in** an oven **at** ~80 °C **in between each** printing cycle.

Next, the CGO scaffolds **were impregnated with** a nickel salt, again shown schematically in Fig. 1. The impregnation solution **was prepared from** 0.125 g **of** nickel nitrate hexahydrate **in** 200 μL **of** absolute ethanol. The solution **was**

dropped onto the scaffold **using** a 1–20 μL pipette, **with** the volumes used **determined** empirically **by** visually observing whether the drop spread **beyond the edge of** the scaffold. If it did, then the volume **of** the following impregnation **was reduced**. The first volume used **was** determined by dropping pure ethanol **onto** the scaffold. **In between each** impregnation, the pellets **were placed into** a furnace **directly at** 500 °C **for** 5 min. This cycle **was then repeated** ten times. **After** the final impregnation, the pellets **were placed into** this furnace, and the temperature **was increased to** 800 °C **at** 5 °C min^{-1} and **held for** eight hours **before** cooling **at** 5 °C min^{-1}. The NiO loading **was determined by** weighing.

Four symmetrical cells **were produced**: a single layer cell heat-treated **at** 1300 °C; a single layer cell heat-treated **at** 1000 °C; a double layer cell heat-treated **at** 1000 °C and a triple layer cell heat-treated **at** 1000 °C. In addition, four button cells **for** fuel cell testing **were produced from** single and double layer CGO scaffolds heat-treated **at** 1000 °C, and the same heat-treated **at** 1300 °C.

The scaffolds **were studied by** Ultra Small Angle X-ray Scattering (USAXS) **to obtain information about** the pore structure, while the *in situ* measurements **allowed us to** monitor the development **of** the microstructure **with** temperature.[25] **For** the USAXS measurements, single layered samples **were printed onto** MgO substrates (used instead of YSZ **as it is** less absorbing **of** X-rays) **for** analysis **by** USAXS, and **heat-treated at** either 1000 or 1300 °C. These samples **were compared to** a scaffold **made from** a "control" ink **in** which the nanoparticle component **was replaced by** extra commercial CGO. One sample printed **on** MgO **was heat-treated** *in situ*. The USAXS data **were taken at** sector 15, Advanced Photon Source, Argonne National Laboratory. **Briefly**, small angle scattering intensities around the direct beam **was measured using** channel cut Si crystal monochrometers **in** a Bonse–Hart configuration. The X-ray energy **was** 16.8 keV and the beam size **was** 1.5 × 0.4 mm. The sample **was mounted in** a LinkAm heater **for** the *in situ* USAXS measurements. The USAXS intensity **is plotted** as a function **of** the scattering vector $q = 4\sin(\vartheta)/\lambda$ where λ is the X-ray wavelength and ϑ is the scattering angle. The USAXS spectra **can be viewed as** the autocorrelation **of** the electron density fluctuations **inside** the sample, resulting **from** contrast **between** the pores and the powders. The USAXS **is normally plotted in** a log–log plot, and **at** low q Guinier approximation **is** valid **so** the USAXS intensity **shows** an inflection proportional to $-\exp(q^2R_g^2/3)$ where R_g is the radius **of** gyration. **At** higher *q* values, the USAXS intensity **follows** a power law slope **with** an exponent **of** −3, as expected **from** Porod's law **from** slit-smeared USAXS. Our USAXS **could not resolve** the Guinier inflection **from** the large pores **made by** polymer microbeads, **so we used** a combination **of** a powder law slope and a log-normal size distribution **of** spherical pores to model the USAXS intensity **for** non-linear least squares fitting.

The scaffolds and impregnated anodes **were imaged** by FEG-SEM (LEO Gemini 1525).

Electrochemical measurements **were carried out with** an Autolab PGSTAT. Symmetrical cell tests **were carried out under** humidified hydrogen **in** nitrogen, while fuel cell tests **were carried out under** humidified hydrogen **in** nitrogen and humidified syngas **in** nitrogen (15% H_2, 25% CO, 60% N_2). The exact syngas composition **with** a high content **of** nitrogen **was chosen so that** some of the nitrogen can be **replaced with** other components (*e.g.* CO_2, larger quantities of steam, tars or H_2S) **in** later studies. **For** the syngas tests the cells **were put under** load **in** 50% H_2 **in** N_2 **before** switching to syngas and carrying out the measurements. **This avoids** the carbon deposition caused by direct exposure **to** syngas at OCV. **In all cases** the same procedure **for** reducing the anode **was employed;** the cells **were heated under** dry nitrogen **to** 765 °C **at** 5 °C min^{-1} **before** switching **to** humidified 10% hydrogen **in** nitrogen **for** one hour **before** cooling **to** the operating temperature. **In all cases in this report**, the humidification **was carried out at** 20 °C, giving a humidity **of** 2.3%, while the gas compositions given **refer to** the gas compositions **prior to** humidification. […]

TIPS FOR WRITING A SUCCESSFUL METHODS SECTION

- Check the average length of Methods sections in your target research articles. This will help you determine the level of detail considered appropriate to describe that type of experiment or simulation.
- Check where the Methods normally appear in your target journal. Is it in supplementary offline material or in the print version?
- Plan the entire Methods section before you start creating sentences.
- Don't confuse your lab notes with the Methods section. The first was written for you; the second needs to be written for a reader.

- Remember that your familiarity with the topic may mean that you are not aware of the reader's need for introductory or background information. The amount of background factual information depends on the current level of readers' knowledge, so check this against recent papers dealing with similar topics in similar journals. If a wider readership will access the study via the internet, adjust the amount of introductory or background information accordingly.
- Make sure the reader knows exactly WHY you did what you did at each stage. This creates a narrative that reads coherently and supports your integrity as a researcher.
- The extent of comparison with existing/current methods and the verb tense that describes these methods depends on the current level of readers' knowledge, so check this against recent papers dealing with similar topics in similar journals.
- Check every single sentence to ensure that the verb tense is communicating the correct meaning.
- Make sure you have separated your own work from that of other researchers and from established knowledge. Your contribution may be obvious to you, but it's not obvious to every reader. Use the Agentless Passive table in Section 2.5.1 to check that you have avoided any potential ambiguity.

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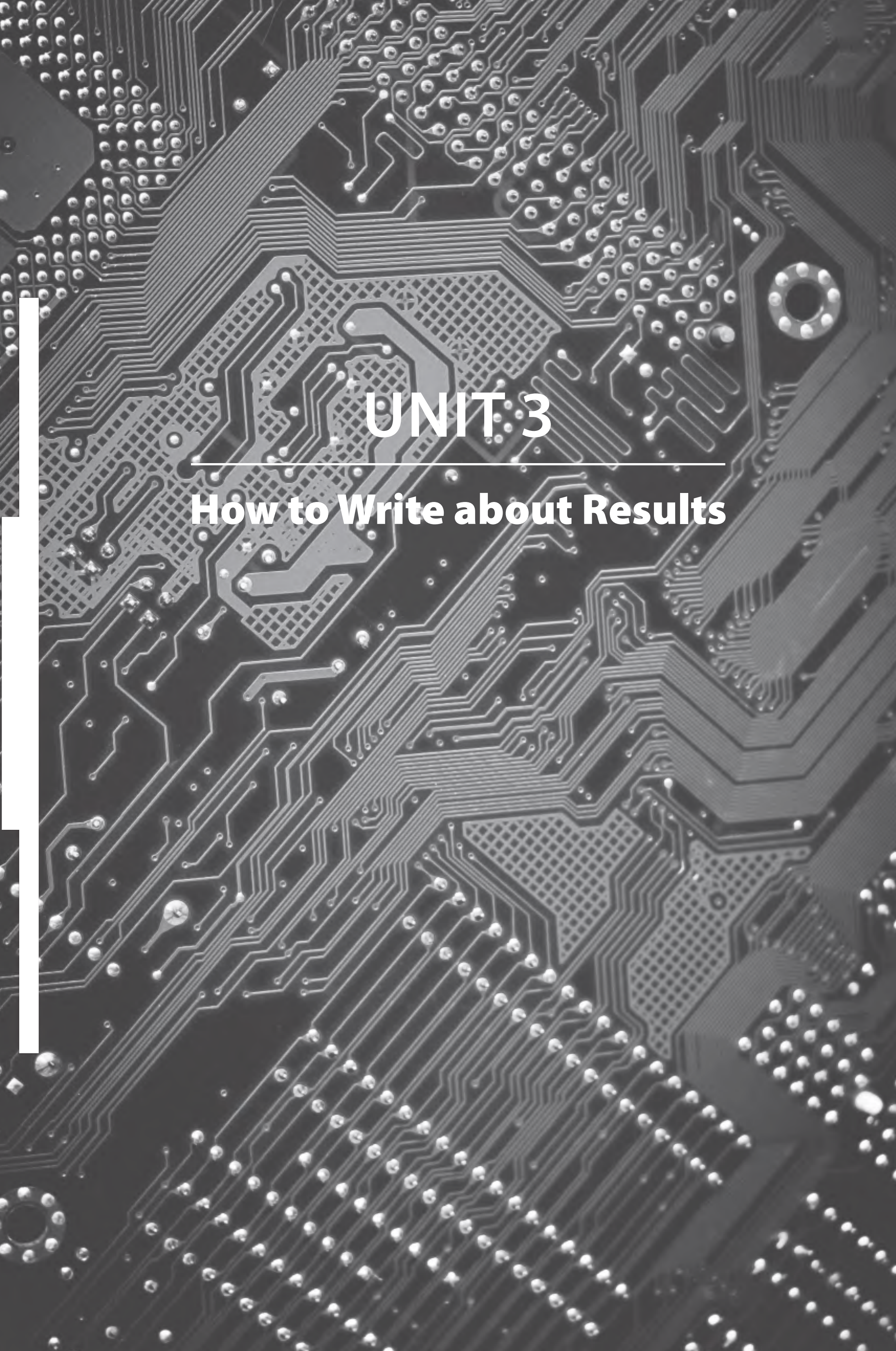
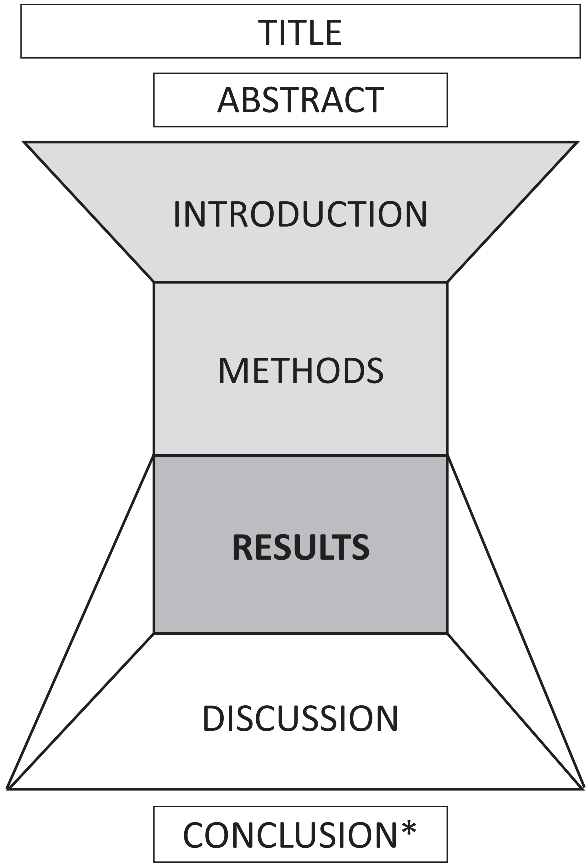


UNIT 3

How to Write about Results



*Some journals call this section CONCLUSION and others call it CONCLUSIONS but this does not seem to reflect the number of conclusions that are drawn.

3.1. The Structure and Content of the Results

The table below shows four common options for the final sections of the research article.

<table>
<tr><th>SUBTITLES
Option 1</th><th>SUBTITLES
Option 2</th><th>SUBTITLES
Option 3</th><th>SUBTITLES
Option 4</th></tr>
<tr><td>Results</td><td>Results</td><td rowspan="2">Results and Discussion</td><td>Results</td></tr>
<tr><td>Discussion</td><td>Discussion</td><td>Ø</td></tr>
<tr><td>Conclusion</td><td>Ø</td><td>Conclusion</td><td>Conclusion</td></tr>
</table>

Your target articles will help you decide between these options, but if your target journal has a flexible structure, aspects of your study may also guide your decision. If your preliminary results influence later ones, you may prefer a combined Results and Discussion section in which you present and discuss preliminary results before presenting and discussing the later ones. Similarly, if your results respond to multiple hypotheses/predictions, it may be easier for the reader to see the results and discussion for each hypothesis together, with appropriate subtitles. If you intend to discuss the results as a whole, you may decide to present all the results together in the Results section, and then move onto a Discussion section. Ultimately, the aim is to make this section as easy as possible for the reader to negotiate, to demonstrate the relationship between the results and the aim/s of the study, and to lay a clear path to the Conclusion.

In this book, the Results section will be treated separately from the Discussion section, and the Discussion section will be treated separately from the Conclusion. This is to ensure that you can train yourself to recognise — and therefore create — the components that are characteristic of each section, whether you keep them separate or combine them.

N.B. In some cases, depending on the journal, the topic, or the type of study, the Results section may be called *Data Analysis* or *Case Study*. As always, the golden rule is to use your target research articles as a guide.

3.2. Building a Model

The advice given to writers about what should and should not be in the Results section often conflicts with what is successfully published. For example, you may be advised to avoid any interpretation of your data in the Results section. You may be advised to use only the past tense, or to avoid repetitive paragraph structures. You may be told that the Results section should only deal with what the results are, and that the Discussion section should only deal with what the results mean. However, when we examine and describe successfully-published research articles, we see that authors do not always — or even often — follow such advice.

A reverse-engineering, descriptive approach based on current published research will generate a more reliable picture of the Results section than a prescriptive approach that tells you what you should or shouldn't do. One reason for this is that the structure and content of the Results section is changing to reflect the way that readers read, and particularly the way they use the internet as a resource. The current trend towards placing the Methods section in Supplementary Materials is also influencing the content of the Results section, since this means that the Results section will need to include information about the method to make the results intelligible. Prescriptive advice may therefore quickly become out of date. By contrast, the descriptive approach makes it easy to update and adapt your writing models as they change over time — and they will.

Developing the reverse-engineering approach for yourself will mean that you can use it for any type of text, now and in the future. In this Unit you are therefore encouraged to take control of the analysis and modelling for yourself and build your own model of the Results section, using your target research articles as the primary source. The aim is to generate **a model for the Results section in current research articles in your own field, and to ensure that you develop the competence to update and adapt it confidently**.

3.2.1 EXERCISE 1: Using target articles to build a model

In most cases, the results of research work can be presented in graphs, tables, equations, photographs or other images (all referred to here as *graphics*). Why, then, do researchers bother to write a Results section at all? Why not simply provide good, clear graphics with good, clear titles and perhaps a note underneath each one? Almost all STEMM research articles currently include a written Results section, so clearly some functions of the Results section, for example *explaining the results*, cannot be achieved without narrative text.

With this in mind, start by writing a brief description of the function of each sentence in the Results section of at least TWO of your target articles to generate a broad list of potential components. Then write a brief description of the function of each sentence in the simplified Results section below, and compare your list with this description. Some components in your list will be similar to the sentence descriptions on page 154; others will be specific to the research you are doing, the current conventions of your field, or the type of article you are writing. Integrate the two lists to generate a robust set of model components for the Results section in research articles in your own current research area which you can adapt or update as your research develops.

On-bicycle exposure to particulate pollution: using a portable device for accurate measurement

Results

1 *Data obtained in previous cycling safety studies*[1,5,7] *used fixed monitors positioned at high-emission locations to measure weekday concentrations of black carbon (BC) and nitrogen dioxide* (NO_2)*.* ***2*** *Those studies found no significant difference in BC and* NO_2 *emissions between cycle lanes shared with buses and cycle lanes separated from vehicle traffic.* ***3*** *In our study, BC and* NO_2 *concentrations were measured using a PEMS-43, a portable emissions measurement system developed by Noxious et al.*[7]*.* ***4*** *The PEMS-43 was fixed to a bicycle and recorded the emissions hourly along each route type.*

5 *Figure 1 shows the BC and* NO_2 *concentrations measured hourly on each route type from 6.00 a.m. to 10.00 a.m.* ***6*** *In line with results from previous studies, the BC and* NO_2 *concentrations were broadly similar for both route types over this 4-hour period.* ***7*** *However, the data obtained by PEMS-43 for journeys later in the day were significantly different.* ***8*** *We recorded a striking reduction in the* NO_2 *concentrations along bike paths separated from vehicle traffic, beginning shortly after*

10.00 a.m. (Figure 2). ***9*** *As can be seen, by 2.00 p.m. the NO_2 levels had fallen by as much as 33%, and this low level was maintained even during the 5.00 p.m. to 7.00 p.m. peak traffic density period.* ***10*** *These results suggest that NO_2 levels along bike paths separated from vehicle traffic may not match those of BC at all times throughout the day.*

11 *The presence of vegetation is known to slightly alter BC and NO_2 concentrations at different times of day[11,18], and the effect of this along the two routes was not investigated.* ***12*** *Nevertheless, the data obtained here suggest that using a portable emissions measurement system to measure BC and NO_2 exposures hourly may provide more accurate information for traffic management strategies than traditional on-site measurement.*

3.2.2 Key

In Sentences 1 and 2 *Data obtained in previous cycling safety studies[1,5,7] used fixed monitors positioned at high-emission locations to measure weekday concentrations of black carbon (BC) and nitrogen dioxide (NO_2). Those studies found no significant difference in BC and NO_2 emissions between cycle lanes shared with buses and cycle lanes separated from vehicle traffic.* **the writer repeats/revisits the methods and findings of studies mentioned earlier in the article.**

In Sentences 3 and 4 *In our study, BC and NO_2 concentrations were measured using a PEMS-43, a portable emissions measurement system developed by Noxious et al.[7]. The PEMS-43 was fixed to a bicycle and recorded the emissions hourly along each route type.* **the writer briefly summarises the method used in this study.**

Why begin by revisiting studies mentioned earlier in the article or by summarising the methods I used?

It is reader-friendly to start a (sub)section with material that provides a smooth transition from the previous section, or prepares the reader for the new section. Recalling or revisiting key parts of previous sections ensures that all readers begin the Results section on a similar basis. For example, some readers may not recall the research gap/problem or key research studies in this area from the Introduction, both of which provide a critical background for the results.

Revisiting earlier sections at the start of the Results also supports readers who are information-surfing (i.e. going directly from the Title/Abstract to the Results and bypassing the Introduction and/or Methods). If you look at the Results sections in your target articles, you may be surprised by the amount of information about the method that is included in this section. Recalling/revisiting key elements of the method is common when the Methods section is very long or in Supplementary Materials, and ensures that readers know enough about the method to understand the results. You of course, know the method well — after all, it's your own research — but your readers don't share that familiarity. They may not have read the Methods section or remembered the key aspects of it when they read the Results.

Why not just start by going through my results in order?

The aim of a paper is not to tell the story of your project in the order it occurred; it is to make a valid contribution to your field and to communicate that contribution efficiently and effectively. Readers look for trends and patterns in the results while they read, and if you simply list the results in the order they occurred, the reader will need to constantly adjust that trend or pattern to detect the direction of travel. You know where you are going with these results, but the reader does not; without narrative guidance, the direction of the results may be unclear. In addition, different readers may see different patterns in the data, some of which may direct them away from, rather than towards, your own interpretations. It is your responsibility as the writer to organise and present the results within a narrative that structures them optimally and leads naturally towards the interpretations and conclusions you want to draw.

So what's a good way to begin?

As always, look at how successful writers in your target journals begin. Some writers begin with a brief general statement about the overall pattern or trend of the results (*In most cases*/*In general*/*Overall*), and may direct the reader to a summary figure or table. Starting with a general statement stabilises the framework in which you present your results and ensures that your reader sees the 'wall' before you — and they — look at the individual 'bricks'. If you are subdividing your results into sets of results, you may want to provide a linking statement to introduce each set.

Some writers begin by re-stating the aim of the study. In the Discussion or Conclusion, you discuss the extent to which your study has fulfilled the aim/s you set out in the Introduction. Re-booting this aim or problem early in the Results section sets a context for the reader to evaluate your results. It's also helpful for you to have the aim of your study clearly in view when you are deciding what to include in the Results, and in what order. Your results should link clearly to your aim/s; in fact, when you look at your results, you may decide to go back to the Introduction and redefine or re-word the aim in light of the results.

Other writers begin by recalling key aspects of the method. As stated above, this is particularly common where the Methods section is only available via a link to Supplementary Materials. It also supports readers who move directly from Title to Results, or from Title + Abstract to Results.

In Sentence 5 *Figure 1 shows the BC and NO_2 concentrations measured hourly on each route type from 6.00 a.m. to 10.00 a.m.* **the writer invites the reader to look at a Results graphic.**

Why do I need to invite the reader to look at the graphics?

Readers will see them as they continue reading, and they may have already looked at the graphics before they started reading the article.

What do you do when you are reading and you come to a sentence like Sentence 5? In most cases, you stop reading and look at the graphic; you try to understand it or interpret the data you see, and then you return to the text with that interpretation in mind as you continue reading.

Placing the graphics at specific locations and framing them with a narrative is clearly important; if not, they would come in a random order at the start or at the end of the Results section, or randomly throughout. To place your graphics optimally, look at the order and location of the graphics in the Results sections of your target articles, and the narrative text that comes before and after the graphic. Think about why the writer put the graphics in that order, and how you, the reader, responds to them at those locations, in that order, and framed by that narrative text. You may be impatient to present your most important and exciting results, but it may be more effective to start with the graphics and narrative that underlie or lead to the more important ones so that the reader can 'discover' the important ones with you.

Sometimes a graphic that summarises the data or findings is presented at the start of the Results section before any text, particularly if the data is visually very clear and unambiguous. However, if the visual representation of the data in your figures, tables and photographs can be interpreted in more than one way, it may be better to comment on that data before inviting the reader to take a look. If you don't, the reader might interpret it differently from you. This will affect their response to the next graphic or set of results, and ultimately to your conclusions.

In Sentences 6 and 7 *In line with results from previous studies, the BC and NO_2 concentrations were broadly similar for both route types over this 4-hour period. However, the data obtained by PEMS-43 for journeys later in the day were significantly different*. **the writer compares the results with those in other studies, using subjective, evaluative language** *(In line with, broadly similar, significantly different)***.**

Do I need to compare my results with those of other researchers?

When you start to do original research, you cross an invisible line. Until this point you were writing for people — tutors or course leaders — who knew more about the subject than you did, and who knew what they expected to see in your report. Your task was to describe your methods and results to readers who already knew what methods you would use, what results you should obtain, and how those results compare with those in other studies. By contrast, a defining characteristic of research is that it must make a new contribution to the field, and your communication must identify that contribution.

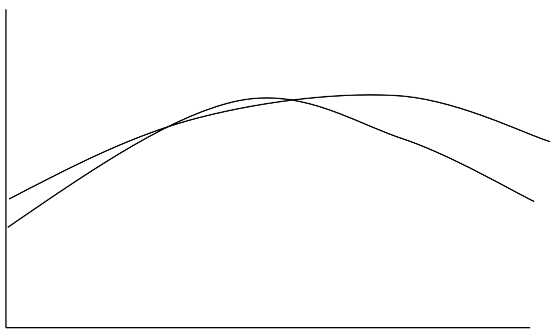
The relationship between your study and the literature is a theme that runs through the entire research article from beginning to end. In the Results section, comparing your results with those in the literature demonstrates how your results have advanced or modified knowledge in your field, and enables the reader to position your study on the research map. This mapping of your study is developed in the Discussion, but in order to do it effectively, you need to first set your results against existing results.

Many types of comparisons can be found in the Results section. In addition to comparing your results with those in the literature, you may want to compare your own results with your predictions, or compare your modelled/simulated results with your experimental results. The language used to communicate the level of similarity or difference in these comparisons can be central to the success of the article, and a wide range of options can be found on pages 179–180.

Why do I have to use evaluative language — why not simply describe what is in the graphic?

The most important reason for using language in the Results section rather than relying only on graphics is that results do not speak for themselves. You are not simply writing up your results, you are writing **a guide to the results that should lead logically and naturally towards the conclusions you will draw.**

The language that you use to describe your results and the comments you make on your results influence the way readers perceive them. For example, look at the two curves in the figure below:



If you write *As can be seen in Fig. 3.1, the two curves are very similar*, the reader will focus on the similarity between the curves. However, if you write *As can be seen in Fig. 3.1, the two curves are significantly different*, the reader will notice the difference between them.

Your description of the results supports the alignment between the aim of the study, the results themselves, and your conclusions. If you do not comment on your results so that the reader can share your understanding of them, the reader may interpret them differently from you and the conclusions you eventually draw will not seem either logical or natural to the reader; in fact, they may seem surprising or inappropriate. For example, if you just write: *As can be seen in Fig. 1, the effect occurred in 23% of cases*, you may be basing your conclusions on a belief that *23% of cases* is a high proportion, but without any evaluative language to 'fix' the value of the number, the reader may independently decide that *23% of cases* is low. This will have a damaging effect on the rest of your paper, and particularly on the Conclusion.

Although results are sometimes described objectively (i.e. numerically or using non-evaluative language), if you simply describe what is in the graphic, you have not added anything to what the reader can already see, so why bother? You are a legitimate member of your research community, and you are entitled to — and should — present your understanding of the results you have obtained. Your readers do not have to agree with you but they need to know where you are going with the results, otherwise the gap between your results and the conclusions you draw from them will be too wide to negotiate. Results are therefore usually presented including some evaluative language.

Evaluative language may occur together with the relevant number/quantity (*only 23 ml*), or it may replace the number/quantity (*in many cases*). The language you choose guides the reader towards your own interpretation of the data, so if the effect you were looking for occurred in 23% of cases, you can choose to communicate this as a strong result (*in as many as 23% of cases*) or a weak result (*in only 23% of cases*). Interestingly, researchers often deny that writers do this in their own field — until the evaluative language in their target articles is pointed out to them. A list of evaluative language commonly used to describe and comment on results can be found on pages 171–179. After you look at the list, start underlining or highlighting examples when you see them in your target articles. This will give you a clear indication of what, when, how, and how much evaluative language to include in your own papers.

Notice that in Sentence 8, in addition to the evaluative language such as *broadly similar*, the writer adds a clear functional signal at the start of the sentence (*However*,) to ensure that the reader is ready to see the difference. This is a short sentence, so it doesn't really matter where the signal is placed. In a long sentence it may be better to place the signal close to the start because a long sentence that ends with a signal requires the reader to 'loop back' through the sentence in order to understand it. Compare these two:

In such cases, the patient may require a higher dose of intravenous antibiotics, an intravenous load of phenytoin, or even a brief procedure under intravenous conscious sedation, unfortunately.

Unfortunately, in such cases, the patient may require a higher dose of intravenous antibiotics, an intravenous load of phenytoin, or even a brief procedure under intravenous conscious sedation.

In Sentence 8 *We recorded a striking reduction in the NO_2 concentrations along bike paths separated from vehicle traffic, beginning shortly after 10.00 a.m. (Figure 2)*. **the writer directs the reader's attention to a specific result, describing it with strongly evaluative language** *(striking)***.**

Isn't language like 'striking' too informal?

Apparently not. Science writers do not normally use exclamation marks, even when the results are very exciting. Instead, they use language such as *striking* to achieve that 'wow!' feeling. A list of these '!-substitutes' can be found in the Language section for the Discussion (pages 225–226).

In Sentence 9 *As can be seen, by 2.00 p.m. the NO_2 levels had fallen by as much as 33%, and this low level was maintained even during the 5.00 p.m. to 7.00 p.m. peak traffic density period*. **the writer selects a specific result to present in more detail, and comments on it** *(as much as, even)***.**

How do I decide which results to present in detail? Why not describe all of them in detail?

Remember that your job is to provide **a guide to the results**, not simply a description of the results. If you present all your results in detail they will all seem to be equally important. This is unlikely to be the case: you know that some of your results are key results, that others are less important, and that even within the set of key results, some are more significant than others. Your sentences are, in the end, just black lines on a white page — the reader cannot hear your voice and so cannot hear you emphasising the importance of a particular result. You cannot print it in red and, as we have seen, you cannot even use an exclamation mark. It's your responsibility to select the important results and focus on them in more detail so that your reader can share your perception of what is important. You can also make this clear by beginning sentences with language like *It is important to note that…/ Importantly,/It is significant that…*

It is interesting that the best results are often described in such a way as to give the impression that they are typical results — look out for that in the papers you read. Writers may make a general statement about the results followed by a phrase like *for example* and the 'best' result: *The SFS results are generally in very good agreement with their FE counterparts; for example, at midspan the values are almost identical.*

Should I explain the results as well as comment on them?

By now, it should be clear that this decision can only be made by careful reverse-engineering analysis of similar current papers; however, you will see that explanations are common in most Results sections. Explaining **how** a particular result was obtained may consist of details about the method you used. Explaining **why** it occurred may consist of information about the properties of the material you are studying. It is helpful to think about the difference between the *explanation* of a result and the *implication* of a result (what the data suggest or imply). In the Results section, *explanations* tend to be limited to direct explanations of the data; the implications are often mentioned briefly in the Results (see Sentence 10), but a full discussion of what the results suggest or imply is generally kept for the Discussion.

In Sentence 10 *These results suggest that NO_2 levels along bike paths separated from vehicle traffic may not match those of BC at all times throughout the day.* **the writer mentions a possible implication of the results.**

In Sentence 11 *The presence of vegetation is known to slightly alter BC and NO_2 concentrations at different times of day[11,18], and the effect of this along the two routes was not investigated.* **the writer mentions a possible limitation, minimising its potential impact** *(slightly)* **on the results.**

Do I need to mention limitations or problems? Won't it make the reader doubt my results?

As discussed in the Methods (pages 85–86), the opposite is true. Don't ignore problems in your results unless you are certain that the problems are both insignificant and invisible. If your results are incomplete or some of them don't 'fit', it is common to mention this, minimise its importance if possible, and suggest reasons for the problem or offer a solution. If you fail to mention problems or gaps in your results, it may look as though you are not aware of them, and this suggests to the reader that you don't fully understand your own study. By contrast, mentioning a problem does exactly the opposite: it shows you to be in control of your research and able to evaluate it clearly. An additional advantage of mentioning problems or gaps in the results is that it provides you with a key element of the Discussion/Conclusion: directions or suggestions for future research — in this case, a suggestion that future studies should investigate the possible effects of vegetation on emissions levels.

As stated earlier, if you delay submitting your research for publication until it is perfect, you may never be ready to publish it. Lab-to-journal speed is critical. Write it up as soon as your results are worth communicating, and acknowledge problems or difficulties you encountered with the results within the Results section — it isn't appropriate to mention them for the first time when you are discussing suggestions for future work in the Discussion/Conclusion.

So what do I say about problems in the Results?

Use language that minimises the problem, and/or suggests possible reasons for it and/or offers a solution or a way forward. In the example above, the writer acknowledges that there was a problem and minimises its impact (*slightly*). You can find examples of language to refer to imperfect or problematic results on pages 180–181.

In Sentence 12 *Nevertheless, the data obtained here suggest that using a portable emissions measurement system to measure BC and NO_2 exposures hourly may provide more accurate information for traffic management strategies than traditional on-site measurement.* **the writer focuses the reader's attention away from the problem and towards the positive value of the study in terms of the implications and applications of the results** *(Nevertheless…may provide more accurate information)***.**

Shouldn't the implications and applications of the Results wait until the Discussion?

The implications are a central topic in the Discussion, but almost all writers give some indication of what their results imply within the Results section. Once the results have been presented, the focus of the paper begins to open out and face away from the central reporting section and towards the Discussion/Conclusion, so it is common to see verbs like *suggest* or *indicate* at this point. This helps the reader to see where the paper is going, and opens the path into the Discussion section.

Mentioning the applications helps the reader to link the results of the study to the aims or applications mentioned in the Introduction or Abstract. The writer can create this link by using language that echoes those aims or applications. For example, if the aim stated in the Introduction was to *improve the accuracy of* something, using the phrase *more accurate* to describe the results will help the reader to see the link clearly. These words and phrases are often very positive; see the lists of 'happy words' ☺ on pages 51, 107, 175, 225 and 294 for some examples.

3.2.3 A Results model

Compare the sentence descriptions below with the list you made in Section 3.2.1, Exercise 1:

In Sentences 1 and 2, the writer	repeats/revisits the methods and findings of studies mentioned earlier in the article.
In Sentences 3 and 4, the writer	briefly summarises the method used in this study.
In Sentence 5, the writer	invites the reader to look at a Results graphic.
In Sentences 6 and 7, the writer	compares the results with those in other studies, using subjective, evaluative language.
In Sentence 8, the writer	directs the reader's attention to a specific result, describing it with strongly evaluative language.
In Sentence 9, the writer	selects a specific result to present in more detail, and comments on it.
In Sentence 10, the writer	mentions a possible implication of the results.
In Sentence 11, the writer	mentions a possible limitation, minimising its potential impact on the results.
In Sentence 12, the writer	focuses the reader's attention away from the problem and towards the positive value of the study in terms of the implications and applications of the results.

These can be streamlined to create a basic, generic Results model (see next page). **Integrate this model with the list of components you created in Section 3.2.1 to generate a robust set of model components for the Results section in your own current research area which you can adapt or update as your research develops.** For example, if the Methods section in your target journal is only available via a link to Supplementary Materials, you may need to present an extensive overview of the method at the start of the Results section. Your target journal may request a *Research in Context* panel specifically to present comparisons with results in other studies. Submitting your study according to the current structural model identifies you as a researcher who is up to date with the literature.

GENERIC RESULTS MODEL	
1	**REVISITING THE LITERATURE/AIM/PREDICTION/HYPOTHESIS/GAP** **REVISITING/SUMMARISING THE METHOD** **GENERAL STATEMENT ABOUT THE RESULTS** **INVITATION TO VIEW GRAPHIC + CONTENT OF GRAPHIC**
2	**SPECIFIC/KEY RESULTS ± EVALUATIVE LANGUAGE/COMMENTS** **COMPARISON WITH RESULTS IN OTHER STUDIES/HAPPY WORDS ☺** **COMPARISON WITH MODEL/SIMULATION/PREDICTED RESULTS** **EXPLANATION OF RESULTS VIA KNOWN FACTS/METHOD DETAILS**
3	**PROBLEMS/ISSUES WITH RESULTS ± REASONS**
4	**POSSIBLE IMPLICATIONS OF RESULTS/HAPPY WORDS ☺**

Notes:

VERB TENSE IN THE RESULTS SECTION

- The description of *what can be seen in a graphic* is generally in the Present Simple tense. This may alternate with sentences that describe *how the information in the graphic was obtained*, which are generally in the Past Simple tense.
- Some of the background facts that explain the results, such as the properties of the material used, may be in the Present Simple tense (*This occurred because material X is able to…*). Others, such as those that refer to the method, may be in the Past Simple tense (*This occurred because we used a…*).
- In Unit 1 **(Section 1.5.1 Verb tense choices)** it was noted that tense choice can communicate the writer's confidence in the permanent value or permanent truth of the results. The Past Simple tense reports what the authors found; by contrast, the Present Simple tense reflects a belief that the findings are reliable enough to constitute a permanent truth.
- The Present Simple tense may be used throughout the Results section, for example, to describe how a model 'runs'. Check your target articles.

SUBSECTIONS/SUBTITLES IN THE RESULTS SECTION

Many Results sections are divided into subsections, and careful reverse engineering of the subsections and their subtitles in your target articles will support effective text planning. Start by observing some simple metrics: how many subsections are in the Results sections of your target articles? How long are the subsections? What are the paragraph functions in each subsection? How long are the subtitles? Are the subtitles grammatical sentences?

When you have done that for a few target articles, consider the function of the subsections and the subtitles. What seems to be controlling the division into subsections? What is the overall function of each subsection? What is the relationship between the subtitle and the content of the subsection? Do the subtitles summarise the subsections? Answering these questions will enable you to plan your text so that you write in ways that reflect the structure of similar Results sections in your field.

3.3. Testing and Adjusting the Model

3.3.1 A demonstration of the model

Using your integrated list, identify the model components in the Results section below. Language that exemplifies the model components is in **bold** type, and some cases, the verb is in **bold** type because the verb tense demonstrates the component.

Amazonian functional diversity from forest canopy chemical assembly[o]

Results

Regional Chemical Diversity. Canopy chemical traits **varied widely** among **the thousands of trees surveyed** along the Andes–Amazon elevation gradient (Table 1 and Table S3). Foliar N, P, and lignin **spanned** an order of magnitude in value, whereas Ca and phenols **varied** by two orders of magnitude. Community-scale variation in **many** chemical traits **tracked** changes in elevation (Fig. S1) and **at times, was closely related to** climate (Table S4). Intercomparison of elevational trends in canopy chemistry **was made possible by applying** a gradient normalization procedure to the data, which **shows** the percentage increase or decrease in a community's average trait value relative to the gradient mean **(SI Methods). By doing** this normalization, elevational trends among all forests **were found to differ from observed trends** among high-fertility sites alone, **revealing the central role of** soils in determining community level canopy chemistry in the region (Fig. 1). **Most notably**, foliar P and Ca concentrations on higher-fertility lowland sites **were** two times that measured on lower-fertility lowland sites, and soluble C concentrations **were elevated** in higher-fertility areas (Table 2). **In contrast**, total C, phenols, and lignin **were suppressed** in the higher-fertility sites.

We also discovered elevation-dependent tradeoffs in canopy foliar C allocation throughout the region. Up the elevation gradient, cellulose and lignin **decreased** 100% relative to their region-wide mean. Soluble C **increased by almost** 150% with elevation (Fig. 1), and **this change**

occurred in parallel to a nearly 200% increase in LMA. Changes in C allocation **were tightly linked to** mean annual temperature and precipitation along the gradient (Table S4).

We found opposing patterns for P and Ca — two rock-derived nutrients **often thought to** limit growth in tropical forests (16). With increasing elevation, foliar P **increased 100%** above the gradient mean value (Fig. 1A), but this elevational pattern **disappeared** after the removal of the low-fertility sites from the analysis (Fig. 1B). **In contrast**, mean foliar Ca concentration **decreased by 100%** from the Amazonian lowlands to tree line in the Andes. Foliar N **declined only slightly** with elevation. Additional analyses **revealed** decreasing P and Ca on a leaf area basis, **despite the fact that** LMA **increased** with elevation (Fig. S2 and Table S5). Finally, foliar $\delta^{13}C$ **increased by about** 200% with elevation relative to its mean gradient value, and **this trend occurred** independent of site fertility (Fig. 1).

[…].Site characteristics **were a relatively small** contributor — less than 20% — to the explained variance in **most** canopy chemical traits (Fig. 2), **indicating that**, within any given community along the elevation gradient, phylogeny dominate**s** over local differences in soils, microclimate, and other factors. […].Foliar δ13C **displayed** the weakest phylogenetic partitioning. Canopy P and Ca patterns **were also dominated by** site conditions, especially soils; **this** soil fertility **effect is evidenced by the fact that** phylogeny **played a much stronger role** in determining foliar P and Ca when only considering high-fertility sites. Regressing the model components against elevation, **it is also clear that** the taxonomic partitioning of **most** canopy chemical traits **is** invariant with elevation (Table S6).

Inter- vs. Intraspecific Variation. Interspecific (between-species) variation in canopy chemical traits was consistently **two to three times greater** than intraspecific (within-species) variation, and intraspecific variation **was often very low** in canopy trees at all sites (Fig. 3 and Table S7). **Moreover, there were very few** elevation-dependent trends in either intra- and interspecific variation (Tables S8 and S9). Maximum intraspecific variation **was recorded** for Ca (24–29%), phenols (21–22%), and P (16–21%). δ13C, total C, and soluble C **showed extremely low** intra and interspecific variations of **less than** 10%.

3.3.2 EXERCISE 2: Identifying the model components

Here are three more Results sections from research articles in different disciplines. They have been edited for length, and ellipses are marked as [...]. Identify the model components using your integrated list.

1 Effect of muscle compensation on knee instability during ACL-deficient gait[l]

Results

In the absence of any muscular compensation, ATT increased throughout the stance phase of ACLd gait relative to that calculated for normal gait (Fig. 2). Peak ATT for the intact and ACLD knee occurred at contralateral toe off, which coincided with the occurrence of peak knee extensor moment (see Fig. 3B). Maximum allowable ATT was always greater than that calculated for normal gait, and at times was even greater than that estimated for ACLd gait (Fig. 2, compare lightly shaded region and solid line around 50% of gait cycle).

The model simulation results showed that it was not entirely possible to restore ATT in the ACLd knee to the amount calculated for normal gait merely by reducing the magnitude of quadriceps force (Fig. 3A, gray solid line). There were periods near heel strike and in midstance when the lower limit of quadriceps force (zero force) was reached, and yet ATT in the ACLd knee was greater than that obtained for the intact knee (Fig. 2, black dashed line). The simulation results also showed that it was not entirely possible to restore ATT in the ACLd knee to the maximum allowable level by reducing quadriceps force alone (Fig. 3A, gray dashed line). In this case, there was a brief period during midstance when the lower limit of quadriceps force was reached, and yet ATT was greater than that incurred during maximum isometric extension (Fig. 2, black dashed line exceeds the gray region during midstance).

Complete elimination of the knee extensor moment (a quadriceps avoidance pattern) was needed to restore ATT in the ACLd knee to the level calculated for normal gait (Fig. 3B, gray solid line). In contrast, some (positive) net extensor moment was predicted when ATT in the ACLd knee was restricted to the maximum allowable limit (Fig. 3B, gray dashed line).

The simulation results showed that it was possible to reduce ATT exactly to the level calculated for the intact knee merely by increasing the magnitude of hamstrings force (Fig. 4A). As expected, the increase in hamstrings force needed to bring ATT in the ACLd knee to the maximum allowable level was less than that needed to bring ATT to the intact level (Fig. 4A, compare gray dashed and solid lines). An increase in hamstrings force led to a decrease in the knee extensor moment, but this effect was noticeably less than that obtained when quadriceps force was reduced (compare gray lines in Fig. 3B and 4B). […]

2 Identification and characterisation of the early differentiating cells in neural differentiation of human embryonic stem cells[c]

Results

Identification of a transient Tra-1-81(-)/SSEA4(+) cell population at early stage neural differentiation of hESCs

Similar to the cells in the ICM, undifferentiated hESCs express embryonic cell specific surface antigens, including stage-specific embryonic antigens (SSEA) 3 and 4, Tra-1-60 and Tra-1-81 [17], which were first identified in human embryonic carcinomas. However, unlike mESCs, they do not express SSEA1. Although the functional significance of these antigens is as yet unclear, they are routinely used as markers for hESCs. Therefore, we anticipated that studying the dynamic changes of these cell surface markers in neural differentiation could potentially enable us to capture and isolate the early differentiating populations which could be used for further analysis.

We focused our study on Tra-1-81, SSEA4 and SSEA1, given that SSEA3 expression is not necessarily required for a pluripotent state [18], and the high similarity between Tra-1-60 and Tra-1-81 [19]. Our results showed that, in self-renewal culture conditions, H1 hESCs express high levels of SSEA4 and TRA-1-81, but not SSEA1 (Figure 1A, top). After differentiation to neural progenitors, expression of Tra-1-81 and SSEA4 were lost while expression of SSEA1 was increased (Figures 1A, bottom). However, it is noteworthy that the loss of Tra-1-81 preceded that of SSEA4. After 9 days in neural differentiation medium, Tra-1-81 expression was almost completely lost, whereas the majority of cells still expressed SSEA4 (Figure 1A, middle). The expression of SSEA4 persisted for several days until 2 weeks into the differentiation at which point the neuroepithelial cells started to emerge and SSEA1 expression was positive. A similar pattern was also observed in H7 hESCs, although Tra-1-81 expression was lost earlier than that in the H1 cells (7 days vs. 9 days) (Figure 1B). The existence of this Tra-1-81(2)/SSEA4(+) population of cells was also confirmed by immunostaining (Figure 1C). Further neural differentiation from this stage lead to the efficient generation of NPCs, which retained the expression pattern of Tra-1-81(2)/SSEA4(2)/SSEA1(+) and could be maintained for an extended time in culture when supplemented with bFGF/EGF (Figure 1D). The neural differentiation experiments were repeated several times in both H1 and H7 hESC lines and the sequential loss of the Tra-1-81 and SSEA4 antigens was reproducible, although the timing of the disappearance of each antigen varied slightly between experiments, depending on the initial seeding density.

To eliminate the possibility that the sequential loss of Tra-1-81 and SSEA4 is a culture-dependent phenomenon, hESCs were also differentiated using the double SMADs inhibition protocol [20,21]. Differentiation with the dual SMAD inhibitors exhibited the same sequential loss of Tra-1-81 and SSEA4 in both H1 and H7 cells (Figure S1A). Furthermore, a previous report using stromal-feeder based neural differentiation protocol observed the same effect [19]. We therefore propose that this initial Tra-1-81(2) and SSEA4(+) population represent cells of early neural differentiation and consequently designated them TR2/S4+ cells.

TR2/S4+cells exhibit an intermediate gene expression pattern between hESCs and neural progenitors

Different cell populations can be distinguished by morphological and developmental criteria, as well as by the temporal and spatial expression of marker genes. In order to characterize the transient TR2/S4+ cells, we isolated them by FACS or by magnetic-activated cell purification (Figure 2A). The Tra-1-81(2) and SSEA4(+) identity of the purified cells was then confirmed by flow cytometry analysis. Gene expression was analysed by quantitative RT-PCR (qRT-PCR) and compared to that of undifferentiated TR+/S4+ hESCs and their TR2/S42 NPCs (Figure 2B). We found that the expression of pluripotent marker genes, Oct4, Nanog and Rex1, was clearly downregulated in the TR2/S4+ cells compared to hESCs but remained higher than that of NPCs. Conversely, the expression of neural progenitor marker genes, Pax6, nestin and Sox1, was upregulated in the TR2/S4+ cells but was considerably lower than in NPCs. However, Sox2, another known pluripotent marker, was consistently expressed in all three cell types, with its highest expression level in the NPCs, implicating a critical role in both pluripotent and neural progenitor cells. In addition, the TR2/S4+ cells also expressed the early differentiation marker, FGF5, which was undetected in both hESCs and NPCs (Figure 2B). A similar gene expression pattern was also found in TR2/S4+ cells from neural differentiation with dual SMAD inhibitors. It was also found by RT-PCR that, compared to the undifferentiated hESCs and their NPCS derivatives, both the isolated TR2/S4+ cells and the unsorted day 9 differentiated H1 cells expressed much lower levels of leukaemia inhibitory factor receptor (LIFR) (Figure 2C).

Western blotting was performed to confirm the expression of Oct4 and Nanog proteins (Figure 3A). While undifferentiated hESCs exhibited high levels of Oct4 and Nanog proteins, they were undetectable in NPCs. However, in the TR2/S4+ cells, Oct4 and Nanog protein levels were lower than in hESCs but higher than in the NPCs. Since both RT-PCR and Western blotting methods quantify average levels of gene expression in a whole population, one cannot exclude the possibility that this TR2/S4+ population contains two groups of cells: one similar to the undifferentiated hESCs (high Oct4 expression but low/no expression of neural markers), and the other similar to the NPCs (high levels of neural markers but no Oct4 expression). Therefore, to confirm that the expression of Oct4 and Pax6 in the TR2/S4+ cells was not due to the co-existence of these two different populations, immunostaining and flow cytometry analysis were carried out. The results showed that Oct4 antibody staining was positive in 97% of hESCs, with almost 80% cells strongly positive (mean value =156.5). Similarly, 97% of TR2/S4+ cells were also stained positive for Oct4, but the majority of cells exhibited a lower level of Oct4 (mean value = 54.49, Figure 3B, left). No clear Oct4 staining was visible in NPCs (mean value =2.9). In addition, TR2/S4+ cells showed a clear upregulation of Pax6 signals (mean value = 12.4) compared to hESCs (mean value =3.14), which was not as strong as in the NPCs (mean value =21.1, Figure 3B, right). Co-staining of Oct4 and Pax6 in situ confirmed the flow cytometry analysis and clearly demonstrates the co-existence of Oct4 and Pax6 proteins in the same cell during early neural differentiation, which are notably expressed in a negatively correlated manner (Figure 3C).

To explore whether the various levels of Oct4 expression are regulated at the promoter, we examined the amount of DNA methylation in the Oct4 promoter region near the transcription start site. A gradual increase in DNA methylation was observed throughout the neural differentiation and was negatively correlated with Oct4 mRNA expression (Figure 3D). In hESCs, very low levels of methylation were detected (0.05%), opposed to the heavy methylation detected in NPCs (84.3%). Interestingly, an intermediate DNA methylation level of 48.1% was observed in the TR2/S4+ cells. Taken together, these results demonstrate that the TR2/S4+ cells exhibit a gene expression profile which is distinct from both undifferentiated hESCs and their fully committed neural progenitors, and co-express both neural progenitor and undifferentiated pluripotent markers. In addition, Oct4 expression is progressively downregulated during neural differentiation, which is accompanied by the upregulation of neural markers.

TR2/S4+ cells generate both neural and non-neural lineage cell types

Under neural differentiation conditions [16], further culture of the TR2/S4+ cells lead to the efficient production of NPCs that express high levels of neural progenitor markers: nestin (97%), Sox1 (82%) and Pax6 (88%) (Figure 3 and 4) but lack expression of pluripotent genes (Oct4 and Nanog) or mesoderm and endoderm markers: GATA6, brachyury and a-fetoprotein (Figure 2) [22]. These neural progenitor cells were able to further differentiate into neurons and astrocytes as revealed by the positive staining of MAP2, TUJ1 and GFAP, respectively (Figure 4).

Since Oct4 expression persists in TR2/S4+ cells, albeit at a lower level, we considered whether these cells were able to generate non-neural lineages in alternative culture conditions. Purified TR2/S4+ cells were differentiated via cell aggregate formation, a method that can initiate spontaneous differentiation and is widely used to examine the differentiation potential of cells in vitro [23]. The TR2/S4+ cell aggregates were able to expand in culture and displayed structures similar to embryoid bodies (EBs) after 7 days of differentiation in suspension (Figure 5A). These EBlike aggregates were then dissociated and plated onto adherent culture dishes for further differentiation. After another 7 days, cells with various morphologies were visible (Figure 5B) and were analysed for gene expression by qRT-PCR and immunocytochemistry. Real-time RT-PCR showed upregulation of markers of the three germ layers: neuroectoderm (Pax6, Sox1 and Sox2), mesoderm (goosecoid (GSC) and Meox1) and endoderm (albumin (ALB) and GATA6) (Figure 5C), while pluripotent markers, Oct4 and Nanog were downregulated. Immunocytochemistry further confirmed that the differentiated cells contained progeny from the three germ layers: AFP, HNF4a and GATA6 for endoderm, muscle actin for mesoderm, nestin and Pax6 for neuroectoderm (Figure 5D). These results demonstrate that TR2/S4+ cells are also capable of differentiating into cells of non-neural lineages.

TR2/S4+ cells cannot be maintained or reverted back to hESCs in self-renewal culture conditions

TR2/S4+ cells express a high level of FGF5, a marker of post-implantation primitive ectoderm of mouse embryos [24]. Given that mESC-derived primitive ectoderm-like cells are capable of reverting back to an ESC state when re-cultured in mESC self-renewal media [25], we examined whether theTR2/S4+ cells can be reverted back to their original hESC state. Purified TR2/S4+ cells were re-plated into matrigel-coated plates and cultured in hESC self-renewal conditions (Figure 6A). To verify that any resulting changes were not a technical artifact, we purified and cultured TR+/S4+ hESCs as controls (Figure 6B). Both cell populations showed similar attachment efficiencies (Figure 6Aa&6Ba) and colonies were clearly visible 3 days after plating. By day 7, TR2/S4+ colonies exhibited structures and morphologies similar to that of hESCs but the expression of Tra-1-81 and SSEA4 could neither be reactivated nor maintained (Figure 6Ab). In contrast, control hESCs (TR+/S4+) expressed high levels of both these markers (Figure 6Bb). This difference became even more apparent after 14 days of culture (Figure 6Ac & 6Bc). Consistent with the changes in cell surface markers, evident differentiation also started to emerge in the TR2/S4+ cells. RT-PCR analysis confirmed that expression of both Oct4 and Nanog was downregulated in TR2/S4+ cells as the culture proceeded. Mesoderm and endoderm markers were up-regulated while the expression of neural markers, Pax6 and Sox1, was reduced, although the levels remained higher than in hESCs (Figure 6C). These results are consistent with the data from EB cultures, which indicate that the cell fate of TR2/S4+ cells are affected by their culture conditions. In CM cultures, there is limited inhibition of BMP signaling in cells, at least not to the level induced by the addition of noggin [16], which may account for the observed nonneural lineage differentiation. These results further confirm that TR2/S4+ cells are distinct from undifferentiated hESCs and cannot be reverted back to their original hESC state by reintroduction into hESC self-renewal conditions. Furthermore, these cells cannot be maintained as TR2/S4+ cells under these conditions.

Comparison of TR2/S4+ cells with cells of early embryoid bodies and definitive endoderm differentiation

Since TR2/S4+ cells are able to generate cells in addition to the neural lineage, it raises the question of whether these cells are equivalent to those of early EBs. To answer this question, we compared our global gene expression data of early neural differentiation (N1), which resembled the TR2/S4+ cells (over 85% cells are TR2/S4+) [22], with the published microarray data from 16-day EBs of the same hESC line, H1 [26]. Interestingly, gene ontology analysis revealed that the genes significantly upregulated during EB differentiation have considerable functions during neural differentiation and development (Table 1) and, as a result, shared >60% of the functions in biological processes with those genes upregulated in TR2/S4+ cells. This becomes more evident when the top 15 functions in the biological process of the gene-ontology list are compared between the two cell-populations as over 70% of them appeared in both lists (Table 1). Similarly, the downregulated genes in both cell populations also shared >60% of gene ontology functions. Therefore, global gene expression analysis does provide certain support for the similar phenotype and differentiation observed between TR2/S4+ cells and the early EBs (EBs in suspension).

Since cells in the early neural differentiation and early EB formation share a similar gene expression pattern and phenotype, we asked whether early mesendoderm differentiation would also generate this population. To address this question, we differentiated H1 hESCs into definitive endoderm using two different methods (Activin A with sodium butyrate or LY294002, see Materials and Methods for details). Both differentiation procedures exhibited a similar phenotype and gene expression pattern, in which expression of Sox17 and FoxA2 steadily increased over the 3-day differentiation period, whereas, after an initial upregulation, expression of the mesendoderm markers, brachyury and Mixl1, were downregulated by day 3 (Figure 7A). Furthermore, Sox2 expression was continuously downregulated (Figure 7A). This gene expression pattern is consistent with our previous data and existing published data on endoderm differentiation [6,7,27], indicating that the majority of these cells have differentiated to mesendoderm by day 1–2 of the differentiation and are committed to endoderm by day 3. However, during the differentiation, both Tra-1-81 and SSEA4 were continuously expressed in a considerable proportion of cells, approximately 90% and 70% after 2 and 3 days of differentiation, respectively (Figure 7B). These results demonstrated that differentiated mesendoderm and early endoderm cells can also express TRA-1-81 and SSEA4, which is in line with a previous report that found Tra-1-60 and SSEA4 positive cells in a proportion of Sox17+ cells that could only be differentiated into endoderm and mesoderm [28]. As a whole, these results therefore indicate that differentiation towards the neural lineage may share a similar initial process to differentiation via EB formation that is distinct from that of high-dose Activin-induced definitive endoderm differentiation.

3 Rapid alloy prototyping: compositional and thermo-mechanical high throughput bulk combinatorial design of structural materials based on the example of 30Mn–1.2C–xAl triplex steels[p]

4. *Results*

4.1 Mechanical testing of the RAP samples

Following the high throughput procedure outlined above five alloy compositions, each exposed to nine respective heat treatments, were produced, processed and evaluated within 35 h. The mechanical properties of these 45 different material conditions (i.e. in total 135 tensile tests and hardness measurements) are shown as an overview in Fig. 2 in terms of the yield strength (YS) (Fig. 2a), ultimate tensile strength (UTS) (Fig. 2b), total elongation (TE) (Fig. 2c) and hardness (Fig. 2d). The results are plotted according to the systematically varied Al content (Table 1) and colour coded according to the individual ageing conditions. Pronounced effects associated with the changes in chemical composition and ageing parameters on the mechanical behaviour of the materials can be clearly distinguished. For the reference material (no Al addition, i.e. Fe–30Mn–1.2C) the best mechanical behaviour was observed for the as-homogenised, non-aged state. This alloy was characterised by a YS of 360 MPa, strong work hardening (UTS = 830MPa) and high ductility (TE = 77%). Ageing of the Fe–30Mn–1.2C alloy showed that the YS was virtually unchanged and the hardness slightly increased. However, ageing greatly reduces both the UTS and TE. This embrittlement becomes most apparent for long ageing times (24 h) and higher temperatures (>500°C). For the alloy Fe–30Mn–1.2C–8Al, i.e. the material with the highest Al concentration, the opposite trend applied. Without ageing the mechanical data are similar to those of the Al-free alloy, with only a slight change in YS (increase), UTS and TE (decrease). Ageing treatments for 1 h, however, led to a simultaneous improvement in YS, UTS and hardness (increasing with temperature) and to only a slight drop in TE. Ageing of alloy Fe–30Mn–1.2C–8Al for 24 h further increased YS, UTS and hardness to values almost twice as high as in the as-homogenized state, but also drastically reduced the ductility. The mechanical data for the alloys with intermediate Al contents appear as the superimposition of the two different behaviours described above: as a general rule, the values obtained for the alloys with 2, 4 and 6 wt.% Al lie between the respective data from alloys without and with 8 wt.% Al. The alloys with Al additions of 4 and 6 wt.% especially are only very weakly affected by the applied ageing treatments in terms of their mechanical data compared with the alloys Fe–30Mn–1.2C (weakening/embrittlement) and Fe–30Mn–1.2C–8Al (strengthening). […]

4.2 Microstructure of the RAP samples

[…]. Microstructures in the as-homogenised state (unaged) are shown on the left-hand side of Fig. 5, those after ageing at 550°C for 24 h on the right-hand side, respectively. In the as-homogenized state the three alloys exhibit almost identical austenitic microstructures with an average grain size of about 80 lm, few twins (increasing with higher Al content) and no apparent micro-segregations. After ageing, however, pronounced differences between the three alloys could be observed. Coarse particles with a diameter of ~10 μm appear at the grain boundaries of the Al-free alloy (Fe–30Mn–1.2C), most probably consisting of a pearlitic ferrite/(Fe,Mn)3C microstructure. The addition of Al to the alloy Fe–30Mn–1.2C–4Al apparently constrained the formation of those phases during ageing, as the number density and size of the particles was now significantly lower than in the Al-free material and only thin films appeared on the grain boundaries of the alloy with 4 wt.% Al. A further increase in Al content (alloy Fe–30Mn–1.2C–8Al) resulted in the complete absence of grain boundary particles during ageing, but a large number of unevenly distributed small particles appeared within the grains, giving them a darker contrast.

4.3 Tensile testing of the conventionally produced samples

For reference and comparison Fig. 6 shows exemplar engineering stress–strain curves for the alloys Fe–30Mn–1.2C–2Al (red) and Fe–30Mn–1.2C–8Al (blue) after ageing at 450°C for 1 h, obtained by following the conventional synthesis and processing (Fig. 6a) and RAP (Fig. 6b) approaches. For the alloy Fe–30Mn–1.2C–8Al both the RAP and conventional data are in the same range, with an only lightly increased YS (610 to 540 MPa), lower UTS (810 to 890 MPa) and almost identical ductility (76 to 73%) of the RAP samples. While this trend (slightly higher YS and lower UTS) is the same for the alloy Fe–30Mn–1.2–2Al, the RAP samples now exhibited significantly less ductility than the conventional specimens (49 compared with 84%) under this specific material condition. The unusually large elastic strain that is apparent in Fig. 6b can be attributed to slight deformation (bending) of the RAP samples, which could not be completely avoided despite the clamping procedures applied during quenching of the thin segments.

3.4. Useful Words and Phrases

3.4.1 Language task

EXERCISE 3 Look through the Results sections in this Unit and in your target research articles. Underline or highlight words or phrases that you think could be used in the four areas below and compare your suggestions with the lists in Section 3.4.2.

1 SUBJECTIVE DESCRIPTIONS OF RESULTS, e.g. *extremely, often*
2 LANGUAGE THAT COMPARES RESULTS WITH SIMULATIONS/PREDICTED RESULTS/RESULTS IN OTHER STUDIES, e.g. *in line with*
3 LANGUAGE THAT DEALS WITH PROBLEMS IN RESULTS, e.g. *unfortunately*
4 LANGUAGE THAT PRESENTS THE IMPLICATIONS OF RESULTS, e.g. *suggesting that*

3.4.2 Language for the Results section

This section lists words and phrases for the Results section taken from analysis of over 2,500 published research articles in different disciplines. The list only includes words and phrases which appear frequently and are therefore considered normal and acceptable by writers and editors.

The list will also keep the flow of writing moving. Underneath each list there are examples of how the words and phrases are used in sentences, so look at the list and the sentence examples when you are feeling stuck and can't think of what to write or how to continue.

INVITATION TO VIEW RESULTS

according to the data in Fig. 1, as can be seen from/in* Fig. 1, based on (data in) Fig. 1, can be found in Fig. 1 can be identified from/in Fig. 1 can be observed in Fig. 1 can be seen from/in Fig. 1	**Verbs** Fig. 1: contains demonstrates displays

(close) inspection of Figure 1 indicates data in Fig. 1 suggest that (data not shown) evidence for this is in Fig. 1 (Fig. 1) in/from Fig. 1 (it can be seen that) in Fig. 1 we (compare etc.) is/are apparent from/in Fig. 1 is/are clearly visible in Fig. 1 is/are evident in the figure is/are given in Fig. 1 is/are shown in Fig. 1 is/are visible in Fig. 1 results are given in Fig. 1 (see Fig. 1) we observe from/in Fig. 1 that	illustrates lists plots presents represents reveals shows summarises

Note*: ***from* means that *it can be understood/concluded/deduced from* the data in the graphic, whereas ***in*** means that *it actually appears in/is visible in the graphic itself.*

Here are some examples of how these are used:

- As **is apparent from Fig**. 1, the extractibility of the dehydroisoandrosterone did not change significantly.
- The data in Fig. 18 **reveal** that H3K36 can repair damaged DNA.
- The coefficients given in Table 1 **represent** mean values from both spectrophotometers.
- ZnO thin-film islands which cover the substrate surface **can be observed** in Fig. 3a.
- Figure 1 **illustrates** the responses from the three regions of the right ventricle.
- Results for individual groups are **displayed** in Supplementary Figure 5.
- As we **can see from** Figure 3, the spectrum changed significantly during the phase scan.
- The lack of correlation between IR and PLFA patterns can be seen by **comparing** Figs 1 and 5.

- An analysis of the follow-up status of the subjects is **presented** in Table 2.
- The exchange current densities are **summarised** in Table 9.

SPECIFIC/KEY RESULTS

(i) OBJECTIVE DESCRIPTIONS OF RESULTS

is/was absent	change/d	match/ed
is/was constant	decline/d	occur/red
is/was different	decrease/d	peak/ed
is/was equal	delay/ed	precede/d
is/was higher, etc.	drop/ped	prevent/ed
is/was highest, etc.	exceed/ed	produce/d
is/was identical	exhibit/ed	reduce/d
is/was obtained	exist/ed	remain/ed
is/was present	expand/ed	resume/d
is/was seen	fall/fell	rise/rose
is/was unchanged	find/found	take/took place
is/was uniform	increase/d	vary/varied

Note: Numerical representations of percentages, levels, locations, amounts etc. (e.g. *a 2% increase*) are also, of course, *objective* descriptions of results.

Here are some examples of how these are used:

- Protein expression **peaked at** day 3 after infection.
- The frequencies of the jets **were constant**, and **did not change** linearly with velocity.
- Concentration scales **decreased** with the fuel fraction.
- It was observed that the female rats **exhibited higher** levels of plasma corticosterone than male rats.
- Leaf enlargement **resumed** toward the end of the desiccation period.
- The UV-visible spectra of the purified components **were identical** to those of lutein.
- Mean SAOC values **rose** to 682 moI/L within the first hour.

(ii) SUBJECTIVE DESCRIPTIONS OF RESULTS: general comments

abrupt	important	reasonable	**Useful verbs:**
acceptable	in general	remarkable	emphasise
adequate	in principle	serious	highlight
appropriate	in the main	severe	reflect
brief	inadequate	sharp	resemble
broadly	likelihood	similar	
by and large	mainly	steep	**Comments:**
clear	major	striking	Importantly,
comparable	measurable	strong/ly	In fact,
comparatively	merely	subtle	Indeed,
consistent	minor	sudden	Interestingly,
distinct	more or less	sufficient	Intriguingly,
dramatic	obvious	suitable	It is noteworthy
effectively	perceptible	unexpected	that...
equivalent	poor	unlikely	Notably,
essentially	powerful	unremarkable	Overall,
excessive	profound	unusual	Significantly,
extensive	pronounced	virtually	Surprisingly,
generally	predominant/ly	weak/ly	
gradual	rapid		

Note that whereas *higher* is objectively true or false, *high* is a subjective assessment of a quantity/level/amount.

(iii) SUBJECTIVE DESCRIPTIONS OF RESULTS: comments about quantities

The subjective language used to comment on quantities in STEMM writing can be divided into five groups:

Group 1 contains words/phrases which ‘increase’ the size/quantity:
A considerable amount of residue remained in the pipe.

Group 2 contains words/phrases which ‘reduce’ the size/quantity:
Barely 74% of the residue remained in the pipe.

Group 3 contains words/phrases which emphasise how big/small/high/low the size/quantity is:

The amount that remained in the pipe was even higher/even lower than predicted.

Group 4 contains words/phrases which communicate that the size/quantity is similar or close to another:
Almost half of the residue remained in the pipe.

Group 5 is useful when you do not want to interpret the size/quantity:
Some of the residue remained in the pipe.

Look at the list below, and place each word/phrase in the correct group. (Those marked with an asterisk [*] appear in two groups.)

a great deal (of)	easily (over/under)	little	numerous	significant
a few	even (higher/lower)	low	only	significantly
a little	exceptionally	marginal	over (half/25%)	slight
a number (of)	extremely	marked	particularly	slightly (more/less)
abundant	fairly	markedly	plenty of	small
appreciable	far (more/less)	minimal*	practically	so (high/low)
appreciably	few	minor	quite (high/low)	some
approximately	fewer (than)	moderate	quite a few	somewhat
as many as	greater (than)	modest	quite a lot	substantial
as few as	hardly	more (than)	rather (high/low)	substantially
at least	high	most	reasonably	to some extent
barely	imperceptible	much*	relatively	under
below	in some cases	near/ly	remarkably	upwards of
close (to)	just*	negligible	roughly	very
considerable	large	noticeable	scarcely	virtually
considerably	less	noticeably	several	well (over/under)

KEY

Group 1: *words/phrases which 'increase' the size/quantity*

a great deal (of)	high	over (half/25%)
a number (of)	large	plenty of
abundant	marked	quite a few
appreciable	more (than)	quite a lot
as many as	most	several
at least	much	significant
considerable	noticeable	substantial
greater (than)	numerous	upwards of

Group 2: *words/phrases which 'reduce' the size/quantity*

a few	hardly	minor
a little	just	modest
as few as	less	only
barely	little	scarcely
below	low	slight
few	marginal	small
fewer (than)	minimal	under

Group 3: *words/phrases which emphasise how big/small the size/quantity is*

appreciably	far (more/less)	significantly
considerably	markedly	so (high/low)
easily (over/under)	much (higher/lower)	substantially
even (higher/lower)	noticeably	very
exceptionally	particularly	well (over/under)
extremely	remarkably	

Group 4: *words/phrases which communicate that the size/quantity is similar or close to another*

approximately	just (over/under)	practically
close (to)	little (i.e. close to none)	roughly
few (i.e. close to none)	minimal	slightly (more/less)
imperceptible	near/ly	virtually
	negligible	

Group 5: *words/phrases which you can use when you do not want to interpret the size/quantity*

fairly	quite (high/low)	some
in some cases	rather (high/low)	somewhat
moderate	reasonably	to some extent
	relatively	

(iv) SUBJECTIVE DESCRIPTIONS OF RESULTS: 'happy' words ☺

accurate advantageous beneficial better effective	efficient excellent feasible improve precise	reliable satisfactory simple successful superior	useful valuable viable worthwhile

(v) SUBJECTIVE DESCRIPTIONS OF RESULTS: comments about frequency

Frequency modifiers help readers to evaluate the results. For example, if a researcher states that a particular result occurred *every time* a particular test was carried out, then it is clearly a very reliable result. If it *generally* occurred, that is still reliable, but perhaps less so. If the writer simply states *x occurred* without a frequency modifier, readers may not be able to evaluate the results appropriately, or at all.

The evaluative language used to comment on frequency in STEMM writing can be divided into ten levels. Imagine that you want to find a colleague on a Monday morning, and you want to know whether you should look for her in the Library.

1. If she *always* goes to the Library on Monday mornings you will find her there today.
2. If she *generally* goes to the Library on Monday mornings you expect to find her there today and you will be surprised if she is not there.
3. If she *often* goes to the Library on Monday mornings there is a good chance that you may find her there today.
4. If she goes to the Library *more often than not* on Mondays, you should start by looking for her there, but she may not be there today.
5. If she goes to the Library *as often as not* on Monday mornings you may find her there today — or you may not. It's impossible to predict because the chances are equal; she goes there as often as she doesn't go there.
6. If she *sometimes* goes to the Library on Monday mornings perhaps she will be there today, but you won't be surprised if she isn't there.

7. If she *occasionally* goes to the Library on Monday mornings she might be there today but it's unlikely.
8. If she *rarely* goes to the Library on Monday mornings she probably won't be there today, so don't bother to look for her there.
9. If she *hardly ever* goes to the library on Monday mornings she is not expected to be there today, and you would be surprised to find her there.
10. If she *never* goes to the Library on Monday mornings she won't be there today.

The list below shows the ten levels in decreasing order of frequency. However, note that statements about frequency tend to be subjective: saying that something occurred *frequently* may refer to how often it was **expected to occur**. For example, if previous research indicated that a particular result was unlikely to occur but in your study it occurred on 22% of occasions, you may present that as a *frequent* occurrence. On the other hand, if previous research indicated that something is very likely to occur but in your study it occurred on only 22% of occasions, you may present that as a *rare* occurrence.

1	each/every time without exception on each/every occasion always invariably
2	habitually as a rule generally normally usually
3	regularly repeatedly frequently often commonly

4	more often than not
5	as often as not **(neutral frequency)**
6	sometimes on some occasions at times
7	occasionally now and then from time to time
8	infrequently rarely seldom
9	hardly ever barely ever almost never scarcely ever
10	on no occasion not once at no time never

When you look at your target articles, you will notice that it is harder to find examples of the language used to provide an *objective* description of the results than it is to find examples of the language used to provide a *subjective* description of the results. When objective language does occur, a subjective 'add-on' is often provided. For example, *slightly lower* or *much lower* is found more often than *lower* on its own. This is probably because, as mentioned earlier, an objective description of the results does not tell readers anything they don't already know from looking at the graphic.

If you are having difficulty seeing the difference between *objective* and *subjective* language, remember that saying that one level or quantity is *higher* than another is an objective truth; saying that it is *high* is a subjective evaluation.

Here are some examples of subjective descriptions of results:

- **Minor** clinical abnormalities of nerve function were **fairly common** in the rheumatoid group.
- **Significantly**, we found that the activation energy for oxidation in both gases is **much** higher.
- The yeast samples were, however, found to be **relatively** poor sources for dehydrogenases.
- Overall, there was a **close similarity** between the biological activity and immunoreactivity of plasma ACTH in the three specimens.
- The impacts of other micronutrients were **in general quite** weak.
- Extracts prepared at 0.3 M NaCl were **only slightly** active while extracts prepared at concentrations of 0.35 0.5 M NaCl were **quite** active.
- **In several cases** the chromaticity of exposed skin was **noticeably** different from that of unexposed skin.
- **Notably**, the non-magmatic IAB and IIICD irons display overlapping Zn contents, in accord with the previous conclusion that these two groups are **closely related**.
- The solenoid valve **frequently** generated a more accurate pressure response.
- Ageing of the alloy showed that the YS was **virtually** unchanged.
- Survival rates in the steroid treated patients were **essentially identical** to those of the placebo treated patients.
- The magnitudes of the ionic displacements were found to be **extremely** large.
- These abnormalities were **invariably** preceded by symptoms of toxicity.
- The calculated Young's modulus was **almost** constant in the area above the nucleus.
- There was a **striking** difference in the image contrast between the gradient echo image and the spin echo image.
- The colours of the two lights were found to be **extremely similar**, if not identical.

- The amount of dye adsorbed on gold was **even higher** than that on the silver particles.
- Breaks in nanotubes were **rarely** observed following specimen cutting.

COMPARISON WITH RESULTS IN OTHER RESEARCH/MODELLED RESULTS/ PREDICTED RESULTS

as expected,	**Verbs**
better than	accord with
broadly similar to	align with
comparable to	compare well with
comparatively (low/high etc.)	confirm
consistent with	contradict
contrary to	correlate with
(effectively) the same as	corroborate
(essentially) identical	deviate from
in accordance with	differ
in (good) agreement with	disprove
in contradiction to	mirror
in contrast to	prove
in line with	refute
much the same as	reinforce
not dissimilar	resemble
not unlike	substantiate
relative to	support
similar	validate
unlike	verify
well known	

Note: The verb tense may change as time passes and knowledge and information develop. This means that a sentence like *X has been found to occur*[4] in a paper from five years ago may now be written as *X occurs*[4] or even simply *X occurs*.

Adding risk-reducing phrases such as *appear to, seem to, tend to* can be used to communicate the level of certainty the writer wants to express (see ***IMPLICATIONS AND EXPLANATIONS OF RESULTS*** on page 182, Section 3.5 ***THE CERTAINTY CONTINUUM,*** and Section 4.5 ***MODAL VERBS***).

Here are some examples of how these are used:

- These data **appear to confirm** the prevalence of Vitamin D deficiency in the normal population.
- Thus, the new data from the Human Genome Project **tend to corroborate** the result in Fig. 2.
- Our results **differ from** those in the literature, and **agree better with** published CDF data.
- These new results are **consistent with**, and **substantially more** sensitive than, previously published anisotropy measurements.
- The bubble growth predicted from numerical analysis **compares well with** that obtained in this work.
- The location of the gas concentration in the simulation is **in remarkably good agreement with** that of the observed dust lanes.
- The accumulation rates **we observed are in line with** those reported from sulfate incorporation methods.

PROBLEM/S and ISSUES/S

minimise problem *(no big deal)*	**minimise responsibility *(not my fault)***	**maximise good aspects *(I got good stuff anyway)***
a preliminary attempt	as far as possible	despite this
acceptable	difficult to (simulate)	fairly well
did not align precisely	hard to (control)	nevertheless
immaterial	impossible	quite good
insignificant	impractical	reasonably robust
less than ideal	inevitable/ly	**….and focus on a solution or a reason**
less than perfect	(it was) difficult to	future work should...
marginal/ly	(it was) hard to	

minor deficit negligible effect non-ideal/not ideal not complete not identical not perfect not significant of no consequence of no significance reasonable slightly (disappointing) (some) imperfection/s somewhat (problematic) technicality unimportant	limited by necessarily not examined not explored in this study not investigated not possible not within the scope of this study unavoidable unexpected unfortunately unpredictable unreachable unworkable	future work will… further work is required (is) currently in progress (is) currently underway [this] was because…

Here are some examples of how these are used:

- **Inevitably**, considerable computation was involved.
- **Unfortunately, it was not possible to** quantify the extent of Zn loss from the experimental charges.
- Only a brief observation was feasible, **however**, given the number in the sample.
- **Although** centrifugation could not remove all the excess solid drug, the amount remaining **was negligible**.
- Solutions using (q=1) **differed slightly** from the analytical solutions.
- **A further study will** examine dc-dc converters to determine whether these efficiencies can be achieved in practice.
- While the anode layer was slightly thicker than 13 µm, **this was a minor deficit**.
- **Future work should** therefore include numerical diffusion effects in the calculation of permeability.
- This type of control saturation is fairly common and therefore **of no significance**.

IMPLICATIONS AND EXPLANATIONS OF RESULTS (see example sentences below in Section 3.5: THE CERTAINTY CONTINUUM)

could* be explained by could* be interpreted as could* be seen as likely perhaps possible presumably probably unlikely **Verbs** deduce imply indicate infer mean signify suggest	apparently, evidently, in part due to… it appears that… it could* be inferred that… it is [fairly/abundantly] evident that… it is [very/highly] probable/likely that… it is logical that… it is thought/believed that… it may (well) be that… it may be concluded that… it may/can be assumed that… it seems (very/highly) probable/likely that… it seems that… it would seem/appear that… the evidence suggests that… there is evidence to indicate that… this implies/seems to imply/may imply that… this is (compelling) evidence for… this is indicative of… this seems to suggest that… we have confidence that… we propose that…

**Note*: *could* can be replaced by *may or might,* or sometimes *can*. There is a section on how to use these modal verbs in the next Unit.

3.5. Language and Writing Skills: The Certainty Continuum

The Results section presents the relationship between what you did and what you found/what happened. Sometimes there is enough evidence for you to state that what you did definitely caused a particular result to occur; at other times you may be certain that it did, but you do not have sufficient evidence. How do you communicate that level of confidence to readers?

Another function of the Results section is to indicate the possible implications of your findings. Sometimes you may be certain that your findings imply something, but your results do not prove it. The certainty continuum runs from speculation all the way to proof. Where do your beliefs about your results fit on that continuum? How confident are you? How certain are you? How committed are you to those beliefs, and how do you communicate that to readers?

3.5.1 Choose a verb that accurately reflects the causal relationships you are describing

Some communicate a direct/strong causal connection (*cause, produce, be due to*).
Some refer to a partial cause (*contribute to, be a factor in*).
Some imply a causal process (*lead to*).
Some refer to the initial cause in a causal chain (*originate in*).
Some refer to a product rather than an effect (*produce/yield*).
Some communicate an indirect/weak/implicit causal connection (*be related to, be linked to*).

(be) a factor in	accompany	govern
(be) a/the cause of	account for	influence
(be) a/the consequence of	affect	initiate
(be) a/the result of	arise from	lead to
(be) ascribed to	cause	originate in
(be) associated with	contribute to	produce
(be) attributed to	create	result from
(be) connected to	drive	result in
(be) due to	generate	yield
(be) linked to	give rise to	
(be) related to		

In some cases, the position of the cause and the effect are fixed by the verb. For example, in *X produced Y*, X is the cause and Y is the effect; in *X originated in Y*, X is the effect and Y is the cause. In other cases, such as *X is linked* to *Y*, the writer may simply want to indicate that X and Y are connected in some way. These verbs (*linked to, connected to, related to*) do not specify which is the cause and which is the effect — nor do they even mean that the connection between the two is necessarily a cause-effect relationship.

Articles and prepositions also affect the meaning of cause/effect statements. For example:

- if X is **a** cause of or **a** result of something, this implies that other factors were also involved, whereas if X is **the** cause of or **the** result of something, this implies that X is the only cause or result.
- *X results **from** Y* means that X is a/the consequence of Y. *X results **in** Y* means Y is a/the consequence of X.

3.5.2 Choose the appropriate verb tense

In Unit 1 **(Section 1.5.1 Verb tense choices)** it was noted that tense choice can communicate the writer's confidence in the permanent value or permanent truth of the results. For example, in these sentences:

> *We found that sunbathing **was related to** cancer.*
> *We found that sunbathing **is related to** cancer.*

the Past Simple ***was related to*** simply describes what the authors found in their study; the findings are linked to that study and are not presented as generally-accepted or established truths. By contrast, choosing the Present Simple ***is related to*** reflects a belief that the findings are reliable enough to constitute a permanent truth.

3.5.3 Adding risk-reducing language

Adding language such as *it appears that…/there is evidence to indicate that…* can be used to reduce the risk level of a statement. Other risk-reducers include:

- frequency qualifiers such as *often, commonly* (see pages 175–177).
- quantity qualifiers such as *in some cases, in virtually all cases* (see pages 172–174).
- modal verbs such as *may, might* (see the **Discussion** unit, Section 4.5).

In summary, Section 3.5 suggests language along the entire certainty continuum. Once you are clear about where your beliefs about your results fit on that continuum and how committed you are to those beliefs, select the appropriate language. You can use the language in Section 3.5 to communicate all levels of confidence and certainty, from **absolute certainty** to **a very tentative suggestion about the possible implications of your results**:

- *We **find/found that** sunbathing **causes** cancer.*
- *We **find/found that** sunbathing **may** cause cancer.*
- *We **find/found evidence to suggest that** sunbathing **may be related to** cancer.*
- ***It appears therefore that in some cases**, sunbathing **may have been related to** the onset of cancer.*
- ***The evidence points to the possibility that in some cases, excessive** sunbathing **may have contributed to** the onset of **certain types of** cancer.*

Here are some examples from Results sections in recent published research to show how language is used to communicate different levels of confidence and certainty:

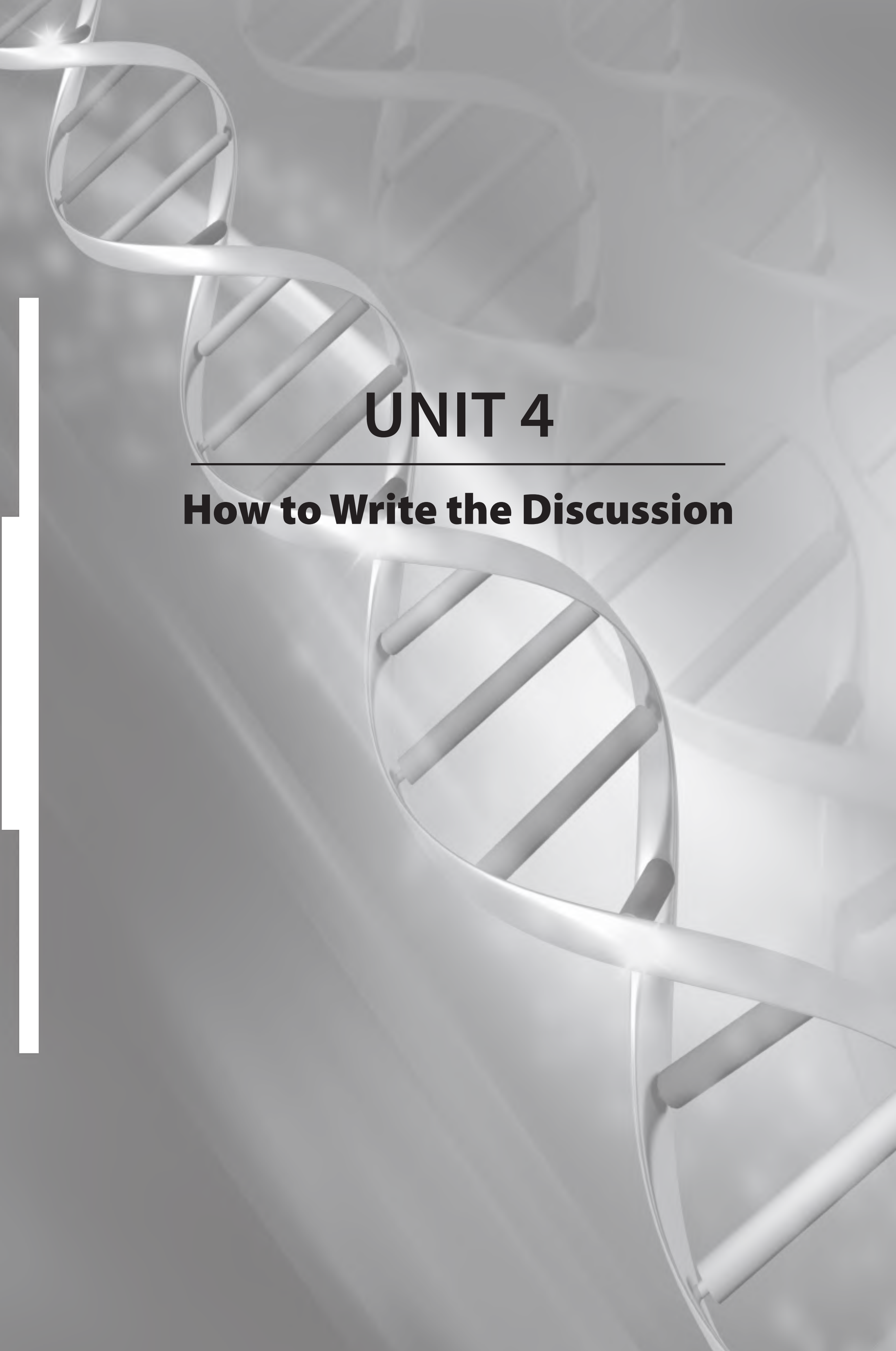
- The temperature of the Ti target **appeared to be somewhat** critical.
- **It seems therefore** that the plating solution **probably affects** the ceria.
- The identified pattern **is potentially indicative of** altered cellular processes.
- **It is** therefore **reasonable to suppose that** the duplexity of pitch **is a reflection of** duplexity in the auditory process.
- Therefore, from these results **it could be inferred that** the sealant did not improve the coating protective performance.

- The Zn correlations of the samples (Figs. 3, 4a–c) are hence **most plausibly explained by** indigenous processes.
- This **provides strong evidence for** the importance of NADW in glacial-interglacial climate change.
- We **speculate that this reflects** the increase in blood pressure that is known to occur in some of these patients.
- **It is therefore possible that** the correlations reflect variable contamination.
- **This suggests that** the polysulfide **may** undergo more complicated electrochemical reactions with **likely** involvement of more polysulfide species.
- **These results indicate that** EGFR mutations **may** predict sensitivity to gefitinib.
- The differences in recurrence rates increased over time, **suggesting that** there is a carryover effect.
- **It seems**, **therefore**, **that** spontaneous reactivation of viral replication **may be** a rare event in HBsAg-positive patients**.**
- Therefore, **it appears that** the plating solution **probably affects** the ceria within the anode composite.

TIPS FOR WRITING A SUCCESSFUL RESULTS SECTION

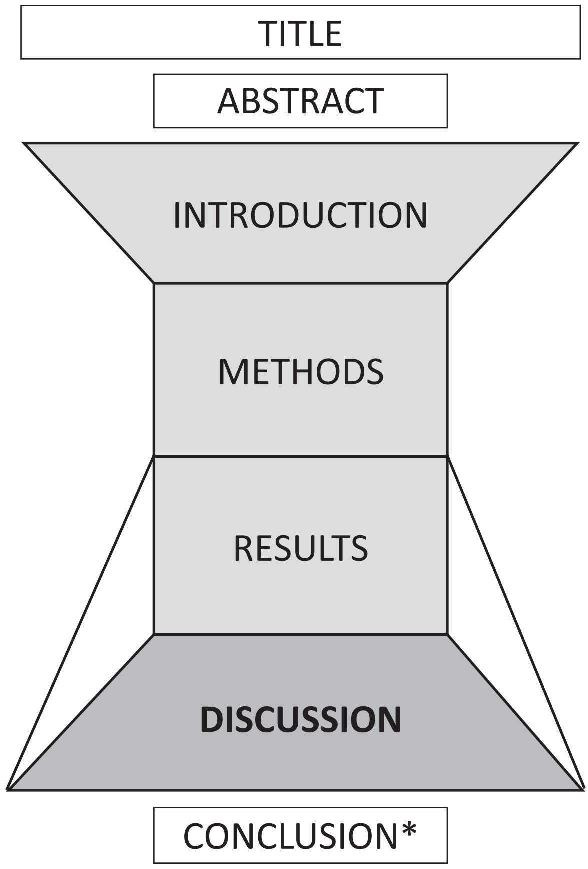
- Check the format of Results sections in your target articles in terms of length, subsections and subtitles.
- Check where the Methods section normally appears in your target journal, and how this impacts on the content of the Results section, i.e. how much information about the method is included in the Results section.
- Plan the structure of the entire Results section before you start creating whole sentences: decide the order in which you will present your results, the subsections and their headings, and the location of graphics.
- Review the Introduction after you have obtained your results to ensure that the aim of the paper as stated in the Introduction matches the outcome of the study.
- Remember that many readers will move directly from the title or Abstract to the Results, so include enough information for the Results to function as a standalone section.

- Remember that data and results do not speak for themselves. Present the results within a narrative that leads the reader logically and naturally towards the interpretations and conclusions you want to draw and that you want your reader to share.
- Check the amount of commenting/evaluative language in the Results sections of your target articles.
- Decide where your results and the implications of your results fit on the certainty continuum, and choose language that represents that location.



UNIT 4

How to Write the Discussion



*Some journals call this section CONCLUSION and others call it CONCLUSIONS but this does not seem to reflect the number of conclusions that are drawn.

4.1. How to Write the Discussion

As stated on page 141, the Results section will be treated separately from the Discussion section, and the Discussion section will be treated separately from the Conclusion. This is to ensure that you can train yourself to recognise — and therefore create — the components that are characteristic of each section, whether you keep them separate or combine them.

4.1.1 Wrapping the discussion in a narrative

The key to a successful Discussion section is a forward-moving, well-organised *narrative wrap* (see page xiv) that leads the reader patiently, logically and explicitly from the results to the conclusions.

Before planning the Discussion, it is helpful to begin by stepping back from the study and considering its **main value or contribution**. For example:

- Has the study obtained identical or similar results to other studies but uses a modified or new method that is better than existing methods? *In that case, the main contribution may be the method*.
- Has the study obtained better (e.g. more accurate) results than other studies? *In that case, the main contribution may be the results themselves.*
- Is the study a game-changer, i.e. is it setting a new direction for research/invalidating previous work? *In that case, the main contribution of the study may be its impact on the literature/research world.*
- Has the study identified or created new or extended applications? *In that case, the main contribution may be its impact on industry/the real world.*

This sets a clear 'destination' that can be explicitly communicated to the reader via the narrative, and also ensures that the take-home message of the study will not get lost in irrelevant detail. Researchers typically spend less than 30 minutes reading a research article, so it is essential to prioritise and communicate the main value or contribution as unequivocally as possible.

4.2. Building Your Own Model

Although the order of individual components in the Discussion is flexible, the components themselves are relatively straightforward, and follow the symmetrical 'shape' of the research article. The Introduction starts out by being fairly general and gradually narrows towards the Method/Results, whereas the Discussion moves away from the Method/Results towards a wider focus. Reviewing the generic Introduction model below is therefore a good starting point.

GENERIC INTRODUCTION MODEL (FROM Unit 1)	
Block 1	**ESTABLISH THE IMPORTANCE OF THE TOPIC/FIELD** **PROVIDE BACKGROUND FACTUAL INFORMATION** **PRESENT THE GENERAL PROBLEM AREA/CURRENT RESEARCH FOCUS**
Block 2	**PRESENT PREVIOUS AND/OR CURRENT RESEARCH AND CONTRIBUTIONS: the research 'map'**
Block 3	**LOCATE A GAP IN THE RESEARCH** **DESCRIBE THE PROBLEM YOU WILL ADDRESS** **PRESENT YOUR MOTIVATION AND/OR HYPOTHESIS** **IDENTIFY RESEARCH OPPORTUNITY**
Block 4	**DESCRIBE THE PRESENT PAPER, sometimes mentioning aims/results/methods/conclusions, and often including 'happy' ☺ words**

In Block 4 of the Introduction the writer describes the present paper or study, providing a logically-flowing interface between the Introduction and the central sections of the paper. *In the Discussion, writers often begin by revisiting some aspect of the study such as the research aim/gap or the key results. This sets the Discussion in motion; it enables the writer to create that interface in reverse and move away from the central report section in a logical flow towards the Conclusion/s.*

Block 3 presents a gap in the research or describes a problem that will be addressed in the research article. *In the Discussion, the writer is expected to say to what extent the study has responded to that gap or solved that problem.*

Block 2 presents a research map that identifies key studies and contributions. *In the Discussion the current study is positioned in relation to that research map*.

Block 1 provides an interface between the outside world and the research article that prepares the reader to 'cross the border' into the article by establishing that the topic is significant, providing background information and/or identifying the current focus of research. *The end of the Discussion creates a similar interface, preparing the reader to exit the article and carry the key message to the outside world and/or the research world.*

The diagram below shows how the Introduction and the Discussion mirror each other:

4.2.1 EXERCISE 1: Using your own target articles to build a Discussion model

In this Unit you are encouraged to use the reverse-engineering approach to build ***a model that represents the Discussion section in current research articles in your field that deal with your own research topic***.

With the above symmetrical diagram in mind, generate a list of potential components by reverse engineering the Discussion sections of your target articles. To create this list, write a brief description of the function of each sentence in the Discussion section of at least TWO target articles. When you have finished, read the analysis of the simplified Discussion section below, and then compare your list with the generic model on page 208. Some components in your list will be similar to those in the generic model; others will be specific to the research topic you are dealing with, the current conventions of your field, or the type of article you are writing. Integrate your list with the generic list to produce a robust set of model components for the Discussion section in your current research area, and adapt or update this as necessary.

An assessment of post V2D sequelae in disease survivors

Discussion

1 *To our knowledge, the study reported here is the largest study of patients who have survived the viral disease V2D, and provides a key contribution to the understanding of post-V2D health issues following infection.* ***2*** *Our study is the first to record a wide range of post-V2D complications, and provides clear evidence that survivors who experience a given symptom during V2D infection often present with a closely-related symptom within 300 days following infection.* ***3*** *This was particularly true in relation to some specific complications, such as hearing loss (Fig. 1).* ***4*** *A key finding was that some post-V2D health issues appear to be age-related: infants below the age of 2 experienced post-V2D cardiac complications far less frequently than adults irrespective of the severity of such complications during the acute stage (Figs. 2a and 2b).* ***5*** *This has clear implications for post-V2D-related public health management, and suggests that when resources are limited, cardiac screening priority could be given to adults.*

6 *Some questions remain; for example, anecdotal evidence collected from patients during the study period suggested that there was a positive correlation between viral load at the acute stage and the severity of post-V2D health issues.* ***7*** *However, this was not addressed formally during the study.* ***8*** *Although many studies have quantified viral load during acute V2D*[17,22,27,33]*, a direct comparison with the* *post-viral period would provide valuable data to support such a correlation.*

9 *V2D RNA is known to persist in the bodies of survivors long after disease onset*[30,42]*, and the results of our study provide compelling evidence that follow-up of all convalescent patients is warranted for at least 10 months after discharge from hospital.* **10** *In addition, the study provides evidence-based guidance for pragmatic public health recommendations that include age-related follow-up and treatment of post-V2D complications.*

4.2.2 Key

In Sentence 1 *To our knowledge, the study reported here is the largest study of patients who have survived the viral disease V2D, and provides a key contribution to the understanding of post-V2D health issues following infection.* **the writer explicitly identifies the contribution of the study in relation to the existing literature and knowledge.**

Doesn't 'to our knowledge' sound a bit weak? Aren't I supposed to know whether it is the largest study or not?

In Sentence 1, the writer includes the phrase *to our knowledge* in case a study has been overlooked accidentally. Even after every effort has been made to search all relevant journals, it is difficult to be absolutely sure that no-one has ever done a particular type of study until now. Immediately before submission you should check current research as thoroughly as possible, using a wide range of keywords. The information you get from the internet will only be as good as your skill in looking for it, and it is unprofessional to make a mistake in a sentence like this. Research develops and is published at a very fast rate, and during the time it takes to submit to your target journal/receive peer review/redraft and resubmit, it is possible that similar research may have been published. If that is the case, don't panic. It may only be necessary to review and clarify the similarities and differences between your study and others in order to separate and identify the contribution yours makes to the topic.

Why begin the Discussion with this?

In the Methods and Results subsections, the writer can create a reader-friendly entry by beginning with a general statement about the content of that subsection. For example, in Unit 3 we saw that writers sometimes begin the Results section with a general statement about the results. However, although some Discussion sections do begin with a general statement about what the Discussion will contain, this is not common. In most cases, the Discussion begins in one of the following two ways, both of which create a clear path to the destination or take-home message of the article:

1. Identifying the achievement, contribution or potential applications of the study

The achievement, contribution, potential applications and impact of the study are key factors in relation to research funding and professional reputation, and this is driving a trend towards transparent and unambiguous statements about impact in the Abstract and the Discussion/Conclusion. Identifying the achievement, contribution or potential applications at the start of the Discussion sets up a thematic framework that keeps the impact firmly in your own mind as well as in the mind of the reader. The achievement may be obvious to you and to your immediate colleagues, but it is by no means certain that it will be obvious to all readers, particularly interdisciplinary readers.

Another reason for identifying the impact or value of the study early in the Discussion is that the reader may have a simple question that is governing a fast and highly selective reading of the article, such as *What exactly did this study manage to achieve?* or *How does this study affect my own research?* The reader may be an interdisciplinary reader with minimal knowledge of the technical aspects of the study, whose question is a more practical one: *What are the potential applications of these findings?* Beginning the Discussion by stating the achievement, contribution or potential applications is a strong response to this type of information-surfing.

2. 'Rebooting' the reader by:

- revisiting relevant background factual information.
- revisiting the gap in the literature or the aim of the study.
- revisiting key features of results or methods.

As discussed in the Preface, most readers don't read the entire research article linearly from beginning to end. Many only read the Title, Abstract and Discussion/Conclusion, and these need to be viable as standalone, independent communications. In addition, even if the reader has read the entire article up to this point, it should not be assumed that they have read it with the same focus and concentration as the writer, or that they remember everything they have read. For these reasons, writers often re-position or reboot the reader at the start of the Discussion section by restating relevant aspects of the study.

If I decide to 'reboot' the reader, how do I choose which part/s of the article to revisit?

The success of the Discussion relies on a controlling narrative that clearly identifies the primary value of the study, and that takes the reader logically and effectively to the Conclusion. That narrative begins with the first sentence of the Discussion, so thinking about the main achievement or contribution of your study (see Section 4.1.1) may help you decide what to focus on first. For example, if the main contribution of your study is the change or modification you have made to an existing method, you might begin by revisiting the difficulties associated with that existing method, or by revisiting the key features and comparative advantages of your new method. If the main achievement of your study is that your results are more accurate than existing results, or reveal new information, you may begin by revisiting your results. If the main contribution of your study is that it provides a strong response to the gap or problem identified in the Introduction, you may begin by revisiting that gap.

Using similar sentences to those in the section you have chosen to revisit will provide an echo for the reader and will help them recall or find that section. As always, reverse engineer by looking at how writers in your target journals start the Discussion section.

In Sentence 2 *Our study is the first to record a wide range of post-V2D complications, and provides clear evidence that survivors who experience a given symptom during V2D infection often present with a closely-related symptom within 300 days following infection.* **the writer identifies the specific novel feature of the study in relation to the existing literature, and summarises the results.**

In what way might my study fit into the existing literature?

Mapping the study onto the existing literature and knowledge identifies where your 'product' sits in the research 'market'. Mapping is a central function of the Discussion and demonstrates how the study moves the research topic forward. For example, your method may generate results faster than previous methods, which could affect the status of those methods and their application. Your study may confirm results obtained in a previous study, which would validate that study, and perhaps also its conclusions. Alternatively, your study may contradict results obtained in a previous study, which would raise a question about those results and potentially set a new direction for research.

How many citations should there be in the Discussion?

Citations are essential to position your study and separate your contribution from previous knowledge. You can get a rough idea of what is normal for a given topic in a particular journal by simply averaging the number of citations in the Discussion sections of your target articles. Pay attention to the function of each citation, its location, how often that particular citation is repeated, and how each citation supports the Discussion. Every citation should be relevant, and its relevance should be made explicit to the reader via the narrative.

In the example below, sentences that develop the relationship between the current study and existing research/knowledge have been 'lifted' off a Discussion to show how the narrative is constructed around the citations. It is particularly useful to look at the way the sentences start, as these phrases develop the relationship between the current study and the existing literature and knowledge.

We first demonstrated that ___________, consistent with the literature (2, 4, 45).
In particular, ___________ was shown to___________ (40).
Regarding this concern, Söderholm et al. (45) reported that ___________.
In contrast, O'Malley et al. (34) reported___________.
To verify this assumption, ___________was used, as previously depicted for ___________ (7, 38).
Using ___________, Lai et al. (27) demonstrated that ___________.
As a result, ___________, as determined by Rahli et al. (36).
In line with this, a recent in vivo study by Wrzosek et al. (47) clearly showed that___________.
Likewise, the role of ___________has been proposed by Gaudier et al. (18).

Edited extract from: Stress disrupts intestinal mucus barrier in rats via mucin _O_-glycosylation shift: prevention by a probiotic treatment[q]

Discussion

IBS is a multifactorial disease, frequently associated with psychological distress and characterized by altered gastrointestinal motor function, viscerosensitivity, and, more recently, low-grade inflammation and impaired intestinal barrier function. Noteworthy, a positive correlation between increased intestinal permeability and visceral pain has been shown in IBS patients (2). Since stressful life events contribute to the IBS symptom exacerbation, the most commonly animal models reproducing "IBS-like" symptoms result from the use of central nervous system-directed stressors (33). In this study, WAS was used as a reliable model of chronic psychological stress. **We first demonstrated that a 4-day WAS induced intestinal epithelial barrier impairment, consistent with the literature (2, 4, 45). In particular, for WAS, colonic permeability increase was shown to occur from the third day of a 5-day stress application (40).** […] information regarding the effects of chronic stress on mucus barrier, a major actor ensuring intestinal barrier integrity, remains scarce in IBS-like models. **Regarding this concern, Söderholm et al. (45) reported that a 10-day WAS decreased the number of mucus-containing goblet cells in the ileum and colon and increased bacterial adhesion.** A reduction in the goblet cell number was also depicted in the duodenum of maternally deprived rats (15). **In contrast, O'Malley et al. (34) reported an increased colonic mucus secretion and number of goblet cells in maternally deprived rats.**

[…] Larsson et al. (29) depicted in active phase UC patients an altered Muc2 *O*-glycosylation profile, which was correlated with inflammation severity. Such profile was characterized by changes in the rate of glycanic structures and decreased overall sulfation (29). More recently, the same group showed that mucus of patients with active UC was penetrable ex vivo to 2-µm-sized fluorescent beads (24), suggesting that biochemical changes in mucins impact mucus "penetrability," resulting in a loss of barrier integrity. In this framework, we hypothesized that structural *O*-glycan alterations induced by stress may in turn change the physical properties of intestinal mucus. **To verify this assumption, AFM was used, as previously depicted for the characterization of conformational and hydrodynamic properties of individual mucin polymers (7, 38).** […] At the nanoscale, mucus has been described as a heterogeneous mesh network of mucin fibers (41, 44). **Using engineered nonmucoadhesive nanoparticles, Lai et al. (27) demonstrated that the mesh structure of human cervicovaginal mucus was more open (average pore size 340 ± 70 nm, range ~50–1800 nm) than the 15- to 100-nm pore size expected.** […] **As a result, the mucus network may exhibit higher pore size and increased permeability since, for a given porosity (in the range 0–0.7), the permeability of a fibrous network is directly proportional to the square of the fiber diameter, as determined by Rahli et al. (36) for porous media made up of randomly packed monodisperse fibers.**

[…] Direct or indirect regulation of glycosylation enzymes may be a possible candidate. **In line with this, a recent in vivo study by Wrzosek et al. (47) clearly showed that commensal bacteria, such as *Bacteroidetes thetaiotaomicron*, could directly influence goblet cell development and enhance expression of genes encoding host enzymes involved in mucin glycosylation, like sialyltransferase *st3gal4*.** In an in vitro study, Freitas et al. (17) deciphered the ability of a heat soluble factor from *B. thetaiotaomicron* to modulate specifically the galactosylation pattern of HT29-MTX cells, through a mechanism involving posttranslational induction of glycosyltransferase activities. **Likewise, the role of other bacterial metabolites, and particularly butyrate, as factors directly acting on mucin glycosylation has been proposed by Gaudier et al. (18).** […]

Can I cite a study in the Discussion that I have not mentioned earlier?

This depends on how relevant the citation is to your Discussion. Citations that mention the interpretations of data in another study or applications discussed in another study are highly relevant to the Discussion, and as such could be mentioned there for the first time.

How do I know which tense to use?

Reverse engineering a recent target text will generate useful data about verb tense in the Discussion. For example, the number of sentences in the Present Simple tense that provide background factual information will give you a good idea of how common — and therefore how necessary — such information is for the type of study you are doing and the readership you are targeting.

Why is Sentence 2 in the Present Simple tense?

Verb tense is often a matter of choice, in which case it reflects what the writer wants to communicate rather than referring to when an event occurred. In Unit 1 **(Section 1.5.1 Verb tense choices)** it was noted that tense choice can communicate the writer's confidence in the permanent value or permanent truth of a statement. For example, if we were to rewrite Sentence 2 above in the Past Simple tense (*…clear evidence that survivors who experienced a given symptom during V2D infection often* ***presented*** *with a closely-related symptom following infection.*) the sentence would just describe what the authors found in their study. Using the Past Simple tense implies that the results are linked to that study rather than being presented as permanent, independent truths. By contrast, choosing the Present Simple tense (*…clear evidence that survivors who experience a given symptom during V2D infection often* ***present*** *with a closely-related symptom following infection.*) empowers the statement, and reflects the writer's belief that the findings are reliable enough to constitute a permanent, independent truth.

Unlike most decisions regarding the conventions of academic writing in science, choosing which tense to use for communicating results and the implications of results cannot really be resolved by looking at target articles for guidance. In most cases, the writer needs to make his or her own decision about whether the data is robust enough to support a statement in the Present Simple tense. Notice that even when the Present Simple tense is chosen, it is possible to include some disclaimers that mitigate the writer's confidence in or commitment to the statement: often present with a closely-related symptom.

In Sentences 3 and 4 *This was particularly true in relation to some specific complications, such as hearing loss (Fig. 1). A key finding was that some post-V2D health issues appear to be age-related: infants below the age of 2 experienced post-V2D cardiac complications far less frequently than adults irrespective of the severity of such complications during the acute stage (Figs. 2a and 2b).* **the writer revisits the results and comments on them** *(particularly true…a key finding was…appear to be…far less)***.**

I've been told that the Discussion section shouldn't repeat the results. Should I mention the results at all? And if so, how do I mention them without repeating them?

There is considerable overlap between the Results and Discussion sections. For example, as we saw in Unit 3, in the Results section most writers include a comment about what the results *suggest* or *imply* although in theory, this belongs in the Discussion. Equally, it is difficult, if not impossible, to develop the implications in the Discussion without referring to or repeating key results, since they provide the evidence that underpins and validates those implications. However, repeating or even re-wording key results is not sufficient; the Discussion should move on from the Results. The aim of research is not simply to obtain and describe results; it is to make sense of those results in the context of existing knowledge, and to say something sensible and useful about their implications, i.e. what the results mean in that context, and how they relate to the original question, hypothesis or objective stated in the Introduction. **Saying what your results *are* is the central function of the Results section; going on to talk about or explore what they *mean* is the central function of the Discussion.**

Reverse engineering successfully-published texts will help you avoid a 'should I or shouldn't I?' dilemma, and will focus your attention instead on what successful writers actually do. If you examine the Discussion sections in your target journals, you will see that virtually all Discussion sections repeat or summarise key results in order to anchor the interpretations and implications.

What if I'm not confident about what my results mean?

Science research never reaches an endpoint where everything is known about a particular topic. Most science writers are careful not to make over-confident generalisations because the next piece of research will refine and develop the preceding one, and so on. However, it is equally important not to underplay the implications of your work just to be on the safe side, as this undermines and diminishes it.

It is essential that the level of certainty you attribute to the meaning of your results can be validated on the basis of those results and existing knowledge. Choosing the appropriate language is critical here. If the language you use to discuss the meaning of your results does not match or reflect the power of the results this is likely to be a point of criticism at the peer-review stage. You can choose language that shows you are confident about what your results mean, or you can choose language that tells the reader you are speculating about their meaning (see **Section 3.5: The Certainty Continuum**, pages 183–186).

Why are Sentences 3 and 4 in the Past Simple tense? Is that related to the level of certainty?

As stated above, the writer chooses a verb tense that reflects the appropriate level of confidence or certainty.

How do the verb tenses in these sentences affect the reader's response?

- *A key finding was that some post-V2D health issues appeared to be age-related…*
- *A key finding was that some post-V2D health issues appear to be age-related…*
- *A key finding is that some post-V2D health issues appear to be age-related…*

It's a good idea to highlight the verbs in the Discussion sections of your target articles and consider how the tense affects your response as a reader. Does the verb tense seem to 'match' the power of the results?

In Sentence 5 *This has clear implications for post-V2D-related public health management, and suggests that when resources are limited, cardiac screening priority could be given to adults.* **the writer mentions a potential application arising from the results.**

Isn't it better to mention potential applications at the end of the Discussion?

The end of the paper interfaces with the research world via suggestions for future research, and with the real world via potential applications, so it is certainly appropriate to mention applications at the end of the paper. However, there seems to be a growing trend to state the main contribution or applications at the start of the Discussion. In some cases, the potential applications are themselves the main contribution of the study or a central theme of the Discussion, which is a good reason for stating them at the start of the Discussion. Check your target journal frequently to see how it is responding to current trends and developments.

Suppose my work doesn't have any obvious or current applications?

Although many studies don't have obvious applications, it's a good idea to check in two places before you give up on the idea. First, look at the Introductions in your target articles as well as your own Introduction, because the Introduction often mentions in what way this type of research can be used. Another possible source is the Discussion or Conclusion section of your target articles, as these may include speculations about potential future applications.

Including potential applications shows the value of your study beyond the aims of your specific research question. However, research has many functions — it may clarify a theory, or it may simply add the next layer of knowledge onto a developing field, so the type of research you do may not have a clear application at this stage, or ever.

In Sentences 6, 7 and 8 *Some questions remain; for example, anecdotal evidence collected from patients during the study period suggested that there was a positive correlation between viral load at the acute stage and the severity of post-V2D health issues. However, this was not addressed formally during the study. Although many studies have quantified viral load during acute V2D[17,22,27,33], a direct comparison with the post-viral period would provide valuable data to support such a correlation.* **the writer mentions a limitation of the study** *(this was not addressed formally during the study)* **that leads to a suggestion for future research.**

How do I decide which limitations to focus on here? Can I mention the limitations of the study for the first time in the Discussion?

Most limitations derive from problems or issues encountered during the study, and these are normally mentioned for the first time in the relevant subsection. However, in this case, the *anecdotal evidence* was not a formal or intentional part of the data collection procedure, nor was it presented as a result. It is linked to a suggestion for future research, and as such it is acceptable to mention it for the first time in the Discussion.

Another possible reason for mentioning a limitation for the first time in the Discussion is if you are finding it difficult to commit to your conclusions because of the need for further work. This is a limitation that can be mentioned in the Discussion and linked to an invitation to the research community to continue and make further progress.

Why should I try to fix the direction of future work — why not let researchers decide for themselves?

Good studies are rarely an end in themselves; in most cases, they open up forward directions for research. Inviting the research community to follow your work in a specific way has many advantages. First, it provides researchers with a rational, defined project, which is more attractive than a vague suggestion and therefore more likely to be carried out. Second, it encourages a line of direct continuity from your research. Studies that follow from your own will cite your paper, which enhances the status of your study. In addition, a study which responds to difficulties or limitations that you encountered may provide you with useful data for your current and future work. The obvious question at this point therefore is: where should the research go next?

In Sentence 9 *V2D RNA is known to persist in the bodies of survivors long after disease onset*[30,42]*, and the results of our study provide compelling evidence that follow-up of all convalescent patients is warranted for at least 10 months after discharge from hospital.* **the writer mentions background factual information in the literature** *(is known to persist)* **to support the conclusions of the study.**

Do I really need to add more background information even at this late stage?

As stated above, paying attention to the function of each citation in the Discussion section of your target articles, its location, and how it supports the Discussion will give you a benchmark for current writing in your field. The number and location of sentences in the Present Simple that cite background factual information will give you a good idea of how common — and how necessary — such information is at each point in the Discussion section.

In Sentence 10 *In addition the study provides evidence-based guidance for pragmatic public health recommendations that include age-related follow-up and treatment of post-V2D complications*. **the writer closes strongly with the applications of the study.**

4.2.3 A Discussion model

Now compare the sentence descriptions below with the list you made in Section 4.2.1, Exercise 1:

In Sentence 1, the writer	explicitly identifies the contribution of the study in relation to the existing literature and knowledge.
In Sentence 2, the writer	identifies the specific novel feature of the study in relation to the existing literature, and summarises the results.
In Sentences 3 and 4, the writer	revisits the results and comments on them.
In Sentence 5, the writer	mentions a potential application arising from the results.
In Sentences 6, 7 and 8, the writer	mentions a limitation of the study that leads to a suggestion for future research.
In Sentence 9, the writer	mentions background factual information in the literature to support the conclusions of the study.
In Sentence 10, the writer	closes strongly with the applications of the study.

These can be streamlined to create a basic, generic Discussion model (see next page). **Integrate this model with the list of components you created in Section 4.2.1 to generate a robust set of model components for the Discussion section in your own current research area which you will adapt or update as your research develops.** The order of components is reasonably fluid; however, those at the top of the list tend to occur early in the Discussion while those at the bottom tend to occur later or towards the end.

GENERIC DISCUSSION MODEL
ANNOUNCE THE STRUCTURE OR CONTENT OF THE DISCUSSION SECTION
STATE THE ACHIEVEMENT/CONTRIBUTION OF THE STUDY*
REVISIT BACKGROUND INFORMATION/LITERATURE TO 'REBOOT' READER
REVISIT GAP/AIM/METHOD
REVISIT RESULTS AND EXPLORE THEIR IMPLICATIONS
MAP TO LITERATURE/KNOWLEDGE FOR COMPARISON/SUPPORT
IDENTIFY POTENTIAL LIMITATIONS AND SUGGESTIONS FOR FUTURE WORK
RESTATE THE ACHIEVEMENT/CONTRIBUTION/IMPACT OF THE STUDY
IDENTIFY POTENTIAL APPLICATIONS

**Note*: The ACHIEVEMENT/CONTRIBUTION of the study is the most free-flowing component — in some cases it occurs both at the start and at the end, as in this model; in others it occurs throughout the Discussion.

Is there a difference between the ACHIEVEMENT and the CONTRIBUTION?

Sometimes they are the same thing. The achievement is internal to the study and is linked to the success of resolving the specific research question stated in the Introduction. For example, if the study aimed to *identify* something, then identifying it is the achievement of the study. It's easier for the reader to track this if the writer uses the same verb, rather than switch to a so-called synonym such as *find* or *detect*. The contribution is more outward-facing, essentially how the study affects the real or research world in terms of applications or knowledge.

4.3. Testing and Adjusting the Basic Generic Model

4.3.1 A demonstration of the model

Identify the model components in the Discussion section below. Language that exemplifies the model components is in **bold** type. Notice how the model creates a narrative framework for the Discussion.

Rapid alloy prototyping: compositional and thermo-mechanical high throughput bulk combinatorial design of structural materials based on the example of 30Mn–1.2C–xAl triplex steels[p]

5. Discussion

5.1 Microstructure and mechanical properties of the 30Mn–1.2C–xAl steels

The **novel** bulk RAP approach **introduced in this work provides, for the first time**, a systematic evaluation of the compositional and thermo-mechanical trends associated with a change in the Al content of a group of Triplex steels with high Mn and C concentrations. **We observed that** without the addition of Al to the 30Mn–1.2C steels **the most favourable mechanical properties were obtained for** the as-homogenised state (Figs. 2 and 3a). **The observed properties are in reasonable agreement with data reported for** Mn–C alloyed TWIP steels of a **similar** chemical composition **[27, 28]**. **The observed embrittlement during ageing can be related to** the formation of the coarse, pearlitic particles on the grain boundaries **[27]** (Fig. 5a).

High amounts of Al (~8 wt.%), on the other hand, **result in** pronounced strengthening during ageing, depending on the time and temperature (Figs. 2 and 3c), and no coarse particles **could be observed in this case** (Fig. 5c). **In the light of previous results this typical** precipitation hardening behaviour, which **allows** tuning of the strength and ductility, **can be explained by** the formation and growth of j carbides during ageing **[17, 18, 21]**. **Due to** their **reportedly small** size, which is of the order of several nanometres, the j carbides **could not be reliably detected or identified** in the high throughput RAP OM observations conducted in this study. The darker particles visible in Fig. 5c **might be linked to** j carbides.

Alloys with intermediate Al concentrations (about 2–6 wt.%) **do not offer** mechanical properties on the same level compared with the aforementioned extreme cases under their respective optimal conditions (i.e. after the respective most suitable ageing treatments). On the other hand, a **much smaller** influence of the ageing parameters on tensile behaviour **can be observed in these cases** (Figs. 2 and 3b).

Within the limitations of this study (confined range of applied heat treatments, OM investigations, etc.) **this improved stability** of the mechanical properties during thermal exposure **can be attributed to** a concerted formation of j carbides and grain boundary pearlite, balancing the strengthening and embrittlement effects of intermediate amounts of Al.

In general it should be underlined that detailed investigations of the role of j carbides and pearlite particles on the deformation mechanisms, as well as the precipitation type and the structural nature of the j carbides (i.e. spinodal vs. nucleation/growth), **require** higher resolution techniques, such as TEM or APT. **Nonetheless**, the mechanical data on both RAP (Figs. 2 and 3) and conventionally synthesised and processed alloys (Fig. 6a) **are in good agreement with previously reported values** for Fe–Mn–Al–C steels [17,18]. The RAP results **suggest that future efforts** regarding more detailed nanostructural investigations **should focus on** such high-C triplex steels with high Al concentrations (>8 wt.%), as they **offer the possibility of** covering the widest range of mechanical properties via ageing treatments (scalability, Fig. 2) and exhibit the lowest possible specific weight of all such steels.

4.3.2 EXERCISE 2: Identifying the model components

Here are two more Discussion sections from research articles in different disciplines. They have been edited for length, and ellipses are marked as [...]. In the first one, identifiers of the model are in **bold** in the first half of the Discussion. In some cases, the verb is in **bold** to draw attention to the function of the verb tense. Underline the identifiers of the model in the second half of the Discussion, and then underline the identifiers of the model for the whole of the second Discussion.

Notice how the way the sentences start reveals the narrative scaffold containing the information.

1 Sensory nerve induced inflammation contributes to heterotopic ossification[r]

Discussion

Heterotopic ossification **is** a disorder involving rapid bone formation within muscle, tendon, and ligaments, adjacent to skeletal bone, and **it has been linked to** an elevation in BMP2 signaling **[Shore and Kaplan, 2010]**. **Further**, the incidence of HO **appears to be** dramatically increased in individuals who have sustained traumatic injury to the nervous system **[Forsberg *et al*., 2009]**. **Here we determined whether** localized changes in BMP signaling, which lead to heterotopic bone formation, can also alter peripheral nerve signaling through induction of neuroinflammation. **Our results suggest that** in the presence of BMP2, sensory neurons **express** mediators of neuroinflammation, resulting in the recruitment of mast cells and remodeling of the nerve structure.

BMP2 **has been shown previously to** induce the expression of the neuroinflammatory mediators, substance P and CGRP, in sensory neuron cultures **[Bucelli *et al*., 2008]**. **Here we quantified** changes in these mediators, in vivo, after delivery of cells expressing BMP2. **We found** a **significant and immediate** elevation of both proteins, in relation to the control, which **received** the same cells transduced with an Adempty virus. **Interestingly, we observed** a **strong** correlation in elevation of these mediators, **immediately** following our delivery of BMP2. **However**, as the process continued over time, **we observed** a cyclical pattern in the expression of these mediators, with a **significant** decline in expression on day 2, followed by a **significant** rise in expression on day 3, and a trend towards another increase in expression by day 6. **Although** BMP2 would presumably be expressed for the first 3–4 days, prior to the rapid clearance of the cells **[Fouletier-Dilling *et al*., 2007]**, the kinetics of BMP2 receptor signaling in this model **is unclear**. **Intriguingly**, one of the first steps **is** the rapid formation of brown adipocytes within the tissues

[Olmsted-Davis *et al.*, 2007]. **We have previously shown** brown adipocytes to be necessary for patterning of the new bone, by their unique capacity to regulate the oxygen microenvironment, not only by stimulation of new vessels, but also by uncoupling of aerobic respiration and ''burning'' of oxygen **[Olmsted-Davis *et al.*, 2007]**. The result of this uncoupling **is** a release of energy as heat, which **could potentially** re-stimulate sensory neurons to respond and release substance P and CGRP. **This could potentially explain** the observed cyclical nature of the response, **suggesting** secondary or tertiary signaling events.

Performing the assay in animals lacking TRPV1, **we saw** a significant decrease in the volume of heterotopic bone formed, compared to animals with functional TRPV1. The suppression, rather than complete ablation, **suggests that** other TRPV family members present on sensory neurons **may also** contribute to the induction of HO. **Although we do not rule out** alterations in other peripheral nerve signaling to the central nervous system in these animals, both substance P and CGRP **were found to be significantly** decreased in the TRPV1 mice. **We still observed a trend towards** an increase in substance P and CGRP upon addition of the AdBMP2 transduced cells. **However, this was not** above the normal background levels observed in wild type mice, nor was it statistically significant for CGRP, and the induction was over three folds lower for SP, **so it is unclear whether this** contributes to HO. **The result that** BMP2 **does** not induce SP or CGRP in TRPV1 mice **is not surprising, as it has been previously shown that** TRPV1 **induces** SP in response to capsaicin **[Theriault *et al.*, 1979]** and that TRPV1 also **controls** heat- and acid-induced CGRP release from sensory nerves **[Kichko and Reeh, 2009]**. **In addition, previous studies have revealed** decreased injury-induced neuropeptide release in TRPV1 mice **[Wang and Wang, 2005]**. While TRPV1 **is unquestionably involved** in pain and neuroinflammation, TRPV **has also been found** to be involved in diabetes **[Razavi *et al.*, 2006]** and obesity **[Motter and Ahern, 2008]**. Whether this is by the same mechanism proposed here, or by alternative mechanisms, **remains undetermined**. **Consequently**, deletion of TRPV1 **could have** additional pleiotropic effects. TRPV1 mice receiving Adempty transduced cells **did not produce** heterotopic bone, **which is in line with our previous findings** that Adempty transduced cells **have not produced** HO in any animal model we have tested **[Olmsted-Davis *et al.*, 2002]**.

Mast cells **are known to be** recruited to nerves during times of neuroinflammation. Upon degranulation, mast cells **release** a number of digestive factors, chymases, tryptases, and other enzymes, which can cleave proproteins, leading to their activation. **These factors appear to be essential** for tissue remodeling of not only the nerve, but also other surrounding tissues, including the vasculature **[Johnson *et al*., 1988; Richardson and Vasko, 2002; Kleij and Bienenstock, 2005; Schaible *et al*., 2005; Kulka *et al*., 2008]**. Nerve remodeling **is thought to be** part of neurite outgrowth, or the ability to remodel and extend neurons. **Perhaps** this process is utilized to innervate the newly forming HO. **Alternatively, Adameyko *et al*. [2009] recently demonstrated** the presence of a stem cell population residing within peripheral nerves that would migrate from the nerve to undergo melanocyte differentiation. **We quantified** the number of mast cells after induction of HO **and found a significant** elevation in this population within 48 h, when compared to tissues receiving the control cells. **We observed** an upward trend in the number of mast cells on all days. **However, perhaps due to** the immune response evoked to clear the injected cells, **there was** also an increase in mast cell numbers in the control tissues, leading to a significant difference only on day 2. **Further, we observed** the mast cells, within the first 48 h, associating with the nerves and within the nerves, as compared to control tissues where the mast cells were usually located randomly throughout the tissues. **It is intriguing that we observed** the most significant difference at these early stages, since **this appears to parallel our findings** for the release of SP and CGRP within the tissues, **suggesting** mast cells **may be** recruited after release of these factors.

[…]

We next looked at whether the nerve remodeling was releasing cells that were essential to bone formation. As noted above, it has been previously demonstrated that precursors in peripheral nerves are the origin of skin melanoctyes. Therefore, mast cell degranulation, and subsequent nerve remodeling, was blocked using cromolyn, and we observed a significant decrease in HO. We next analyzed the nerves from these animals and found an increase in cells expressing markers of early stem cells (nanog and Klf4). These primitive markers were sporadic in the nerves of untreated animals, but completely covered the nerve in the cromolyn treated animals. This not only suggests that the early tissue changes lead to expansion of these cells, but also that the pool size of these cells within the nerve of untreated animals is extremely low, due to concomitant and rapid migration and differentiation. However, blockade of these latter steps with cromolyn leads to accumulation of these cells expressing primitive markers within the nerve. We note here, however, that the mechanisms of cromolyn action are incompletely understood. Although cromolyn is widely characterized as a ''mast cell-stabilizer'' (i.e., an agent that blocks the release of mast cell mediators following appropriate activation of the cell) that can suppress mouse mast cell function in vivo, its molecular targets are neither fully defined nor restricted to mast cells [Galli *et al*., 2008]. Moreover, while the mechanism of action of cromolyn mainly involves mast cell degranulation [Cox, 1967], other mechanisms, such as inhibition of neutrophils and eosinophil induced chemotaxis [Bruijnzeel *et al*., 1990], have also been described.

To our surprise, we observed osterix positive cells on the nerve as early as day 2, in the presence of cromolyn. There were also cells that expressed primitive stem cell factors, which appeared to simultaneously express osterix, suggesting that these cells are osteoblast precursors. The majority of osterix positive expression was associated with the nerve. We also observed Klf-4$^+$ and nanog$^+$ cells that were not associated with osterix, suggesting that these cells may have other potentials. Besides osteoblasts, another possible fate of these cells may be brown adipocytes, which we have shown previously to be critical for reduction of the oxygen tension in the microenvironment for cartilage formation [Olmsted-Davis *et al*., 2007] and for secreting VEGF for vessel formation [Dilling *et al*., 2010]. It has recently been noted that the Misty mouse phenotype [Sviderskaya *et al*., 1998], which is deficient in brown fat, is caused by a mutation in dock 7 [Blasius *et al*., 2009], a neuronal factor that regulates Schwann cell migration and neuronal polarity. It is intriguing to speculate that brown fat progenitors may also reside in peripheral nerves, particularly since TRPV1 responds to heat [Szallasi *et al*., 2007]. Additionally, it is interesting that the mutation in a single neuronal protein, dock7, not only dramatically increases HO in the Misty mouse [Olmsted-Davis *et al*., 2007], but also causes severe osteoporosis in the skeletal bone (Rosen C., unpublished). Further, we previously demonstrated the rapid formation of new vessels early after BMP2 induction [Dilling *et al*., 2010], suggesting that several types of tissues are being assembled simultaneously during this period. Osterix has previously been suggested to play a role in osteoblast lineage commitment of progenitors, suppressing the adipose phenotype [Cheng *et al*., 2003]. Perhaps the early osterix expression, 4 days prior to the appearance of osteoid matrix, may be part of a regulatory mechanism to preserve these cells for future osteogenic fate. Finally, although not highlighted in this manuscript, we did observe osterix positive cells, at later times, in vessel-like structures that co-aligned with early endothelial markers, such as flk 1, which we have previously identified as characteristic of this early vasculogenesis [Dilling *et al*., 2010]. This notion supports the work of Lounev *et al*. [2009], suggesting that osteoblast progenitors reside within the newly forming vessels, have a Tie 2 marker, and are not derived from marrow [Kaplan *et al*., 2007]. Other investigators have also provided evidence for this concept of osteoblast progenitors being associated with the vasculature [Kolf *et al*., 2007; Medici *et al*., 2010].

This study is the first step in identifying a potential direct role for the peripheral nervous system in the induction of heterotopic ossification. The data suggest that early neuroinflammation, elicited in the presence of BMP2, may be capable of expanding a population of cells within the nerve, which can migrate and potentially contribute to a number of structures, rapidly assembling to produce HO. Suppression of these steps significantly decreases HO formation. Although it is unclear what effects this may have on the adjacent skeletal bone, the data suggest that there is direct communication with the hypothalamus, which could, in part, signal to impact bone remodeling. Understanding these earliest steps of HO will, for the first time, provide us novel targets for therapeutic intervention, which may ultimately lead to effective treatments. Finally, it is conceivable that such a mechanism could play a role in many other disease states, including neurofibromatosis and vascular calcification.

2 Supervised learning in spiking neural networks with FORCE training[s]

Discussion

We have shown that FORCE training can take initially chaotic networks of spiking neurons and use them to mimic the natural tasks and functions demonstrated by populations of neurons. For example, these networks were trained to learn low-dimensional dynamical systems, such as oscillators which are at the heart of generating both rhythmic and non rhythmic motion[45]. We found FORCE training to be robust to the spiking model employed, initial network states, and synaptic connection types.

Additionally, we showed that we could train spiking networks to display behaviors beyond low-dimensional dynamics by altering the supervisor used to train the network. For example, we trained a statistical classifier with a network of Izhikevich neurons that could discriminate its inputs. Extending the notion of an oscillator even further allowed us to store a complicated sequence in the form of the notes of a song, reproduce the singing behavior of songbirds, and encode and replay a movie scene. These tasks are aided by the inclusion of a high-dimensional temporal signal (HDTS) that discretizes time by segregating the neurons into assemblies.

FORCE training is reminiscent of how songbirds learn their stereotypical learned songs[35,46]. Juvenile songbirds are typically presented with a species specific song or repertoire of songs from their parents or other members of their species. These birds internalize the original template song and subsequently use it as an error signal for their own vocalization[35–37,39,46–49]. Our model reproduced the singing behavior of songbirds with FORCE training as the error correction mechanism. Both the spiking statistics of area RA and the song spectrogram were accurately reproduced after FORCE training. Furthermore, we demonstrated that altering the balance between excitation and inhibition post training degrades the singing behavior post-training. A shift to excess excitation alters the spectrogram in a highly non-linear way while a shift to excess inhibition reduces the amplitude of all frequencies.

Inspired by the clock-like input pattern that songbirds use for learning and replay[35,36] we used a similar HDTS to encode a longer and more complex sequence of notes in addition to a scene from a movie. We found that these signals made FORCE training faster and the subsequent replay more accurate. Furthermore, by manipulating the HDTS frequency we found that we could speed up or reverse movie replay in a robust fashion. We found that compressing replay resulted in higher frequency oscillations in the mean population activity. Attenuating the HDTS decreased replay performance while transitioning the mean activity from a 4–8Hz oscillation to a slower (≈2Hz) oscillation. Finally, replay of the movie was robust to lesioning neurons in the replay network.

While our episodic memory network was not associated with any particular hippocampal region, it is tempting to conjecture on how our results might be interpreted within the context of the hippocampal literature. In particular, we found that the HDTS conferred a slow oscillation in the mean population activity reminiscent of the slow theta oscillations observed in the hippocampus. The theta oscillation is strongly associated to memory; however, its computational role is not fully understood, with many theories proposed[50–53]. For example, the theta oscillation has been proposed to serve as a clock for memory formation[50,54].

Here, we show a concrete example that natural stimuli that serve as proxies for memories can be bound to an underlying oscillation in a population of neurons. The oscillation forces the neurons to fire in discrete temporal assemblies. The oscillation (via the HDTS) can be sped up, or even reversed resulting in an identical manipulation of the memory. Additionally, we found that reducing the HDTS input severely disrupted replay and the underlying mean population oscillation. This mirrors experimental results that showed that theta power was predictive of correct replay[55]. Furthermore, blocking the HDTS prevents learning and prevents accurate replay with networks trained with an HDTS present. Blocking the hippocampal theta oscillation pharmacologically[56] or optogenetically[57] has also been found to disrupt learning.

The role of the HDTS is reminiscent of the recent discovery of time cells, which also serve to partition themselves across a time interval in episodic memory tasks[58–60]. How time cells are formed is ongoing research however they are dependent on the medial septum, and thus the hippocampal theta oscillation[61]. Time cells have been found in CA1[58], CA3[62] and temporally selective cells occur in the entorhinal cortex[63].

In a broader context, FORCE trained networks could be used in the future to elucidate hippocampal functions. For example, future FORCE trained networks can make use of biological constraints such as Dale's law in an effort to reproduce verified spike distributions for different neuron types with regards to the phase of the theta oscillation[64]. These networks can also be explicitly constructed to represent the different components of the well studied hippocampal circuit.

FORCE training is a powerful tool that allows one to use any sufficiently complicated dynamical system as a basis for universal computation. The primary difficulty in implementing the technique in spiking networks appears to be controlling the orders of magnitude between the chaos inducing weight matrix and the feedback weight matrix. If the chaotic weight matrix is too large in magnitude (via the G parameter), the chaos can no longer be controlled by the feedback weight matrix[1]. However, if the chaos inducing matrix is too weak, the chaotic system no longer functions as a suitable reservoir. To resolve this, we derived a scaling argument for how Q should scale with G for successful training based on network behaviors observed in ref. [1]. Interestingly, the balance between these fluctuations could be related to the fading memory property, a necessary criterion for the convergence of FORCE trained rate networks[65].

Furthermore, while we succeeded in implementing the technique in other neuron types, the Izhikevich model was the most accurate in terms of learning arbitrary tasks or dynamics. This is due to the presence of spike frequency adaptation variables that operate on a much slower time scale than the neuronal equations. There may be other biologically relevant forces that can increase the capacity of the network to act as a reservoir through longer time scale dynamics, such as synaptic depression and NMDA mediated currents for example[66–68].

Furthermore, we found that the inclusion of a high-dimensional temporal signal increased the accuracy and capability of a spiking network to reproduce long signals. In ref. [2], another type of high-dimensional supervisor is used to train initially chaotic spiking networks. Here, the authors use a supervisor consisting of $O(N^2)$ components (see ref. [2] for more details). This is different from our approach involving the construction of an HDTS, which serves to partition the neurons into assemblies and is of lower dimensionality than $O(N^2)$. However, from ref. [2] and our work here, increasing the dimensionality of the supervisor does aid FORCE training accuracy and capability. Finally, it is possible that an HDTS would facilitate faster and more accurate learning in networks of rate equations and more general reservoir methods as well.

Although FORCE trained networks have dynamics that are starting to resemble those of populations of neurons, at present all top-down procedures used to construct any functional spiking neural network need further work to become biologically plausible learning rules[1,5,8]. For example, FORCE trained networks require non-local information in the form of the correlation matrix $\mathbf{P}(t)$. However, we should not dismiss the final weight matrices generated by these techniques as biologically implausible simply because the techniques are themselves biologically implausible.

Aside from the original rate formulation in ref. [1], FORCE trained rate equations have been recently applied to analyzing and reproducing experimental data. For example, in ref. [69], the authors used a variant of FORCE training (referred to as Partial In-Network Training, PINning) to train a rate network to reproduce a temporal sequence of activity from mouse calcium imaging data. PINning uses minimal changes from a balanced weight matrix architecture to form neuronal sequences. In ref. [70], the authors combine experimental manipulations with FORCE trained networks to demonstrate that preparatory activity prior to motor behavior is resistant to unilateral perturbations both experimentally, and in their FORCE trained rate models. In ref. [71], the authors demonstrate the dynamics of reservoirs can explain the emergence of mixed selectivity in primate dorsal Anterior Cingulate Cortex (dACC). The authors use a modified version of FORCE training to implement an exploration/exploitation task that was also experimentally performed on primates. The authors found that the FORCE trained neurons had a similar dynamic form of mixed selective as experimentally recorded neurons in the dACC. Finally, in ref. [72], the authors train a network of rate neurons to encode time on the scale of seconds. This network is subsequently used to learn different spatio-temporal tasks, such as a cursive writing task. These FORCE trained networks were able to account for psychophysical results such as Weber's law, where the variance of a response scales like the square of the time since the start of the response. In all cases, FORCE trained rate networks were able to account for and predict experimental findings. Thus, FORCE trained spiking networks can prove to be invaluable for generating novel predictions using voltage traces, spike times, and neuronal parameters.

Top-down network training techniques have different strengths and uses. For example, the Neural Engineering Framework (NEF) and spike-based coding approaches solve for the underlying weight matrices immediately without training[5,6,8,9,11]. The solutions can be analytical as in the spike based coding approach, or numerical, as in the NEF approach. Furthermore, the weight matrix solutions are valid over entire regions of the phase space, where as FORCE training uses individual trajectories as supervisors. Multiple trajectories have to be FORCE trained into a single network to yield a comparable level of global performance over a region. Both sets of solutions yield different insights into the structure, dynamics, and functions of spiking neural networks. For example, brain scale functional models can be constructed with NEF networks[8]. Spike-based coding networks demonstrate how higher order error scaling is possible by utilizing spiking sparsely and efficiently through balanced network solutions. While the NEF and spike based coding approaches provide immediate weight matrix solutions, both techniques are difficult to generalize to other types of networks or other types of tasks. Both the NEF and spike based coding approaches require a system of closed form differential equations to determine the static weight matrix that yields the target dynamics.

In summary, we showed that FORCE can be used to train spiking neural networks to reproduce complex spatio-temporal dynamics. This method could be used in the future to mechanically link neural activity to the complex behaviors of animals.

4.4. Useful Words and Phrases

This section lists words and phrases for the Discussion section from analysis of over 2,500 published research articles in different disciplines. The list only includes words and phrases which appear frequently and are therefore considered normal and acceptable by writers and editors. The list will also keep the flow of writing moving. Underneath each list there are examples of how the words and phrases are used in sentences, so look at the list and the sentence examples when you are feeling stuck and can't think of what to write or how to continue.

Language suggestions for many of the components of the Discussion have appeared in previous Units. For example:

- ANNOUNCE STRUCTURE OR CONTENT OF DISCUSSION SECTION — see Unit 1
- [REVISIT] LITERATURE — see Unit 1
- [REVISIT] GAP/AIM OF STUDY — see Unit 1
- [SUMMARISE/REVISIT] KEY FEATURES OF RESULTS/ METHOD — see Units 2 and 3
- RESULTS + EXPLANATION — see Unit 3
- RESULTS + INTERPRETATION/IMPLICATION — see Unit 3
- LIMITATIONS — see Units 2 and 3

When you revisit previous sections, don't change the language or the sentence for the sake of style. Your aim is to create an echo that will remind the reader of what was said before, so repeating the same words and phrases is advantageous. By contrast, changing the language can be a disadvantage, since it places a burden on the reader to work out whether it refers to the same thing. For example, if the aim of the study as stated in the Introduction was to *identify* something, it is helpful to the reader if the same verb is used in the Discussion to describe the achievement of the study.

4.4.1 Language task

EXERCISE 3 The following five model components occur for the first time in the Discussion:

1 MAP TO LITERATURE/KNOWLEDGE
2 REFINE/EXPLORE IMPLICATIONS

3 ACHIEVEMENT/CONTRIBUTION TO LITERATURE/KNOWLEDGE
4 CURRENT AND FUTURE WORK
5 APPLICATIONS/USE/APPLICABILITY/IMPLEMENTATION

Look through the Discussion sections in this unit and in your target research articles. Underline or highlight words or phrases that you think could be used in these five areas, and compare your suggestions with the lists in Section 4.4.2.

4.4.2 Language for the Discussion section

1 MAP TO LITERATURE/KNOWLEDGE

an alternative scheme/strategy	**Verbs:**
analogous to	This study/These results
comparable to	
consistent with	challenge
contrary to	compare well (with)
distinct from	complement
entirely different	confirm
equivalent to	conflict (with)
except for	contradict
fundamentally the same as	correspond to
identical to	corroborate
in accordance with	differ from
in agreement with	disprove
in conflict with	expand
in contrast to	extend
in good agreement (with)	improve
in line with	mirror
new/novel	modify
previously described/reported/suggested	pave the way for
rather than	prove
recently	provide insight into
significantly different (to/from)	provide support for
similar	refute
the first time/first of its kind	resemble

to the best of our knowledge, unlike	shed new light on substantiate support verify

Note: A simple comparative (e.g. *stronger/more accurate/quicker*) is also effective here, and the GAP/PROBLEM language from Unit 1 is useful to recall previous/current knowledge or show how the gap in the literature has been filled.

Here are some examples of how these are used:

- **Rather than** being excluded **as is often suggested**, the sulfate reducers seemed to be thriving.
- The frequency domain algorithm proposed here **resembles** the so–called Frisch Scheme approach.
- **Unlike existing** control schemes, in this scheme the parameters can be freely changed during operation.
- This is **in agreement with** results from recent studies which suggest that iron reducers can modify their rate of respiration.
- Our data therefore **provide support for** the theory proposed by Stephen Robbins [Robbins *et al*., 2013].
- The presented structure-based approach **complements existing** experimental methods.
- This study **extends** previous research by analysing corporate brand and industry image simultaneously.
- These results **are consistent with** the theory that fungal infection leads to plant death.
- The current study therefore both **confirmed and expanded** prior research into these mechanisms.
- On the basis of these results, **we challenge** the assumptions made by existing physical-layer security systems.

2 REFINE/EXPLORE IMPLICATIONS

A full list of language to communicate implications can be found on page 182 **IMPLICATIONS AND EXPLANATIONS OF RESULTS**. The list reflects the fact that in the Discussion the implications are sometimes expressed in a more abstract, general or theoretical way, or by using language that permits evidence-based speculation.

plausible potential tentative to hypothesise to postulate to speculate to theorise	modal verbs (esp. may/might/could) it is conceivable that… it is reasonable to assume that… this is reinforced by… this is substantiated by… this points to… we cannot rule out…	Clearly, Indeed, Perhaps

Here are some examples of how these are used:

- **It is conceivable that** such a mechanism **could** play a role in many other disease states.
- We **postulate that** Brownian motion of nanoparticles in nanofluids produces convectionlike effects at the nanoscale.
- A **tentative** explanation is that the colloidal system **may** be agglomerated at that treatment level.
- **We hypothesize that** our work **could** serve as a catalyst for new forms of real-time interventions.
- It is intriguing **to speculate** that brown fat progenitors **may** also reside in peripheral nerves.
- However, **we do not rule out** the possibility of a reaction with hemicellulose and lignin.

3 ACHIEVEMENT/CONTRIBUTION

It is essential to communicate the value of your study explicitly, and a range of options is given in (i) Positive language ('happy' words). In some cases, the achievement or contribution is extremely exciting or highly significant. Science writing does not generally permit the use of the exclamation mark (!), but there are many acceptable ways of communicating that 'wow!' feeling, and these are listed in (ii) !-substitutes ('very happy' words).

(i) Positive language ('happy' words)

accurate advantage appealing appropriate attractive beneficial clear comprehensive convenient convincing correct cost-effective direct easy economical effective	efficient encouraging entirely exact fast favourable feasible flexible important intuitive low-cost new novel practical precise productive realistic relevant	reliable robust significant simple smooth stable straightforward strong successful superior systematic unambiguous useful valid valuable versatile viable	**Verbs/verb phrases:** allow avoid compare well with confirm enable enhance ensure explain facilitate help to improve is able to offer outperform	prove provide a first step provide a framework provide evidence of provide insight into remove the need for resolve reveal solve streamline succeed in support validate yield

(ii) !-substitutes ('very happy' words)

compelling crucial dramatic excellent exceptional	exciting extraordinary ideal invaluable outstanding perfect	powerful remarkable superb surprising striking	undeniable unique unusual unprecedented unquestionably vital

Here are some examples of how these are used:

- This results in a **cost-effective** approach which **significantly improves** scalability.
- We were able to demonstrate a **striking** difference between neonates at high and at low risk of atopy.
- This work demonstrates that multimodel predictions can **provide a more reliable estimate** of uncertainty.

- We describe not only neutral but also ionized systems with **unprecedented accuracy**.
- The system described here **enables fast and easy** analysis of LRRC8 proteins.
- The study **provides a first step** towards a **better** representation of southern African dust sources in dust emission models.
- We achieved **outstanding** performance compared to similar catalysts reported in the literature.
- The **rapid, easy-to-perform** mRNA-based method presented here is a **robust** approach to detect rare coding.
- The system described here provides **novel** means to **systematically** study this in diseased tissues.
- A **straightforward** analysis procedure is presented which **enables accurate** prediction.
- The model is thus **both realistic and flexible**, taking advantage of both types of computational phantoms.
- The analytical method described here **removes the need for** difficult and time-consuming pre-treatment.

4 CURRENT AND FUTURE WORK

a/the need for at present currently encouraging fruitful promising urgent further work is needed future work/ studies should	holds promise possible direction research opportunities include… starting point the next stage we recommend we suggest worthwhile would be beneficial/ useful would be of interest	should be explored should be investigated should be replicated should be validated further work is planned* future work/studies will* is being investigated* work is (currently) underway* work is in progress*

**Note*: These indicate that the writer is currently working on this; they are NOT suggestions for research by others, or invitations to other researchers.

Here are some examples of how these are used:

- **Future studies should** investigate whether reducing household air pollution may lead to improvement in cardiac morbidity.
- Developing a model able to answer all these questions is an exciting challenge **for future studies**.
- **Future work should** focus on a qualitative analysis of patient-reported benefits of group therapy.
- **Further work is in progress** to determine whether a different drought response could help these trees to survive.
- In the future, **it would be of interest to** develop a more efficient numerical method for simulating these system dynamics.
- To support these findings, variations in cfDNA test performance **should be investigated** further.
- **Recommendations for future studies include** an investigation of polysaccharide redundancy during cell wall assembly.
- **Work is currently underway** to determine the extent of this genetic control.
- **Future research opportunities include** improving the measurement of sustainability indicators.

5 APPLICATIONS/USE/APPLICABILITY/IMPLEMENTATION

eventually in due course in future soon	to apply to enable to facilitate to generalise to generate to implement to lead to to operate/put into operation to produce to realise to serve as to use to utilise	applicable appropriate feasible operable practicable practical realistic suitable viable

Here are some examples of how these are used:

- The study **provides** evidence-based guidance for **realistic** public health recommendations.
- The dissection protocol outlined here is **appropriate** for all long bone analyses including ex vivo imaging.
- The approach presented here is also **suitable** for problems where structural information is incomplete.
- The experimental paradigm outlined here could be **used** to evaluate future robotic social agents.
- The proposed technique could be **implemented** widely within the bioprocess industry, including in the production of antibiotics.
- Although it focuses on the specific case of supernovae, the concepts presented here are **applicable** to other astrophysical cases.
- Our protocol will **enable** the transport and storage of samples, thereby **facilitating** mitochondrial function analysis of liver biopsies.
- We see miR-CLIP as a **broadly applicable approach that can be used** in conjunction with others.
- This work shows that low-cost air quality sensor networks are **feasible for widespread use**.
- The data reported in this study could **eventually lead to** recommendations to guide optimal Clozapine use.

4.5. Language and Writing Skills: Modal Verbs

Section 4.5 deals only with modal verb usage that is relevant for STEMM research writing or formal academic writing. Modal verb usage in informal or spoken communication, such as the use of *may* for permission, is not included.

To find out how reliable your current use of modal verbs is, match the modal verbs in Column A to their meanings in Column B. Most modal verbs can be used to communicate more than one meaning, so fill in the blank spaces with as many options as you can.

COLUMN A	COLUMN B
1 should 2 must 3 can 4 may 5 could 6 need to 7 might 8 have to	*The model **is able to** predict a wide range of experimental data.* = The model ____________ predict a wide range of experimental data. ***It is possible that** these interactions are the same for each species*. = These interactions ____________ be the same for each species. *The ratio **is expected to** remain constant if the expansion is uniform.* = The ratio ____________ remain constant if the expansion is uniform. ***It is obvious that** this is the result of direct collision between the electron and the nucleus.* = This __________ be the result of direct collision between the electron and the nucleus. ***It is advisable to** centrifuge the tubes before the experiment.* = The tubes ___________ be centrifuged before the experiment. ***It is necessary to** centrifuge the tubes before the experiment.* = The tubes __________ be centrifuged before the experiment.

Now check your answers with this Key:

The model ***is able to*** *predict a wide range of experimental data.*
The model **can/could** predict a wide range of experimental data.

It is possible that *these interactions are the same for each species.*
These interactions **may/might/could** be the same for each species.

The ratio ***is expected to*** *remain constant if the expansion is uniform.*
The ratio **should** remain constant if the expansion is uniform.

It is obvious that *this is the result of direct collision between the electron and the nucleus.*
This **must** be the result of direct collision between the electron and the nucleus.

It is advisable to *centrifuge the tubes before the experiment.*
The tubes **should** be centrifuged before the experiment.

It is necessary to *centrifuge the tubes before the experiment.*
The tubes **must/need to/have to** be centrifuged before the experiment.

4.5.1 Using modal verbs in research writing

Science research is rarely conclusive; studies generally aim at achieving a high level of certainty rather than irrefutable proof. Modal verbs such as *may, might, could, can, should, need to* and *must* are used throughout the research article to express levels of certainty and commitment. They are used in the Introduction to offer hypotheses (*could be due to…*) and identify gaps (*may provide valuable insight into…*); in the Methods section to validate choices (*this meant that we could measure …*); and in the Results section to explain results (*this might have been affected by…*).

In the Discussion section, modal verbs are used to perform a range of functions, for example to communicate the writer's belief that something is a **possible** explanation, a **potential** application, an **obvious** interpretation, a **recommended** direction for future work, or a **probable** implication. Here are two short extracts from Discussion sections which show the prevalence of modal verbs:

… In the light of previous results this typical precipitation hardening behaviour, which allows tuning of the strength and ductility, **can** be explained by the formation and growth of κ carbides during ageing [17, 18, 21]. Due to their reportedly small size, which is of the order of several nanometres, the κ carbides **could not** be reliably detected or identified in the high throughput RAP OM observations conducted in this study. The darker particles visible in Fig. 5c **might** be linked to κ carbides.

Extract from *Rapid alloy prototyping: compositional and thermo-mechanical high throughput bulk combinatorial design of structural materials based on the example of 30Mn–1.2C–xAl triplex steels*[p]

… Although it is unclear what effects this **may** have on the adjacent skeletal bone, the data suggest that there is direct communication with the hypothalamus, which **could**, in part, signal to impact bone remodeling. Understanding these earliest steps of HO will, for the first time, provide us novel targets for therapeutic intervention, which **may** ultimately lead to effective treatments. Finally, it is conceivable that such a mechanism **could** play a role in many other disease states, including neurofibromatosis and vascular calcification.

Extract from *Sensory nerve induced inflammation contributes to heterotopic ossification*[r]

Using the appropriate modal verb in the appropriate tense is essential. Incorrect, inconsistent, indiscriminate or careless choices make the take-home message of the study unclear or ambiguous at this crucial point.

If you write:

*The drop in pressure **may have been** caused by a crack in the pipe.*

you are offering **a possible cause** for the drop in pressure; perhaps it was caused by a crack in the pipe — and perhaps not.

If you write:

*The drop in pressure **must have been** caused by a crack in the pipe.*

you are saying that you are **certain** that the drop in pressure was caused by a crack in the pipe, but you **do not have evidence to prove it**, perhaps because evidence is impossible to obtain, or because it is so obvious that you don't need to provide evidence.

Being certain that something is true and *knowing* that it is true are not the same. For example, we do not look at a clock and say *I'm certain it is ten o'clock* or *It must be ten o'clock;* we simply say *it is ten o'clock.* Interestingly, we only say *It must be ten o'clock* if we cannot see a clock — in other words, when we lack empirical evidence. Although *must* seems to give the verb more power, it also communicates an absence of proof because when we say we are 'sure' that something is true, we are also involuntarily communicating that we don't actually *know* that it is true.

The grammar and usage of modal verbs is complex and does not follow regular grammar rules. For example, most modal verbs have more than one meaning: *should* can mean either 'advisable' or 'likely'. In addition some modal verbs change their meaning in the negative: *He must go home* and *He has to go home* both mean that it is essential or necessary that he goes home. However, *He **must not** go home* means that *it is **essential that he does not*** go home, whereas *He **does not have to** go home* means that *it is **not essential that he does*** go home.

An analysis of current research writing suggests that using alternative structures, e.g. *it is possible* rather than *it may,* is becoming increasingly common, perhaps because of these complexities and the risk of communicating the wrong message. Therefore, in the examples below alternative structures with the same or similar meaning are given where possible.

1 ABLE

Present Simple	**CAN**	The model **can** predict a wide range of experimental data. = *The model **is able to** predict a wide range of experimental data.*
Present Simple negative	**CANNOT**	This system **cannot** identify other pathogenic bacteria. = *This system **is not able to** identify other pathogenic bacteria.*

Past Simple	**COULD** **COULD HAVE**	The algorithm **could** convert unstructured data into spreadsheet format. = *The algorithm* ***was able to*** *convert unstructured data into spreadsheet format.* With a larger sample size, the method **could have** identified more infections. = *With a larger sample size, the method* ***would have been able to*** *identify more infections.*
Past Simple negative	**COULD NOT** *(was not able to)* **COULD NOT HAVE** *(would not have been able to)*	The robot **could not** react dynamically to changes in the environment. = *The robot* ***was not able to*** *react dynamically to changes in the environment.* Without this data, we **could not have detected** the contamination. = *Without this data, we* ***would not have been able to detect*** *the contamination*.

- If you're not sure whether to use **can** or **be able to**, use **be able to** — it's safer and less likely to be misinterpreted.
- If you need the future tense, use **will be able to**: *The model* ***will*** *eventually* ***be able to*** *predict a wide range of experimental data.*
- **could** means *possible* as well as *able*, so consider whether using **could** makes the meaning ambiguous.
- **could** also refers to conditional/hypothetical ability: *If there was a 100% uptake of the vaccine, this* ***could (would be able to)*** *prevent infection.*
- **be capable of** is an alternative to **can/could** in some contexts.

2 POSSIBLE/OPTIONAL

Present Simple	**MAY** **MIGHT** **COULD**	These interactions **may/could/might** be the same for each species. = ***It is possible*** *that these interactions* ***are*** *the same for each species.*

	CAN	This intervention **may/could/might** lead to effective treatments. = ***It is possible*** *that this intervention* ***will*** *lead to effective treatments.* The method presented here **can/could/may** be extended to other systems. = ***It is possible*** *to extend the method presented here to other systems*.
Present Simple negative	**MAY NOT** **MIGHT NOT** (but not **COULD NOT** or **CANNOT**; see page 236)	These interactions **may not/might not** be the same for each species. = ***It is possible*** *that these interactions* ***are not*** *the same for each species.* This intervention **may not/might not** lead to effective treatments. = ***It is possible*** *that this intervention* ***will not*** *lead to effective treatments*.
Past Simple	**MAY HAVE** **MIGHT HAVE** **COULD HAVE** (but not **CAN HAVE**)	This response **may have/might have/could have** caused the reduction in the noise level. = ***It is possible*** *that this response* ***caused*** *the reduction in the noise level*.
Past Simple negative	**MAY NOT HAVE** **MIGHT NOT HAVE** (but not **COULD NOT HAVE** or **CANNOT HAVE**; see page 236)	This response **may not have/might not have** caused the reduction in the noise level. = ***It is possible*** *that this response* ***did not cause*** *the reduction in the noise level.*

- The examples above show that in the Present Simple, **may/might/could** refer to future possibilities (***It is possible*** *that this intervention* ***will*** *lead to effective treatments*) as well as current/permanent possibilities (***It is possible*** *that these interactions* ***are*** *the same for each species*).

- **might** is slightly weaker than **may**, and it is less common in research writing.
- Don't use **may/might/could** just to stay safe or cover your back — if you're pretty sure about something and your results support your interpretation, upgrade to phrases such as *highly likely/probable/almost certain.*
- **can** is ambiguous and therefore risky. A sentence such as *Particle formation **can** occur in the boundary layer* could mean any of the following:

    - *Particle formation **may [possibly] occur** in the boundary layer.*
    - *Particle formation **is able to occur** in the boundary layer.*
    - *Particle formation **sometimes occurs** in the boundary layer.*

  Where there is a potential ambiguity, replace **can** with one of these.
- **can** is good for communicating options or choices: *An X or a Y **can** be used = It is possible to use either an X or a Y*.
- **can not** does not mean the same as **cannot**! **can not** means *possibly not* in the same way as **may not** or **might not**. It is used in structures such as *This **can not** only damage the sample, it **may** even destroy it completely.* By contrast, **cannot** means impossible (see page 236).
- **could not**, **cannot have** and **could not have** also mean *impossible*:

    - *This **cannot** be due to a change in pressure. (impossible)*
    - *This **could not** be due to a change in pressure. (impossible)*
    - *This **cannot have been** due to a change in pressure. (impossible)*
    - *This **could not have been** due to a change in pressure. (impossible)*

3 EXPECTED/LIKELY/PROBABLE

Present Simple	**SHOULD**	The ratio **should** remain constant if the expansion is uniform. = *The ratio **is expected to/is likely to/will probably** remain constant if the expansion is uniform.*
Present Simple negative	**SHOULD NOT**	The ratio **should not** change unless the expansion changes. = *The ratio **is not expected to/is not likely to/will probably not** change unless the expansion changes.*

Past Simple	**SHOULD HAVE**	Our data suggest that the decrease **should have** occurred during the first year. = *Our data suggest that the decrease* ***was expected to*** *occur during the first year.*
Past Simple negative	**SHOULD NOT HAVE**	Our data suggest that corrosion **should not have** occurred for at least two years. = *Our data suggest that corrosion* ***was not expected to*** *occur for at least two years.*

- **should have** often refers to something that didn't happen, whereas **should not have** often refers to something that did happen.
- **was likely/probable** and **was not likely/probable** do not refer to whether something did or did not happen; they refer to the level of certainty about a past event.
- **ought to** is the same as **should**, but it is becoming less common in science writing, so examples are not given.

4 OBVIOUS/IMPOSSIBLE

Present Simple	**MUST** **HAVE TO**	This **must** be the result of direct collision between the electron and the nucleus. = ***It is obvious that*** *this is the result of* direct collision between the electron and the nucleus.
Present Simple negative	**CANNOT**	This **cannot** be a result of direct collision between the electron and the nucleus. = ***It is impossible that*** *this is the result of* direct collision between the electron and the nucleus.
Past Simple	**MUST HAVE**	This effect **must have been** due to the increased rate of synthesis. = ***It is obvious that*** *this effect was due to the increased rate of synthesis.*
Past Simple negative	**CANNOT HAVE** **COULD NOT HAVE**	This effect **cannot have been/could not have been** due to the increased rate of synthesis. = ***It is impossible that*** *this effect was due to the increased rate of synthesis.*

- **OBVIOUS/IMPOSSIBLE** modals are used when you mean that *no other explanation is possible.*
- **must not** means *not allowed*, it doesn't mean *impossible*.
- **have to** is only used in spoken communication.

To understand the difference between **POSSIBLY**, **PROBABLY** and **OBVIOUS/IMPOSSIBLE**, imagine that it normally takes a colleague about 20 minutes to walk home from the lab. Has she arrived home yet? Well, without checking,

> if she left the lab 18 minutes ago, she **may/might/could** be home by now (*possibly*),
> if she left 30 minutes ago, she **should** be home by now (*probably*),
> if she left 50 minutes ago, she **must** be home by now (*obviously*),
> …but if she left only 5 minutes ago she **cannot** be home yet (*impossible*).

5 ADVISABLE/RECOMMENDED

Present Simple	**SHOULD**	The tubes **should** be centrifuged before the experiment. = ***It is advisable to** centrifuge the tubes before the experiment.*
Present Simple negative	**SHOULD NOT**	The tubes **should not** be centrifuged before the experiment. = ***It is not advisable to** centrifuge the tubes before the experiment.*
Past Simple	**SHOULD HAVE**	We later realised that the samples **should have** been diluted with water. = *We later realised that **it would have been advisable/a good idea to** dilute the samples with water.*
Past Simple negative	**SHOULD NOT HAVE**	The samples **should not have** been diluted with water. = *We later realised that **it was not advisable/not a good idea to** dilute the samples with water.*

- **should have** often refers to something that didn't happen, and **should not have** often refers to something that did happen.
- **ought to** is the same as **should**, but it is becoming less common in science writing, so examples have not been given.

We see from the above that **should** has two completely different meanings. It can be used to communicate that something is **EXPECTED/LIKELY/PROBABLE** and it can also be used to communicate that something is **ADVISABLE/RECOMMENDED**. Here are some examples of each — can you separate them into **EXPECTED/LIKELY/PROBABLE** and **ADVISABLE/RECOMMENDED**?

1. Each phial of cells **should** only be used once.
2. Vegetation productivity in tundra **should** increase if shrubs become more abundant.
3. To avoid errors, the calibrated hygrometers **should** be kept at a particular humidity.
4. Theorem 1 **should not** be used unless it is apparent that the conventional assumptions are invalid.
5. This data **should** improve the accuracy of geophysical parameter estimation techniques.
6. If extraction of the plasma cannot be performed immediately, the sample **should** be stored in a deep-freeze.
7. An oil with added antioxidant **should** be used to prevent rancidity.
8. The introduction of carbon nanotubes as a structure element in nanocomposites **should** improve the material properties.
9. Very alkaline soils **should** be washed thoroughly before using them for analysis.
10. This data suggests that the birth rate **should** remain close to 50/1000 for the rest of the 20th century.
11. The bias is the same for all groups, and therefore **should not** change the statistical results.
12. Graphical passwords **should** only be used with handheld devices.
13. All final solutions **should** be filtered through a fine-grain paper.

6 NECESSARY/ESSENTIAL

Present Simple	**MUST** **NEED TO** **HAVE TO**	The tubes **must/need to/have to** be centrifuged before the experiment. = ***It is necessary to*** *centrifuge the tubes before the experiment.*
Present Simple negative	**DO NOT NEED TO** **DO NOT HAVE TO** **NEED NOT**	The tubes **do not need to/do not have to/need not** be centrifuged before the experiment. = ***It is not necessary to*** *centrifuge the tubes before the experiment.*
Past Simple	**NEEDED TO** **HAD TO**	We found that the samples **needed to/ had to** be diluted with water. = *We found that it* ***was necessary to*** *dilute the samples with water.*
Past Simple negative	**DID NOT NEED TO** **NEED NOT HAVE** **DID NOT HAVE TO**	We found that the samples **did not need to be/did not have to be/need not have been** diluted with water. = *We found that it* ***was not necessary to*** *dilute the samples with water.*

- **must not** means *not allowed*, it doesn't mean *not necessary*.
- **did not need to** usually means *it wasn't necessary, and we didn't do it*, whereas **need not have** usually means *it wasn't necessary but we did do it*.
- **did not have to** is less common in formal science research writing.

4.5.2 Modal sentences exercise

Rewrite these sentences using *could, must, may, have to, should, can, might* or *need to* in the appropriate tense.

1. This software is capable of distinguishing between different viruses.
   This software ____
2. It is possible that the fall in pressure was due to a gas leak.
   The fall in pressure ____

3. It is essential to disconnect the equipment during repairs.
   The equipment ____
4. This material will probably remain stable if it is kept below 30°C.
   This material ____
5. It is impossible that the contamination was caused by the presence of salt.
   The contamination ______________________________________
6. Children are not able to use symbols to represent objects until the age of 18 months.
   Children ____
7. It is possible that using a rubber seal will not prevent contamination.
   Using a rubber seal _____________________________________
8. The use of antioxidant compounds is not advised.
   Antioxidant compounds __________________________________
9. This material is not likely to decompose if it is kept below 30°C.
   This material ____
10. It was obvious that the bicarbonate was produced by the mineralisation of carbon.
    The bicarbonate ____
11. We realised later that it was not necessary to expose the composite to heat.
    We realised later that the composite ______________________
12. If we had extended the time period, it would have been possible to produce more crystals.
    If we had extended the time period, we ____________________

4.5.3 Key

1. This software **can** distinguish between different viruses.
2. The fall in pressure **may have been/might have been/could have been** due to a gas leak.
3. The equipment **must be** disconnected during repairs.
4. This material **should** remain stable if it is kept below 30°C.
5. The contamination **cannot have been/could not have been** caused by the presence of salt.

6. Children **cannot** use symbols to represent objects until the age of 18 months.
7. Using a rubber seal **may not/might not** prevent contamination.
8. Antioxidant compounds **should not be** used.
9. This material **should not** decompose if it is kept below 30°C.
10. The bicarbonate **must have been** produced by the mineralization of carbon.
11. We realised later that the composite **need not have been/did not have to be/did not need to be** exposed to heat.
12. If we had extended the time period, we **could have** produced more crystals.

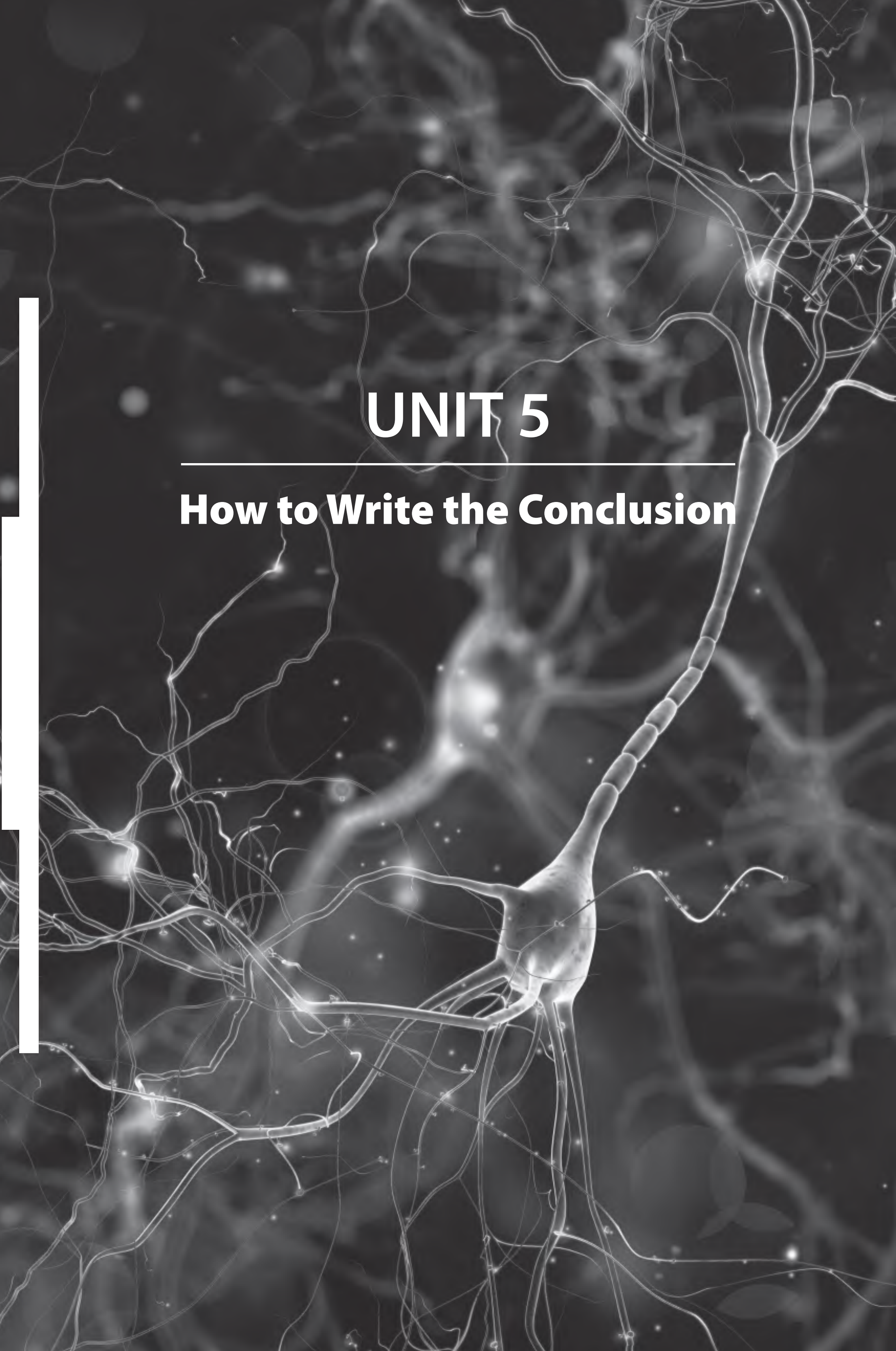
4.6. Summary Discussion Exercise

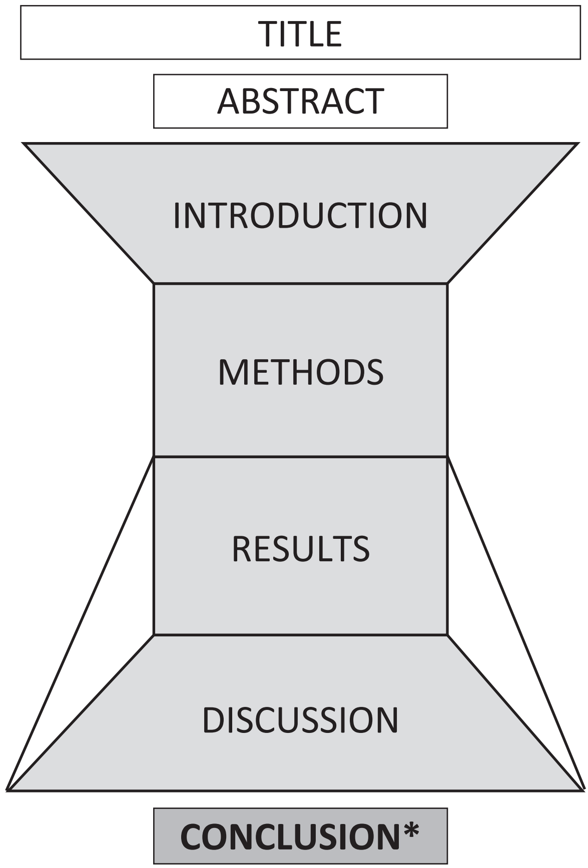
Analyse the Discussion sections of your target research articles to determine all of the following:

- The function of the first sentence.
- The extent to which the structure corresponds to or deviates from the generic Discussion model on page 208.
- The amount and location of background factual information in the Present Simple tense.
- The proportion of the Discussion that repeats/revisits the results.
- Whether the method is revisited in detail.
- Whether there is a clear link between the aim/gap stated in the Introduction and the achievement of the study.
- The use of 'happy' language to explicitly identify the value/achievement of the study.
- Whether there is a clear link between the literature/knowledge presented in the Introduction and the contribution of the study to that literature/knowledge.
- The number of citation references that map the study onto the existing literature/knowledge.
- The use of risk-reducing language, including modals such as *may.*
- The extent to which limitations, weaknesses and discrepancies are mentioned, the location of these, and the language used.

UNIT 5

How to Write the Conclusion





*Some journals call this section CONCLUSION and others call it CONCLUSIONS but this does not seem to reflect the number of conclusions that are drawn.

In some journals, the Conclusion section occurs as the last one or two paragraphs of the Discussion; in most it is a separate section. At the beginning of Unit 3, four structural options were set out for the way research articles are subdivided. The following table provides details of typical Conclusion sections for each of these four scenarios:

SUBTITLES Option 1	**SUBTITLES Option 2**	**SUBTITLES Option 3**	**SUBTITLES Option 4**
Results	Results	Results and Discussion	Results
Discussion	Discussion		Ø
Conclusion/s	Ø	Conclusion/s	Conclusion/s
There is a separate Conclusion section of 1-2 short paragraphs	*The last 1-2 paragraphs of the Discussion section are similar in form and content to a Conclusion section*	*There is a separate Conclusion section of 1-2 short paragraphs*	*There may be a long Conclusion section that is initially similar in form and content to a Discussion section and which ends with 1-2 paragraphs that are similar in form and content to a Conclusion section*

With the exception of Option 4, the Conclusion section averages 100–200 words in total and is usually comprised of one or two fairly short paragraphs, even occasionally including bullet points. However, the length of the Conclusion varies across different disciplines and in different journals within each discipline, so it is worth averaging the number of words in the Conclusion in your target articles as a guide.

The Conclusion section may contain content that overlaps with previous sections, particularly the Abstract, Introduction and Discussion. There is also some overlap with new features that are emerging in some journals, such as *Synopsis* and *Highlights*. However, the function of the Conclusion is different from all of these, and goes beyond either repetition or summary. Reviewers, editors and readers view the Conclusion as a key section that will deliver a clear take-home message focused on the outcome and impact of the study, and this expectation should be met in full by the writer.

5.1. Building a Model

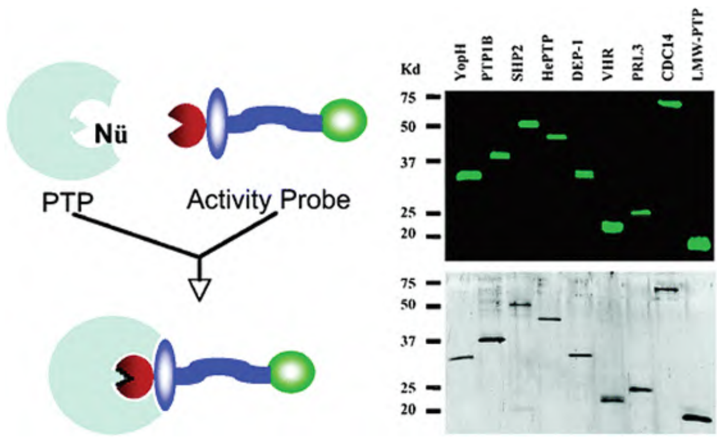
List the sentence functions in the six Conclusion sections below using the reverse-engineering approach in Units 1-4, and then compare your list with the GENERIC CONCLUSIONS MODEL in Section 5.2. In the first two examples, clues to the sentence functions in the Conclusion have been highlighted in **bold**. In some cases, the verb is highlighted simply to draw attention to the verb tense.

Each Conclusion section is preceded by the Abstract of that paper and, where relevant, the *Synopsis* or *Highlights*, to help you see how these differ from the Conclusion section, and to emphasise that the Abstract should not be used as the primary source material for the Conclusion.

1 Global analysis of protein tyrosine phosphatase activity with ultra-sensitive fluorescent probes[t]

Synopsis

Protein tyrosine phosphatases (PTPs) consist of a large family of enzymes regulating virtually all aspects of cellular processes. This paper describes the development of activity-based chemical probes for global profiling the entire PTP family on the basis of phosphatase activity, which should yield new functional insights into pathways regulated by PTPs and contribute to the discovery of PTPs as novel therapeutic targets.



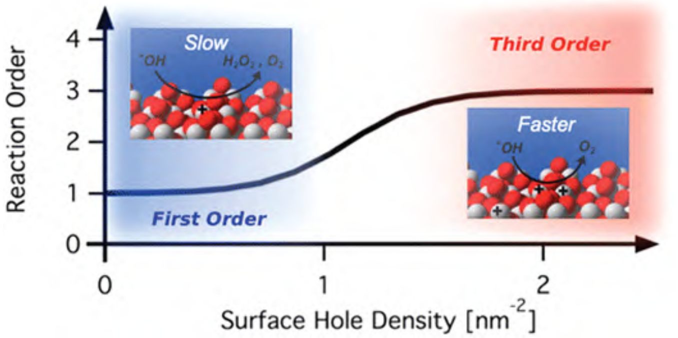
Abstract

Protein tyrosine phosphatases (PTPs) consist of a large family of enzymes known to play important roles in controlling virtually all aspects of cellular processes. However, assigning functional significance of PTPs in normal physiology and in diseases remains a major challenge in cell signaling. Since the function of a PTP is directly associated with its intrinsic activity, which is subject to post-translational regulation, new tools are needed to monitor the dynamic activities of PTPs, rather than mere abundance, on a global scale within the physiologically relevant environment of cells. To meet this objective, we report the synthesis and characterization of two rhodamine-conjugated probes that covalently label the active site of the PTPs in an activity-dependent manner, thus providing a direct readout of PTP activity and superior sensitivity, robustness, and quantifiability to previously reported biotinylated probes. We present evidence that the fluorescent probes can be used to identify new PTP markers and targets for potential diagnosis and treatment of human diseases. We also show that the fluorescent probes are capable of monitoring H_2O_2-mediated PTP inactivation, which should facilitate the study of regulated H_2O_2 production as a new tier of control over tyrosine phosphorylation-dependent signal transduction. The ability to profile the entire PTP family on the basis of changes in their activity is expected to yield new functional insights into pathways regulated by PTPs and contribute to the discovery of PTPs as novel therapeutic targets Protein tyrosine phosphatases (PTPs) consist of a large family of enzymes known to play important roles in controlling virtually all aspects of cellular processes. However, assigning functional significance of PTPs in normal physiology and in diseases remains a major challenge in cell signaling. Since the function of a PTP is directly associated with its intrinsic activity, which is subject to post-translational regulation, new tools are needed to monitor the dynamic activities of PTPs, rather than mere abundance, on a global scale within the physiologically relevant environment of cells. To meet this objective, we report the synthesis and characterization of two rhodamine-conjugated probes that covalently label the active site of the PTPs in an activity-dependent manner, thus providing a direct readout of PTP activity and superior sensitivity, robustness, and quantifiability to previously reported biotinylated probes. We present evidence that the fluorescent probes can be used to identify new PTP markers and targets for potential diagnosis and treatment of human diseases. We also show that the fluorescent probes are capable of monitoring H_2O_2-mediated PTP inactivation, which should facilitate the study of regulated H_2O_2 production as a new tier of control over tyrosine phosphorylation-dependent signal transduction. The ability to profile the entire PTP family on the basis of changes in their activity is expected to yield new functional insights into pathways regulated by PTPs and contribute to the discovery of PTPs as novel therapeutic targets.

Conclusions

We have synthesized and characterized two fluorescent rhodamine-containing PTP probes that are highly sensitive for direct in-gel visualization of PTP activity. **Kinetic analyses suggest that** these probes **are** active site directed **and inactivate** a broad range of PTPs in a time- and concentration-dependent fashion. **Direct in-gel fluorescence scanning indicates that** the fluorescent probes **form** a covalent adduct with the PTPs and the amount of labeling correlates with PTP activity. **As expected**, the fluorescent probes can detect on the order of 100 attomole of rhodamine-labeled PTP, a detection limit **nearly 3 orders of magnitude more sensitive than** that of the biotin-conjugated probes. **Moreover**, the fluorescent probes also **exhibit extremely high** selectivity toward PTPs while remaining inert to other proteins. **Thus**, the rhodamine-containing probes **provide superior** sensitivity, quantifiability, and throughput for activity-based PTP profiling. **Initial proof-of-concept experiments show that** the fluorescent probes **are capable of** monitoring **simultaneously** the activity levels of PTPs at the whole proteome level **and that** the activity profiles of PTPs **are significantly different** among a panel of human cancer cell lines. **This highlights the potential to use** the fluorescent probes to identify new PTP markers and targets for the diagnosis and treatment of human diseases. **Finally, it is shown that** the fluorescent probes **are capable of** monitoring H_2O_2-mediated PTP inactivation, **which should facilitate the study of** regulated H_2O_2 production as a new tier of control over tyrosine phosphorylation-dependent signal transduction. **Further application** of the activity-based fluorescent probes **will accelerate global characterization** of PTPs, **thereby increasing our understanding of** PTPs in cell signaling and in diseases.

2 Rate law analysis of water oxidation on a hematite surface[u]



Abstract

Water oxidation is a key chemical reaction, central to both biological photosynthesis and artificial solar fuel synthesis strategies. Despite recent progress on the structure of the natural catalytic site, and on inorganic catalyst function, determining the mechanistic details of this multiredox reaction remains a significant challenge. We report herein a rate law analysis of the order of water oxidation as a function of surface hole density on a hematite photoanode employing photoinduced absorption spectroscopy. Our study reveals a transition from a slow, first order reaction at low accumulated hole density to a faster, third order mechanism once the surface hole density is sufficient to enable the oxidation of nearest neighbor metal atoms. This study thus provides direct evidence for the multihole catalysis of water oxidation by hematite, and demonstrates the hole accumulation level required to achieve this, leading to key insights both for reaction mechanism and strategies to enhance function.

Conclusion

The rate order of the water oxidation reaction **has been investigated** on hematite photoanodes by photoinduced absorption of accumulated holes and photocurrent densities recorded simultaneously. A transition from first order to third order in photogenerated holes **has been identified** when a sufficient density of holes is accumulated at the semiconductor-electrolyte interface to oxidize two nearest neighbor surface metal atoms. This transition **was confirmed by** agreement between three different analyses. The third order reaction **is rationalized** by considering the rate-limiting formation of an intermediate, which requires the incorporation of three holes. **It is argued that*** this rate law **is consistent with** reaction mechanisms based on recent observations of intermediates involving oxygen−oxygen bond formation during the oxygen evolution reaction on other metal oxide surfaces.

This study clearly demonstrates the ability of a metal oxide semiconductor surface, such as hematite, to drive a multihole reaction, but **also highlights** the modest catalytic properties of this surface. **Our findings will help to tailor the design of** metal oxide anodes and photoanodes for water oxidation with regards to achieving high localized hole concentration, and the need for cocatalysts to enhance function. **Further work is currently in progress** with different materials and overlayers to determine their function and abilities to catalyze this complex but fascinating reaction.

It's likely that the authors are referring to themselves, i.e.* ***We argue that*, but the sentence could mean* ***It is argued by others that…***

3 Performance of structural concrete with recycled plastic waste as a partial replacement for sand[v]

Abstract

Environmental concerns arising from the over-dredging of sand have led to restrictions on its extraction across India, with direct economic impacts on concrete construction. A suitable environmentally friendly alternative to sand must be found to match the huge demand from the concrete construction industry. At the same time, waste plastic is rarely recycled in India, with as much as 40% left in landfill. The dumping of such materials which degrade at extremely low rates meaning they persist in the environment is a long-term environmental concern.

To tackle both issues, it is proposed to process waste plastic to create a partial replacement for fine sand in a novel mix for structural concrete. In this paper eleven new concrete mixes are evaluated to study five plastic material compositions, three groups of particle sizes, three different aspect ratios, and two chemical treatments and establish an appropriate choice of material to act as partial replacement for sand.

The results show that replacing 10% sand by volume with recycled plastic is a viable proposition that has the potential to save 820 million tonnes of sand every year. Through suitable mix design the structural performance of concrete with plastic waste can be maintained. This preliminary work was supported through funding from the British Council under the UKIERI (United Kingdom India Educational Research Initiative) programme for the project 'Development of structural concrete with the help of plastic waste as partial replacement for sand'.

Conclusions

This paper has demonstrated the potential for using recycled waste plastic in structural concrete mixes. At a replacement ratio of 10% by volume, this has the potential to save 820 millions tonnes of sand every year from being used in concrete mixes [1]. This is equivalent to approximately 5% of total global annual sand consumption. A further benefit is to add value to waste plastic, helping to reduce the volumes sent to landfill in some countries. A reduction in sand demand from the construction industry would further support efforts to limit the effects of sand dredging in countries such as India and China, where significant sand volumes are extracted every year.

It is generally seen that substituting plastic into a concrete mix causes a decrease in compressive and tensile strength due to the poor bond between the plastic and surrounding matrix. Since failure in concrete propagates in tension, the poor bond around plastic particles leads to a reduced compressive and tensile strength. The use of a graded PET plastic matched to the size of the sand particles it replaces, and at a replacement of 10% by volume, gave the most promising overall performance. This material is furthermore cost effective to produce and comes widely available as a waste material in many markets. This paper has shown that simply shredding a PET material is sufficient processing to provide a viable alternative to sand.

Testing different forms of plastic has demonstrated that the most efficient plastic aggregate used in a concrete mix should have a rough surface, be irregular in shape, and be sufficiently small so as to not create a significant failure surface, but also be graded similar to the sand it replaces. The results indicate that through appropriate mix design reductions in strength can be minimised to acceptable levels.

4 The oxidative corrosion of carbide inclusions at the surface of uranium metal during exposure to water vapour[d]

Abstract

The reaction between uranium and water vapour has been well investigated, however discrepancies exist between the described kinetic laws, pressure dependence of the reaction rate constant and activation energies. Here this problem is looked at by examining the influence of impurities in the form of carbide inclusions on the reaction. Samples of uranium containing 600 ppm carbon were analysed during and after exposure to water vapour at 19 mbar pressure, in an environmental scanning electron microscope (ESEM) system. After water exposure, samples were analysed using secondary ion mass spectrometry (SIMS), focused ion beam (FIB) imaging and sectioning and transmission electron microscopy (TEM) with X-ray diffraction (micro-XRD). The results of the current study indicate that carbide particles on the surface of uranium readily react with water vapour to form voluminous $UO_3{\cdot}xH_2O$ growths at rates significantly faster than that of the metal. The observation may also have implications for previous experimental studies of uranium–water interactions, where the presence of differing levels of undetected carbide may partly account for the discrepancies observed between datasets.

Highlights

High resolution imagery (FIB, SEM and SIMS) of carbide inclusions in uranium metal. ► Real time images following the reaction of the carbide inclusions with water vapour. ► Shown preferential consumption of carbide over that of the bulk metal. ► Quantity of impurities in the metal therefore seriously influence reaction rate. ► Metal purity must be considered when storing uranium in air or moist conditions.

Conclusions

Examination of cast α-uranium surfaces after exposure to water vapour in an ESEM instrument at 19 mbar and 20 °C indicated surface corrosion had occurred, with secondary growths determined to be $UO_3{\cdot}H_2O$ (metaschoepite) forming at carbide inclusions across the surface. Over the period of a week the growths were observed to increase in size, consuming only the carbide particles and not the surrounding metal. In some cases complete decomposition of the surface carbides was observed.

From the results of the current study it is apparent that the carbide particles reacted more readily with the water vapour than the metal. Resultantly it is suggested that disparities between previous studies of the uranium–water reaction may be attributable to differential purities of uranium metal used by different research groups, with resultantly different populations of carbide particles.

5 Measurement and modeling of the phase behavior of the (carbon dioxide + water) mixture at temperatures from 298.15 K to 448.15 K[w]

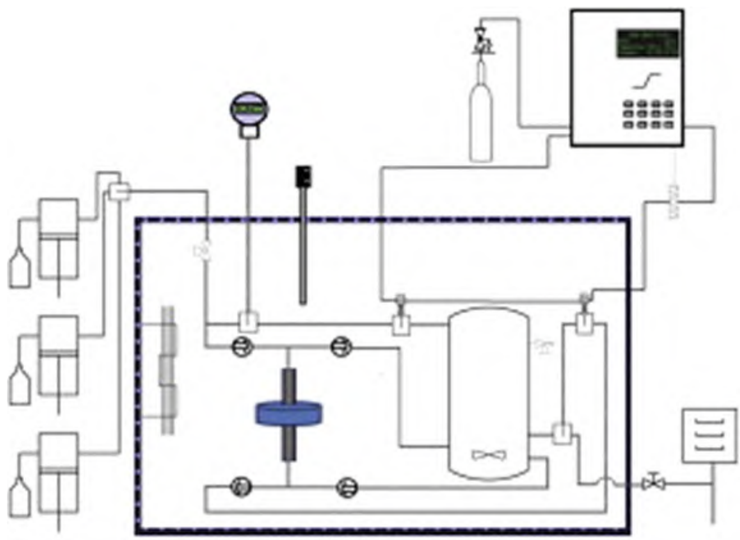
Abstract

An analytical apparatus has been designed to study the phase behavior of fluid mixtures of relevance to CO_2-enhanced oil recovery and carbon dioxide storage in deep aquifers or depleted oil fields. The fluid phases are circulated by means of a dual-channel magnetically-coupled pump and aliquots may be withdrawn from the re-circulation loops, by means of high-pressure sampling valves, for analysis by gas chromatography. The high-pressure cell is fitted with a special probe that may be rotated in order to draw liquid into the re-circulation loop from different heights within the cell, thereby permitting the study of three-phase vapor–liquid–liquid equilibria. The working temperature range of the apparatus is from (298 to 448) K and the maximum working pressure is 50 MPa.

In this work, measurements have been made on the binary system (CO_2 + H_2O) at temperatures from (298.15 to 448.15) K and pressure from

(1.5 to 18.0) MPa, and the results are compared with the available literature data. Vapor–liquid–liquid and liquid–liquid equilibrium points were also measured at $T = 298.15$ K. Standard uncertainties were 0.04 K for temperature, 0.04% of reading for pressure, and typically 3×10^{-4} and 8×10^{-4} for the mole fractions in liquid and vapor phases respectively. The results have been correlated by means of an asymmetric approach based on the Peng–Robinson equation of state, for the vapor phase, and an extended form of Henry's law incorporating the NRTL solution model, for the aqueous liquid-phase. The ability of the Krichevsky–Kasarnovsky (KK) approach to correlate the data has also been evaluated.

Graphical abstract



Highlights

► An analytical apparatus has been designed and commissioned for high *T* and *p* phase behavior measurements. ► Measurements have been made on $CO_2 + H_2O$ at temperatures from (298.15 to 448.15) K and pressures from (1.5 to 18.0) MPa. ► The measured data have been correlated by means of an asymmetric approach. ► The Krichevsky–Kasarnovsky approach and Duan's correlation model are also evaluated.

Conclusions

The phase behavior of ($CO_2 + H_2O$) was measured at temperature from 298.15 K to 448.15 K, and at pressures up to 18 MPa. The experimental results are compared comprehensively with literature data and found to agree with those literature sources identified in earlier reviews as being of the highest reliability. Our results fill key gaps in terms of accurate and high-quality data at high temperature and pressure, and pave the way for measurements on (CO_2 + brine) systems. The results are modeled accurately with a γ–φ approach incorporating the Peng–Robinson EoS with the classical mixing rules for the vapor phase, and an extended form of Henry's law with the NRTL solution model and a Poynting correction for the liquid phase. The Krichevsky–Kasarnovsky (KK) (simplified γ–φ approach) was also studied as well as the empirical correlation of Duan *et al*. Both were found to have significant deficiencies for this system.

6 Computer-controlled stimulation for functional magnetic resonance imaging studies of the neonatal olfactory system[x]

Abstract

Aim: Olfactory sensation is highly functional early in human neonatal life, with studies suggesting that odours can influence behaviour and infant–mother bonding. Due to its good spatial properties, blood oxygen level–dependent (BOLD) contrast functional magnetic resonance imaging (fMRI) has the potential to rapidly advance our understanding of the neural activity which underlies the development of olfactory perception in this key period. We aimed to design an 'olfactometer' specifically for use with neonatal subjects for fMRI studies of odour perception.

Methods: We describe a fully automated and programmable, fMRI compatible system capable of presenting odorant liquids. To prevent contamination of the system and minimize between-subject infective risk, the majority of the olfactometer is constructed from single-use, readily available clinical equipment. The system was used to present the odour of infant formula milk

in a validation group of seven neonatal subjects at term equivalent postmenstrual age (median age 40 weeks).
Results: A safe, reliable and reproducible pattern of stimulation was delivered leading to well-localized positive BOLD functional responses in the piriform cortex, amygdala, thalamus, insular cortex and cerebellum.
Conclusions: The described system is therefore suitable for detailed studies of the ontology of olfactory sensation and perception during early human brain development.

Key notes

- Ofaction is important in early life, but the anatomical substrates of the underlying neural activity are poorly understood.
- We describe a fully automated and safe system for fMRI studies of olfaction in neonatal subjects.
- Functional activation can be identified with fMRI in the primary olfactory areas in the neonatal brain.

Conclusions

We have designed, constructed and implemented a fully automated and programmable olfactometer specifically for fMRI studies of neonatal subjects. The described system is safe, has been designed to minimize infective risks and produces a reproducible but flexible pattern of olfactory stimulation. The system was found to induce a well-localized pattern of positive BOLD functional activity in the primary olfactory areas of seven neonatal subjects at term equivalent PMA. These data suggest that fMRI now offers the opportunity to investigate the ontogeny of olfaction in the human newborn with millimetre-scale precision, and to address specific hypotheses concerning the development of mature olfactory responses.

5.2. Testing and Adjusting the Model

In the Conclusion sections in this Unit, how many examples did you find of sentences, parts of sentences, or language that communicate or recall the components in the Conclusions model below?

	GENERIC CONCLUSIONS MODEL
1	WHAT IS IN THE PAPER
2	WHAT THE PAPER/STUDY HAS ACHIEVED
3	RELEVANT BACKGROUND INFORMATION
4	THE GAP/AIM/NEED FOR THE STUDY
5	THE METHOD/APPROACH
6	KEY RESULTS WITH EVALUATIVE COMMENTS
7	IMPLICATIONS OF THE RESULTS
8	POTENTIAL OR ACTUAL LIMITATIONS
9	POTENTIAL OR ACTUAL APPLICATIONS
10	HOW THE STUDY ADVANCES KNOWLEDGE
11	POTENTIAL FUTURE DIRECTIONS FOR RESEARCH

Map components 1–11 onto the Conclusion sections of your target articles to see where they are similar to or different from the six Conclusion sections in this Unit. Your analysis should consider the order in which the components typically occur, and what proportion of the Conclusion section deals with each component.

5.3. Useful Words and Phrases

Language suggestions for all the components of the Conclusions have appeared in previous Units. For example:

1.	***what is in the paper***	see Units 1 and 2
2.	***what the paper/study has achieved***	see Unit 4
3.	***relevant background information***	all Units
4.	***the gap/aim/need for the study***	see Unit 1
5.	***the method or approach***	see Units 2 and 3
6.	***key results with evaluative comments***	see Units 2 and 3
7.	***implications of the results***	see Unit 3
8.	***potential or actual limitations***	see Units 2 and 3
9.	***potential or actual applications***	see Unit 4
10.	***how the study advances knowledge***	see Unit 4
11.	***potential future directions for research***	see Unit 4

5.4. Language and Writing Skills

5.4.1 Verb tense in the Conclusion

In the Conclusion section, the Present Simple and Present Perfect tenses are commonly used to state what **is** in the paper, what **is** implied by the results, and what **has been** achieved in the study:

- ***We have synthesized and characterized*** *two fluorescent rhodamine-containing PTP probes…*
- ***It is argued that*** *this rate law is consistent with reaction mechanisms based on recent observations…*
- *This long-standing problem* ***is solved*** *by combining micron-sized and nano-sized tougheners in a synergistic manner*.
- *The rate order of the water oxidation reaction* ***has been investigated*** *on hematite photoanodes by…*
- *In the present paper, some shortcomings of the concept of cross-section classification* ***have been highlighted****, and, as an alternative treatment, the continuous strength method* ***has been introduced****.*
- *The level of enhancement in resistance offered by the continuous strength method over conventional design methods for steel structures* ***has been found to be*** *approximately…*
- *Finally,* ***it is shown that*** *the fluorescent probes are capable of monitoring…*
- *Our results* ***fill*** *key gaps in terms of accurate and high-quality data at high temperature and pressure, and* ***pave the way for*** *measurements on (CO_2 + brine) systems.*
- *We* ***have designed, constructed and implemented*** *a fully automated and programmable olfactometer specifically for fMRI studies of neonatal subjects.*
- *The described system* ***is safe, has been designed*** *to minimize infective risks and* ***produces*** *a reproducible but flexible pattern of olfactory stimulation.*

The Past Simple tense is less common, but is sometimes used to repeat key aspects of the method or key results:

- *The phase behavior of ($CO_2 + H_2O$)* ***was measured*** *at temperature from 298.15 K to 448.15 K,…*
- *Damage accumulation* ***evolved*** *slowly at lower strains, but* ***continued*** *at a rapid rate immediately prior to fracture, which is a typical ductile fracture characterized by dimples.*
- *In some cases complete decomposition of the surface carbides* ***was observed***.
- *The system* ***was found to*** *induce a well-localized pattern of…*

5.4.2 Owning your contribution

Identifying your own contribution in the Conclusion is not straightforward and requires you to be explicit and unambiguous. Writers sometimes incorrectly assume that it is obvious which sentences present their own contribution. This assumption has two sources: (1) a belief that the reader has read the rest of the paper before reading the Conclusion; and (2) the writer's own familiarity with the project and its conclusions.

Most readers do not read the entire paper before reading the Conclusion. In the same way that the readers of a murder mystery may jump to the last page in order to discover who committed the murder, readers of research articles may jump to the Conclusion section at some point to discover where the text is going. Moving directly to the Conclusion before reading the rest of the article may help the reader process the intervening information more effectively, or it may be an end in itself, i.e. the reader does not intend to read the intervening sections. Some readers jump to the Conclusion directly from the Abstract, or even from the title. Note, however, that even if the reader has read the entire paper up to the Conclusion, it is not safe to assume that they retain all the information in earlier sections with perfect accuracy.

The writer's own familiarity with the content is also a risk factor. This familiarity has been shared with colleagues on a day-to-day basis for the duration of the research project and extends into the writing period, blinding the writers to potential ambiguity and the need to be more explicit.

If you and your colleagues understand what you have written, it may not seem necessary to make things clearer — you may even feel that it appears condescending or patronising. However, sentences with a non-human grammatical subject and a verb in the Present Simple tense, such as:

> ***Kinetic analyses suggest*** *that these probes are active site directed and inactivate a broad range of PTPs in a time- and concentration-dependent fashion.* ***Direct in-gel fluorescence scanning indicates*** *that the fluorescent probes form a covalent adduct with the PTPs.*

contain nothing to tell the reader that these are in fact conclusions from this study. The sentences could easily be presenting ***relevant background information*** or ***the gap/aim/need for the study***, both of which sometimes occur in the Conclusion (see Section 5.2). Readers do not read forensically; they read fast, and a fast reading of such sentences risks loss of ownership at this critical point.

In the Conclusion sections above, writers can avoid ambiguity by using one or more of the following:

- the Past Simple or Present Perfect
- the active rather than the passive
- a human grammatical subject
- explicit sentence start-up or language that explicitly refers to the paper or study

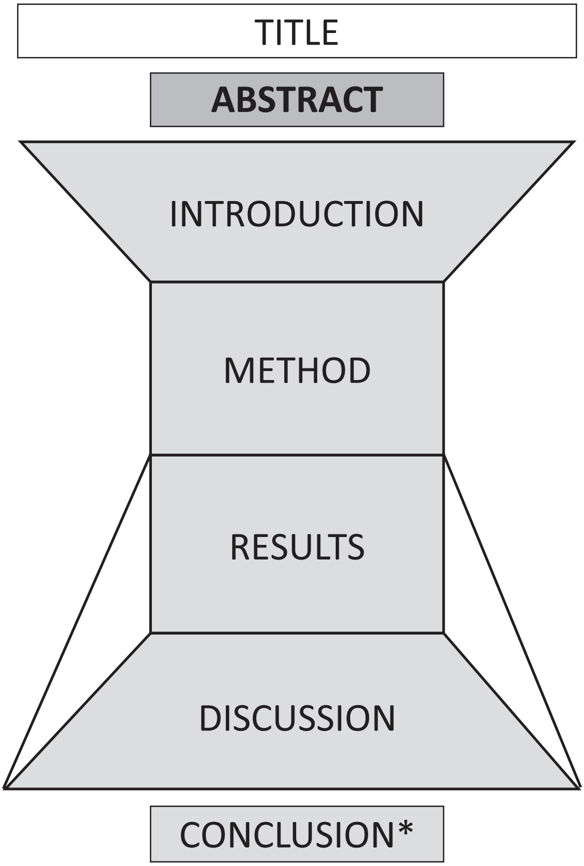
Here are some examples of the above four points:

- **We have synthesized and characterized** two fluorescent rhodamine-containing PTP probes that are highly sensitive for direct in-gel visualization of PTP activity.
- Examination of cast α-uranium surfaces after exposure to water vapour in an ESEM instrument at 19 mbar and 20 °C **indicated that** surface corrosion had occurred,…
- This transition **was confirmed by** agreement between three different analyses.
- **Finally, it is shown here that** the fluorescent probes are capable of monitoring H_2O_2-mediated PTP inactivation,…

- **This study clearly demonstrates** the ability of a metal oxide semiconductor surface, such as hematite, to drive a multihole reaction,...
- **In the present paper**, some shortcomings of the concept of cross-section classification **have been highlighted**, and, as an alternative treatment, the continuous strength method **has been introduced.**
- **From the results of the current study** it is apparent that the carbide particles reacted more readily with the water vapour than the metal.

UNIT 6

Writing the Abstract



*Some journals call this section CONCLUSION and others call it CONCLUSIONS but this does not seem to reflect the number of conclusions that are drawn.

The Abstract is a high-stakes document: many more people will read the Abstract — or briefly look at it — than the whole paper. A good Abstract enhances the visibility of the study, whereas a poor Abstract may result in the study being overlooked.

Abstract writing has changed significantly in recent years and is continuing to evolve alongside developments and changes in research communication. Internet reading means that the Abstract is no longer designed to be read as a prelude or an adjunct to the research article; it is typically read in isolation and has to function as a standalone, independent text that will be accessed by readers who are reading it for a wide range of reasons. Some readers simply want to know what is currently going on in a given research area and may not be interested in technical details; others may be experts in the field who want to know details but are only interested in studies which are directly relevant to their own project. Readers may have just one specific reason for reading an Abstract, for example, they may only want to check that their own current or planned project has not already been covered by another research group. Another possibility is that the reader may only want to know the applications of the study; for example, in medicine, treatment decisions are sometimes made on the basis of the Abstract alone.

Over 3 million research articles are published annually, creating an environment in which studies compete for attention online as readers scroll through titles and Abstracts. However, writing guidelines are sometimes inconsistent or confusing, for example, the suggestion that the Abstract should 'include all relevant information while being concise'. In other cases, the advice is too vague; a recommendation to write 'clearly' or 'coherently' needs to be backed up with practical details of how to do so. Writers always understand what they have written and therefore believe it to be clear, but a very high level of clarity and coherence are required by the reader who is looking at several Abstracts in quick succession.

6.1. Guidelines for the Abstract

6.1.1 Clarity and coherence

Clarity and coherence can be improved by:

- **explicitly identifying your own contribution.** Your familiarity with the study makes it harder to see potential ambiguity in the Abstract, and this is particularly significant in terms of identifying your own contribution. When the verb is in the Present Simple tense there is a risk that the information will seem to be well known, whereas it may in fact be a description of your results. A phrase like *theoretical modelling suggests that…* may refer to established knowledge or it may refer to the content and contribution of the research article. To avoid ambiguity, consider:
  1. using the Past Simple or Present Perfect tense: *Analysis shows concordance for 74% of mutation calls* (unclear who carried out the analysis) vs. *Analysis showed concordance for 74% of mutation calls* (it was the authors who carried out the analysis).
  2. using the active (*we*) rather than the passive.
  3. beginning the sentence with phrases such as *It is known that/It has been previously demonstrated that* or *In this study/Here*.

  The strict word limit in the Abstract means that you may be tempted to omit such phrases, but **your aim is not to make it possible for the reader to understand the Abstract; it is to make it impossible for the reader not to understand the Abstract AND identify your contribution.**
- **avoiding referencing ambiguity.** The referent of words like **it**, **which** or **this** may be obvious to you but unclear to your reader. If there is a potential for ambiguity, follow a word like **this** with the appropriate noun or repeat the noun/phrase. As you will see in Abstract 4 (Section 6.2.1), to avoid ambiguity the phrase *the hybrid method* is repeated no less than four times within a 140-word Abstract.
- **using consistent language.** If something is described as an *approach*, it should not suddenly become a *scheme*; similarly, a *scheme* should not suddenly become a *framework*, a *model* should not suddenly become a *method*, and a *tool* should not suddenly become a *device*. This blurs the identity of what you are offering, and also makes the Abstract difficult to follow.

- **using the sentence start-up techniques described in Unit 1** to create a strong, reader-friendly narrative.
- **keeping sentence length short.** Sentences with fewer than 20 words are understood by 90% of readers at first reading; those with more than 40 words are understood by 10% of readers at first reading. The average sentence length in the 18 Abstracts (Section 6.2) is 22.

How long should the Abstract be?

Averaging the number of words in the Abstracts of your target journals will give you a rough idea. Most are between 80–250 words and are written as a single paragraph.

The word limit is not a target. Because the Abstract is such a high-stakes text there is a temptation to overload it with information, but filling up the space to the maximum permitted number of words irrespective of relevance or narrative coherence makes the take-home message of the study unclear. The Abstract does not have to summarise the whole paper. As tempting as it is to include all the various achievements of the study in the Abstract, this scatters the impact, and readers may actually fail to spot the central value or contribution. Prioritise the central achievement or contribution and signal it explicitly to the reader.

When should I write the Abstract?

The Abstract is normally created after the rest of the writing is finished. There are a number of reasons for this:

1. If the Abstract is written too early there is a risk that it will not be consistent with the content of the paper or contain information that is not in the final version of the paper. Papers are often changed or updated just before submission, so if the Abstract has already been written it should be reviewed, and if necessary, modified or refocused before submission.
2. The content, style and length of the Abstract depend on where you plan to submit it, and that decision may be taken late in the writing process. Last-minute cutting and pasting to rejig an Abstract so that it conforms to a fresh set of submission guidelines risks loss of coherence.
3. The Abstract derives from the paper, not the other away around, therefore it does not require ‘creation’ as such; it requires careful

selection of what is relevant and appropriate, and a strong guiding narrative that makes for easy reading.

What kind of language should I use?

The language should respect the needs of the global reader, the interdisciplinary reader, and the fast reader — in other words, it should be simple and straightforward. The non-technical vocabulary used in the Abstract is similar across all disciplines, reflecting the need for clarity and accessibility. See Section 6.4 for examples.

Some readers may not be familiar with a particular technical term or acronym that you want to use in the Abstract. This will restrict their access to the content of the Abstract, and perhaps affect their willingness to continue reading it. Editors do not appreciate acronym-laden Abstracts, so if an acronym is really necessary in the Abstract because constant repeats of the full version would impact on the word limit, it is probably a good idea to specify (once) what the acronym stands for.

Here are some examples from the Abstracts below:

- We have developed and implemented a robust and practical scheme for anisotropic 3D acoustic full-waveform inversion (FWI)…
- This study aims to quantify and compare the accuracy of traditional radiostereometric analysis (RSA)…
- While brain–computer interfaces (BCIs) can provide communication to people who are locked-in, they suffer from a very low information transfer rate. Further, using a BCI requires a concentration effort and using it continuously can be tiring. The brain controlled wheelchair (BCW) described in this paper aims at providing mobility to BCI users…

6.2. Types of Abstract

There are four main types of Abstract:

1. Simple/Standard Abstracts
2. Structured Abstracts, which have headings such as **Background/Aims/Method/Results** etc.
3. Abstracts that exist alongside a **Significance Statement** or a list of **Highlights**
4. Graphical Abstracts

6.2.1 Simple/Standard Abstracts

Using the reverse-engineering technique demonstrated in the previous Units, create a model based on the sentence functions in the ten SIMPLE/STANDARD ABSTRACTS below. In these Abstracts, identifiers of the model are in **bold**. When you have finished, underline or highlight the model identifiers in the STRUCTURED ABSTRACTS in Section 6.2.2 to support your model, and then check and adjust it against the generic model in Section 6.3.

1 A sub-mW fully-integrated pulse oximeter front-end[y]

Abstract

This paper presents the implementation of the first fully integrated pulse oximeter front-end with a power consumption lower than 1 mW. **This is enabled by** system- and block-level noise optimisation, **also detailed in the manuscript**. The proposed design features an analogue feedback loop **that enables fast and accurate** regulation of the detected photocurrent level and a serial-to-parallel interface **allowing for** extensive programmability of several operation parameters. The front-end **was fabricated** in the AMS 0.35 µm technology and occupies **an occupies an area of 1.35 mm^2**. **Extensive measured results**, both electrical and physiological from human subjects **are reported, demonstrating** an estimated SNR of 39 dB and **ability to** detect 2% changes in SpO2, **similar to** commercial pulse oximeters. **This is despite** the constrained power consumption which amounts to 0.31 mW for the LEDs and 0.53 mW for the rest of the front-end from a 3.3 V supply. Statistical **results** from 20 chips **verify good matching** across the Red and Infrared channels of the front-end **and the accurate operation of the proposed** analogue feedback loop.

2 Anisotropic 3D full-waveform inversion[z]

Abstract

We have developed and implemented a robust and practical scheme for anisotropic 3D acoustic full-waveform inversion (FWI). **We demonstrate this scheme** on a field data set, **applying it** to a 4C ocean-bottom survey over the Tommeliten Alpha field in the North Sea. This shallow-water data set **provides** good azimuthal coverage to offsets of 7 km, with reduced coverage to a maximum offset of about 11km. The reservoir **lies** at the crest of a high-velocity antiformal chalk section, overlain by about 3000 m of clastics within which a low-velocity gas cloud **produces** a seismic obscured area. **We inverted only** the hydrophone data, **and we retained** free-surface multiples and ghosts within the field data. **We invert** in six narrow frequency bands, in the range 3 to 6.5 Hz. At each iteration, **we selected only** a subset of sources, **using** a different subset at each iteration; **this strategy is more efficient than** inverting all the data every iteration. **Our starting** velocity **model was obtained using** standard PSDM model building including anisotropic reflection tomography, and contained epsilon **values as high as** 20%. **The final** FWI velocity **model shows** a network of shallow high-velocity channels that **match similar features** in the reflection data. Deeper in the section, the FWI velocity **model reveals** a sharper and more intense low-velocity region associated with the gas cloud in which low-velocity fingers **match** the location of gas-filled faults visible in the reflection data. **The resulting** velocity **model provides a better match** to well logs**, and better** flattens common image gathers, than does the starting model. Reverse-time migration, **using the** FWI velocity **model, provides significant** uplift to the migrated image, **simplifying** the planform of the reservoir section at depth. The workflows, inversion strategy, and algorithms **that we have used have broad application** to invert a **wide range of analogous data sets**.

3 Mobilizing salt: magma-salt interactions[aa]

Abstract

Salt sequences **form** an integral part of **many** sedimentary basins **worldwide**. **Many** of these basins have experienced igneous activity either syn- or post-deposition of the salt sequences. **Despite this, little work has so far been undertaken to understand** magma-salt interactions within the subsurface, and how aspects such as salt halokinesis may be influenced by igneous activity. **Within this paper, we detail the first direct description of** relationships and textures that are developed during intrusive igneous-salt interaction. **We show that** salt composition **appears to play a dominant role** in controlling where igneous intrusions invade laterally through salt sequences in a sedimentary basin. **In particular, we illustrate that** hydrous salts, such as carnallite, **act** as preferential horizons for lateral magma intrusion. This lithological control **appears primarily related to** the heating and subsequent dehydration reaction of carnallite, which causes the carnallite to behave as viscous fluidal horizons, resulting in the non-brittle emplacement of magma, and spectacular peperitic salt-magma mingling textures. **We suggest that** heating and transformation of carnallite and other hydrous salts into viscous fluidal horizons during igneous intrusion within a regional salt sequence **may act as a possible trigger for** contemporaneous halokinesis, by creating fluid-like viscous detachment layers. Over longer time scales, however, a solidified rigid boxwork of dikes and sills **may create** zones of increased mechanical strength that will locally inhibit further salt flow.

4 A hybrid displacement estimation method for ultrasonic elasticity imaging[bb]

Abstract

Axial displacement estimation **is fundamental to many** freehand quasistatic ultrasonic strain imaging systems. **In this paper, we present a novel estimation method that combines the strengths of** quality-guided tracking, multi-level correlation, and phase-zero search to **achieve high levels of accuracy and robustness**. **The paper includes a full description of** the hybrid method, in

vivo examples to illustrate the method's clinical relevance, and finite element simulations to assess its accuracy. Quantitative and qualitative **comparisons are made with leading** single- and multi-level **alternatives**. In the in vivo examples, the hybrid method **produces fewer** obvious peak-hopping **errors**, and in simulation, the hybrid method **is found to reduce** displacement estimation errors by 5 to 50%. With typical clinical data, the hybrid method **can generate more than** 25 strain images per second on commercial hardware; **this is comparable with the alternative approaches considered in this paper**.

5 A ratchet mechanism for amplification in low-frequency mammalian hearing[cc]

Abstract

The sensitivity and frequency selectivity of hearing **result from** tuned amplification by an active process in the mechanoreceptive hair cells. **In most** vertebrates, the active process **stems from** the active motility of hair bundles. The mammalian cochlea **exhibits** an additional form of mechanical activity termed electromotility: its outer hair cells (OHCs) **change** length upon electrical stimulation. The relative contributions of these two mechanisms to the active process in the mammalian inner ear **is the subject of intense current debate**. **Here, we show that** active hair-bundle motility and electromotility **can** together implement **an efficient mechanism** for amplification that functions like a ratchet: Sound-evoked forces, acting on the basilar membrane, **are transmitted to** the hair bundles, whereas electromotility **decouples** active hair-bundle forces from the basilar membrane. This unidirectional coupling **can extend the hearing range** well below the resonant frequency of the basilar membrane. **It thereby provides a concept for** low-frequency hearing that **accounts for a variety of unexplained experimental observations** from the cochlear apex, including the shape and phase behavior of apical tuning curves, their lack of significant nonlinearities, and the shape changes of threshold tuning curves of auditory-nerve fibers along the cochlea. The ratchet mechanism **constitutes a general design principle for implementing mechanical amplification in engineering applications**.

6 The osteogenic response of mesenchymal stromal cells to strontium-substituted bioactive glasses[dd]

Abstract

Bioactive glasses **are known to** stimulate bone healing, and the incorporation of strontium **has the potential to increase** their potency. **In this study**, calcium oxide in the 45S5 bioactive glass composition **was** partially (50%, Sr50) or fully (100%, Sr100) **substituted** with strontium oxide on a molar basis. The effects of the substitution on bioactive glass properties **were studied**, including density, solubility, and *in vitro* cytotoxicity. Stimulation of osteogenic differentiation **was investigated using** mesenchymal stromal cells obtained from rat bone marrow. Strontium substitution **resulted in** altered physical properties including increased solubility. Statistically significant reductions in cell viability **were observed** with the addition of bioactive glass powders to culture medium. **Specifically**, addition of ≥ 13.3 mg/ml of 45S5 bioactive glass or Sr50, or ≥ 6.7 mg/ml of Sr100, **resulted in** significant inhibition. **Real-time PCR analyses detected** the upregulation of genes associated with osteoblastic differentiation in the presence of all bioactive glass compositions. Some genes, including *Alpl* and *Bglap*, **were further stimulated in the presence of** Sr50 and Sr100. **It was concluded that** strontium-substituted bioactive glasses **promoted** osteogenesis in a differentiating bone cell culture model and, therefore, **have considerable potential for use as improved** bioactive glasses for bone tissue regeneration.

7 An investigation into reinforced and functionally graded lattice structures[ee]

Abstract

Lattice structures **are regarded as excellent candidates for use in** lightweight energy-absorbing applications, such as crash protection. **In this paper we investigate** the crushing behaviour, mechanical properties and energy absorption of lattices made by an additive manufacturing process. Two types of lattice **were examined**: body-centred-cubic (BCC) and a reinforced variant called BCC_z. The lattices **were subject to** compressive loads in two orthogonal directions, **allowing** an assessment of their mechanical anisotropy to be made. **We also examined** functionally graded versions of these lattices, which featured a density gradient along one direction. The graded structures **exhibited distinct** crushing behaviour, with a sequential collapse of cellular layers preceding full densification. For the BCC_z lattice, the graded structures **were able to** absorb around 114% more energy per unit volume than their non-graded counterparts before full densification, 1371 ± 9 kJ/m^3 versus 640 ± 10 kJ/m^3. **This highlights the strong potential for functionally graded lattices to be used in energy-absorbing applications**. Finally, **we determined** several of the Gibson–Ashby coefficients relating the mechanical properties of lattice structures to their density; **these are crucial** in establishing the constitutive models required for effective lattice design. These results improve the current understanding of additively manufactured lattices **and will enable the design of sophisticated, functional, lightweight components in the future**.

8 A transient vanadium flow battery model incorporating vanadium crossover and water transport through the membrane[ff]

Abstract

This paper presents a 2-D transient, isothermal model of a vanadium redox flow battery **that can predict** the species crossover and related capacity loss during operation. **The model incorporates** the species transport across the membrane due to convection, diffusion, and migration, **and accounts for** the transfer of water between the half-cells to capture the change in electrolyte volume. **The model also accounts for** the side reactions and associated changes in species concentration in each half-cell due to vanadium crossover. A set of boundary conditions based on the conservations of flux and current **are incorporated** at the electrolyte|membrane interfaces **to account for** the steep gradients in concentration and potential at these interfaces. **In addition, the present model further improves upon the accuracy of existing models by incorporating a more complete version** of the Nernst equation, which **enables accurate prediction** of the cell potential **without the use of** a fitting voltage. A direct **comparison of the model predictions with experimental data shows**

that the model accurately predicts the measured voltage of a single charge/discharge cycle with an average error of 1.83%, and estimates the capacity loss of a 45 cycle experiment with an average error of 4.2%.

9 Sensory nerve induced inflammation contributes to heterotopic ossification[r]

Abstract

Heterotopic ossification (HO), or bone formation in soft tissues, **is often the result of** traumatic injury. **Much evidence has linked** the release of BMPs (bone morphogenetic proteins) upon injury to this process. HO **was once thought to be a rare occurrence, but recent statistics** from the military **suggest that as many as 60%** of traumatic injuries, resulting from bomb blasts, have associated HO. **In this study, we attempt to define the role of** peripheral nerves in this process. Since BMP2 **has been shown previously** to induce release of the neuroinflammatory molecules, substance P (SP) and calcitonin gene related peptide (CGRP), from peripheral, sensory neurons, **we examined** this process in vivo. SP and CGRP **are rapidly expressed** upon delivery of BMP2 **and remain** elevated throughout bone formation. In animals lacking functional sensory neurons (TRPV1$^{-/-}$), BMP2-mediated increases in SP and CGRP **were suppressed** as compared to the normal animals, and HO **was dramatically inhibited** in these deficient mice, **suggesting that** neuroinflammation plays a functional role. Mast cells, known to be recruited by SP and CGRP, **were elevated** after BMP2 induction. These mast cells **were localized** to the nerve structures and **underwent** degranulation. When degranulation **was inhibited using** cromolyn, HO **was again reduced significantly**. Immunohistochemical analysis **revealed** nerves expressing the stem cell markers nanog and Klf4, as well as the osteoblast marker osterix, after BMP2 induction, in mice treated with cromolyn. **The data collectively suggest that** BMP2 **can act directly on** sensory neurons to induce neurogenic inflammation, **resulting in** nerve remodeling and the migration/release of osteogenic and other stem cells from the nerve. **Further**, blocking this process **significantly reduces** HO, **suggesting that** the stem cell population **contributes to** bone formation.

10 Global anisotropic 3D FWI[gg]

Abstract

Seismic anisotropy **influences** both the kinematics and dynamics of seismic waveforms. **If** anisotropy **is not adequately taken into account** during full-waveform seismic inversion (FWI), then **inadequacies** in the anisotropy model **are likely to manifest as significant error** in the recovered P-wave velocity model. **Conventionally**, anisotropic FWI **uses** either a fixed anisotropy model derived from tomography or such, **or it uses** a local inversion scheme to recover the anisotropy as part of the FWI; **both of these methods can be problematic**. **In this paper, we show that** global rather than local FWI **can be used** to recover the long-wavelength anisotropy model, and **that this can then be followed by** more-conventional local FWI to recover the detailed model. **We demonstrate this approach on** a full 3D field dataset, **and show that it avoids problems** associated to cross-talk that can bedevil local inversion schemes. **Although our method** provides a global inversion of anisotropy, **it is nonetheless affordable and practical** for 3D field data.

6.2.2 Structured Abstracts

11 A finite rate of innovation algorithm for fast and accurate spike detection from two-photon calcium imaging[hh]

Abstract

Objective

Inferring the times of sequences of action potentials (APs) (spike trains) from neurophysiological data is a key problem in computational neuroscience. The detection of APs from two-photon imaging of calcium signals offers certain advantages over traditional electrophysiological approaches, as up to thousands of spatially and immunohistochemically defined neurons can be recorded simultaneously. However, due to noise, dye buffering and the limited sampling rates in common microscopy configurations, accurate detection of APs from calcium time series has proved to be a difficult problem.

Approach

Here we introduce a novel approach to the problem making use of finite rate of innovation (FRI) theory (Vetterli *et al* 2002 IEEE *Trans. Signal Process*: **50** 1417–28). For calcium transients well fit by a single exponential, the problem is reduced to reconstructing a stream of decaying exponentials. Signals made of a combination of exponentially decaying functions with different onset times are a subclass of FRI signals, for which much theory has recently been developed by the signal processing community.

Main results

We demonstrate for the first time the use of FRI theory to retrieve the timing of APs from calcium transient time series. The final algorithm is fast, non-iterative and parallelizable. Spike inference can be performed in real-time for a population of neurons and does not require any training phase or learning to initialize parameters.

Significance

The algorithm has been tested with both real data (obtained by simultaneous electrophysiology and multiphoton imaging of calcium signals in cerebellar Purkinje cell dendrites), and surrogate data, and outperforms several recently proposed methods for spike train inference from calcium imaging data.

12 The *Plasmodium falciparum* cytoplasmic translation apparatus: a promising therapeutic target not yet exploited by clinically approved anti-malarials[ii]

Abstract

Background

The continued spectre of resistance to existing anti-malarials necessitates the pursuit of novel targets and mechanisms of action for drug development. One class of promising targets consists of the 80S ribosome and its associated components comprising the parasite translational apparatus. Development of translation-targeting therapeutics requires a greater understanding of protein synthesis and its regulation in the malaria parasite. Research in this area has been limited by the lack of appropriate experimental methods, particularly a direct measure of parasite translation.

Methods

An in vitro method directly measuring translation in whole-cell extracts from the malaria parasite *Plasmodium falciparum*, the PfIVT assay, and a historically-utilized indirect measure of translation, S35-radiolabel incorporation, were compared utilizing a large panel of known translation inhibitors as well as anti-malarial drugs.

Results

Here, an extensive pharmacologic assessment of the PfIVT assay is presented, using a wide range of known inhibitors demonstrating its utility for studying activity of both ribosomal and non-ribosomal elements directly involved in translation. Further, the superiority of this assay over a historically utilized indirect measure of translation, S35-radiolabel incorporation, is demonstrated. Additionally, the PfIVT assay is utilized to investigate a panel of clinically approved anti-malarial drugs, many with unknown or unclear mechanisms of action, and show that none inhibit translation, reaffirming *Plasmodium* translation to be a viable alternative drug target. Within this set, mefloquine is unambiguously found to lack translation inhibition activity, despite having been recently mischaracterized as a ribosomal inhibitor.

Conclusions

This work exploits a direct and reproducible assay for measuring *P. falciparum* translation, demonstrating its value in the continued study of protein synthesis in malaria and its inhibition as a drug target.

6.2.3 Abstracts that include a Significance Statement and/or Highlights

Note that the Significance Statement and the Highlights do not always appear in the PDF of the paper, so they should be considered as adjuncts to the Abstract rather than as supplements. Using your reverse-engineering technique, describe the sentence functions in the Significance Statements and Highlights. Model identifiers are in **bold**.

13 The oxidative corrosion of carbide inclusions at the surface of uranium metal during exposure to water vapour[d]

Abstract

The reaction between uranium and water vapour **has been well investigated, however discrepancies exist** between the described kinetic laws, pressure dependence of the reaction rate constant and activation energies. **Here this problem is looked at by examining** the influence of impurities in the form of carbide inclusions on the reaction. Samples of uranium containing 600 ppm carbon **were analysed** during and after exposure to water vapour at 19 mbar pressure, in an environmental scanning electron microscope (ESEM) system. After water exposure, samples **were analysed using** secondary ion mass spectrometry (SIMS), focused ion beam (FIB) imaging and sectioning and transmission electron microscopy (TEM) with X-ray diffraction (micro-XRD). **The results of the current study indicate that** carbide particles on the surface of uranium **readily react** with water vapour to form voluminous $UO_3{\cdot}xH_2O$ growths **at rates significantly faster than** that of the metal. **The observation may also have implications for previous experimental studies** of uranium-water interactions, where the presence of differing levels of undetected carbide **may partly account for** the discrepancies observed between datasets.

Highlights

► **High resolution imagery** (FIB, SEM and SIMS) of carbide inclusions in uranium metal. ► **Real time images** following the reaction of the carbide inclusions with water vapour. ► **Shown** preferential consumption of carbide over that of the bulk metal. ► Quantity of impurities in the metal **therefore seriously influence** reaction rate. ► Metal purity **must be considered when** storing uranium in air or moist conditions.

14 Amazonian functional diversity from forest canopy chemical assembly[o]

Significance

Canopy trees are **keystone organisms** that create habitat for **an enormous array of** flora and fauna and **dominate** carbon storage in tropical forests. Determining the functional diversity of tree canopies **is, therefore, critical to understanding** how tropical forests are assembled and predicting ecosystem responses to environmental change. Across the megadiverse Andes-to-Amazon corridor of Peru, **we discovered** a large-scale nested pattern of canopy chemical assembly among thousands of trees. This nested geographic and phylogenetic pattern within and among forest communities **provides a different perspective on current and future** alterations to the functioning of western Amazonian forests resulting from land use and climate change.

Abstract

Patterns of tropical forest functional diversity **express** processes of ecological assembly at multiple geographic scales and **aid in predicting** ecological responses to environmental change. Tree canopy chemistry **underpins** forest functional diversity, **but** the interactive role of phylogeny and environment in determining the chemical traits of tropical trees **is poorly known**. **Collecting and analyzing** foliage in 2,420 canopy tree species across 19 forests in the western Amazon, **we discovered** (*i*) systematic, community-scale shifts in average canopy chemical traits along gradients of elevation and soil fertility; (*ii*) strong phylogenetic partitioning of structural and defense chemicals within communities independent of variation in environmental conditions; and (*iii*) strong environmental control on foliar phosphorus and calcium, the two rock-derived elements limiting CO_2 uptake in tropical forests. **These findings indicate that** the chemical diversity of western Amazonian forests **occurs** in a regionally nested mosaic driven by long-term chemical trait adjustment of communities to large-scale environmental filters, particularly soils and climate, **and is supported by** phylogenetic divergence of traits essential to foliar survival under varying environmental conditions. Geographically nested patterns of forest canopy chemical traits **will play a role in determining** the response and functional rearrangement of western Amazonian ecosystems to changing land use and climate.

15 Ultrafast desorption of colloidal particles from fluid interfaces[jj]

Significance

Solid particles **can** replace surfactants to stabilize emulsions and foams. The attachment of particles onto drops and bubbles is **typically considered to be** irreversible because of a large energy barrier for particle detachment — millions of times the thermal energy for microparticles. **Here we demonstrate a method to** promote the detachment of microparticles from bubbles using ultrasound. **We identified** conditions for complete particle removal and recovery in **under a millisecond**. **Our method** is programmable in time, and does not require any physicochemical modification of the fluids or the interface. **This work addresses the emerging need for** methods to recover interfacial particles from emulsions and foams **in applications ranging from** controlled release to interfacial catalysis and gas storage.

Abstract

The self-assembly of solid particles at fluid–fluid interfaces **is widely exploited** to stabilize emulsions and foams, and in materials synthesis. The self-assembly mechanism **is very robust** owing to the large capillary energy associated with particle adsorption, of the order of millions of times the thermal energy for micrometer-sized colloids. The microstructure of the interfacial colloid monolayer **can also favor** stability, for instance in the case of particle-stabilized bubbles, which **can be** indefinitely stable against dissolution due to jamming of the colloid monolayer. **As a result, significant challenges arise** when destabilization and particle removal **are a requirement**. **Here we demonstrate** ultrafast desorption of colloid monolayers from the interface of particle-stabilized bubbles. **We drive** the bubbles into periodic compression–expansion using ultrasound waves, causing significant deformation and microstructural changes in the particle monolayer. **Using** high-speed microscopy **we uncover different** particle expulsion scenarios depending on the mode of bubble deformation, including highly directional patterns of particle release during shape oscillations. **Complete** removal of colloid monolayers from bubbles **is achieved in under a millisecond**. **Our method should find a broad range of applications**, from nanoparticle recycling in sustainable processes to programmable particle delivery in lab-on-a-chip applications.

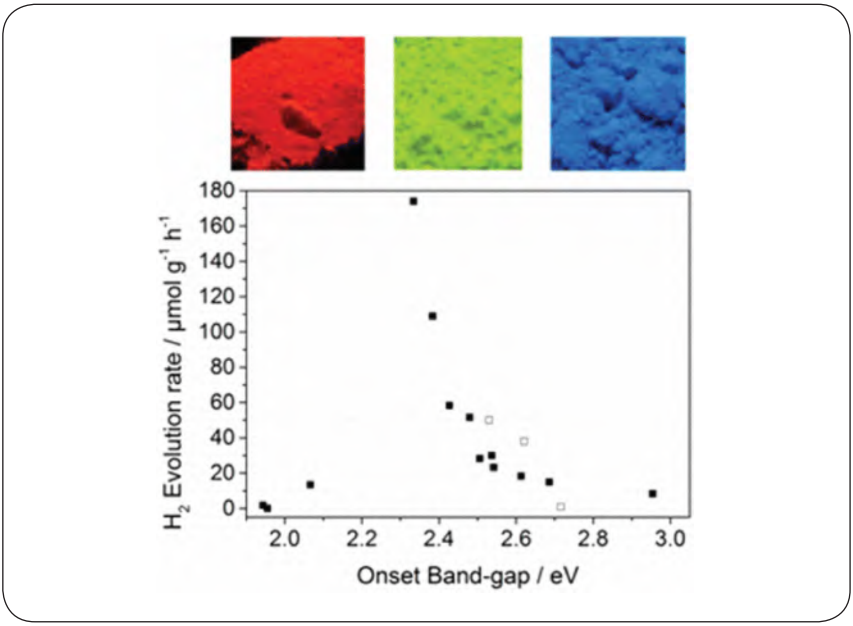
6.2.4 Graphical Abstracts

The Graphical Abstract (GA) is usually one single-panel image designed to give readers an immediate understanding of the take-home message of the paper. The GA should use colour judiciously, and grab attention visually by minimising clutter and unnecessary elements. In some cases the image is reproduced from the paper; in others it is specifically designed as a GA.

The GA communicates the main point right at the start. This improves the reader's understanding and acceptance of the message; furthermore, providing a clear and memorable image enhances retention of that message even after the reader moves on to another article. Note that some GAs also include a short text.

Using your reverse-engineering technique, build a model for the GAs below and compare it with the generic model in Section 6.3. Model identifiers are in **bold**.

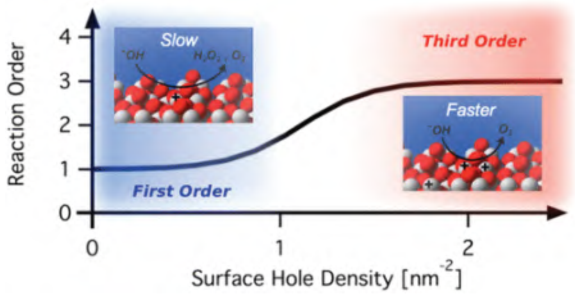
16 Tunable organic photocatalysts for visible-light-driven hydrogen evolution[kk]



Abstract

Photocatalytic hydrogen production from water **offers an abundant, clean** fuel source, **but it is challenging to produce** photocatalysts that use the solar spectrum **effectively**. Many hydrogen-evolving photocatalysts **are** active in the ultraviolet range, **but** ultraviolet light **accounts for only** 3% of the energy available in the solar spectrum at ground level. Solid-state crystalline photocatalysts have light absorption profiles that are a discrete function of their crystalline phase and that are not always tunable. **Here, we prepare** a series of amorphous, microporous organic polymers **with exquisite synthetic** control over the optical gap in the range 1.94–2.95 eV. Specific monomer compositions give polymers that are **robust and effective** photocatalysts for the evolution of hydrogen from water in the presence of a sacrificial electron donor, **without the apparent need for** an added metal cocatalyst. **Remarkably, unlike other** organic systems, the best performing polymer is only photoactive under visible rather than ultraviolet irradiation.

17 Rate law analysis of water oxidation on a hematite surface[u]



Abstract

Water oxidation **is a key chemical reaction, central to** both biological photosynthesis and artificial solar fuel synthesis strategies. **Despite recent progress** on the structure of the natural catalytic site, and on inorganic catalyst function, determining the mechanistic details of this multiredox reaction **remains a significant challenge**. **We report herein** a rate law analysis of the order of water oxidation as a function of surface hole density on a hematite photoanode employing photoinduced absorption spectroscopy. **Our study reveals** a transition from a slow, first order reaction at low accumulated hole density to a faster, third order mechanism once the surface hole density is sufficient to enable the oxidation of nearest neighbor metal atoms. **This study thus provides direct evidence for** the multihole catalysis of water oxidation by hematite, **and demonstrates** the hole accumulation level required to achieve this, **leading to key insights** both for reaction mechanism and strategies to enhance function.

…and some journals accept or encourage Highlights or a Significance Statement together with a GA:

18 Influence of reaction conditions on the composition of liquid products from two-stage catalytic hydrothermal processing of lignin[II]

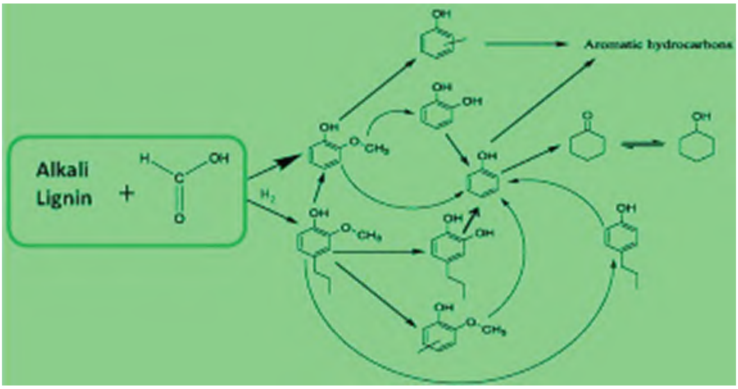
Highlights

- Liquid products' yields **reached up to** 40 wt% based on lignin feed.
- Liquid products' compositions **differed** with different reaction conditions.
- Formic acid **acted as** both depolymerization agent and source of hydrogen.
- Formic acid **influenced** liquid products' selectivity under the different conditions.
- Pt/Al_2O_3 **was** less selective towards liquid products than formic acid.

Abstract

The influence of reaction conditions on the composition of liquid products during two-stage hydrothermal conversion of alkali lignin **has been investigated** in a batch reactor. Reactions **were carried out** in the presence of formic acid (FA) and Pt/Al_2O_3 catalyst. The two different sets of reaction conditions **involved** alternative reaction times of 1 h and 5 h at 265°C and 350°C, respectively. These **provided different contributions** to reaction severity, **which affected** the compositions of liquid products. Yields of liquid products **reached up to** 40 wt% (on lignin feed basis) in the presence of FA under the less severe reaction condition. With 5 h reaction time at 350°C, alkylphenols, alkylguaiacols and hydrocarbons **were the dominant** liquid products. However, with 5 h reaction time at 265°C, phenol and methanol **became dominant**. The two-stage hydrothermal process **led to improved** lignin conversion, with the **potential** to manipulate the liquid product range.

Graphical abstract



6.3. A Generic Abstract Model

Now compare and adjust your model according to the generic model below. Note the number of potential locations for 'happy words' ☺ that communicate the value of the study **quickly and unmistakably**.

	GENERIC ABSTRACT MODEL
1	SIGNIFICANCE OF THE TOPIC/ESSENTIAL FACTUAL BACKGROUND THE CHALLENGE/PROBLEM WHAT THE PAPER/STUDY DOES (may include ACHIEVEMENT/VALUE + ☺)
2	METHOD/MATERIALS + ☺ RESULTS + ☺/COMPARISONS WITH EXISTING RESULTS + ☺ IMPLICATIONS
3	MAPPING TO EXISTING KNOWLEDGE + ☺ ACHIEVEMENT/VALUE/CONTRIBUTION + ☺ APPLICATIONS + ☺

6.3.1 The model components

Which verb tense should I use for each component?

As always, your target articles provide the best guidance, but in general terms:

- When referring to WHAT THE PAPER/STUDY DOES or what is in the paper, most writers use the Present Simple tense.
- When referring to what was done or used, i.e. the Method, most writers use the Past Simple tense.
- RESULTS and IMPLICATIONS can be expressed in either the Past Simple tense or the Present Simple tense. The Abstract presents the contents of the paper in a way that will immediately engage the attention of the reader. As a result, the Present Simple tense is sometimes used for results and implications in the Abstract even if those are expressed in the Past Simple tense in the body of the paper.

- ACHIEVEMENT/VALUE/CONTRIBUTION can be expressed in the Present Perfect tense (have +ed) or the Present Simple tense.

How do I know whether I need to state the significance of the topic or provide background information?

This will depend to some extent on the journal readership and the specificity of the study. However, even within a relatively technical field you should consider the needs of potential interdisciplinary readers outside the scope of your research area. If background information is necessary to understand the Abstract itself, combine and summarise the relevant points in as few words as possible.

Can I include citations in the Abstract, for example to support the background?

Research background may be appropriate to identify the problem or challenge, but it is rare to include actual citations in the Abstract. However, if your article follows directly from an existing published paper or is a major advance or contradiction relating to a specific work or theory, cite the relevant paper.

How much detail should I provide of the method and results?

Regarding the method, if the reader cannot decide whether to read the paper without knowing whether you used simulations, models, or field data, include that information. If the *value* of your study is that you carried out a range of experiments rather than a single case study, include that information.

Key aspects of the method and key results are sometimes provided together with numerical detail:

- *The front-end was fabricated in the AMS 0.35 µm technology and occupies an area of 1.35 mm*^{2}.
- *Extensive measured results, both electrical and physiological from human subjects are reported, demonstrating an estimated SNR of 39 dB and ability to detect 2% changes in SpO2,…*
- *Specifically, addition of ≥ 13.3 mg/ml of 45S5 bioactive glass or Sr50, or ≥ 6.7 mg/ml of Sr100, resulted in significant inhibition.*
- *…the graded structures were able to absorb around 114% more energy per unit volume than their non-graded counterparts before full densification, 1371 ± 9 kJ/m*^{3} *versus 640 ± 10 kJ/m*^{3}.

Note: Adding language to numbers (e.g. ***only*** *38%* or ***as high as*** *38%)* ensures that the numbers will not be misinterpreted at this crucial stage.

In other Abstracts the method and/or results are presented using language alone:

- *Stimulation of osteogenic differentiation was investigated using mesenchymal stromal cells obtained from rat bone marrow.*
- *Here we demonstrate a method to promote the detachment of microparticles from bubbles using ultrasound…*
- *…BMP2-mediated increases in SP and CGRP were suppressed as compared to the normal animals, and HO was dramatically inhibited in these deficient mice.*
- *…the FWI velocity model reveals a sharper and more intense low-velocity region associated with the gas cloud in which low-velocity fingers match the location of gas-filled faults…*

Having spent so much time on the study itself, not to mention the time spent on writing the paper, writers are often tempted to consider the Abstract as a summary of all that work, and include many less relevant details of the method or results. This results in a shapeless, uneven Abstract in which the reader has the task of identifying which are the key aspects of the method or the key results — and is unlikely to succeed.

How strongly should I state the implications of my results?

What you say in the Abstract should be consistent with what you report in the paper. The need for Abstracts to impress and attract is coupled with the writer's need to publish quickly, and this may result in an Abstract that contains statements or conclusions that are over-ambitious, or which are not fully supported by the data obtained in the study. This will be exposed during peer review, and may prolong the review process. If your work represents an early stage in a breakthrough, or its value is in the possible or potential implications of your data, communicate this by including modal verbs (*could/might/may*) or words such as *possible/potential.* In some cases the implications are stated quite strongly in the Abstract and the article includes a discussion of the possible restrictions and constraints of these implications. However, the implications as stated in the Abstract must not be so strong as to be misleading or inconsistent with the data itself.

How can I make the Abstract flow, given the word limit?

The Abstract has to operate within a fixed number of words, and this sometimes means including valuable data or information at the expense of narrative flow. However, the more the narrative 'wrap' is reduced, the less coherent that data or information becomes.

To make the Abstract flow given the word limit while retaining as much information as possible:

1. Review **Section 1.5.2 Linking sentences and information together** and look at how the sentences are linked together in the Abstracts in this Unit and in your target articles. Is it easy for the reader to negotiate the gap between sentences? How does the writer help the reader move from one sentence to the next? Are there places where the lack of an explicit sentence link creates real ambiguity? How could you resolve this?
2. Get the maximum value from the word limit by combining sentence functions, for example:

   - WHAT THE PAPER DOES + ACHIEVEMENT: *In this paper, we present a novel estimation method that combines the strengths of quality-guided tracking, multi-level correlation, and phase-zero search to achieve high levels of accuracy and robustness*.
   - ACHIEVEMENT + GAP: *It thereby provides a concept for low-frequency hearing that accounts for a variety of unexplained experimental observations from the cochlear apex, including…*
   - METHOD + RESULT: *Specifically, addition of ≥ 13.3 mg/ml of 45S5 bioactive glass or Sr50, or ≥ 6.7 mg/ml of Sr100, resulted in significant inhibition.*
   - ACHIEVEMENT + GAP: *In addition, the present model further improves upon the accuracy of existing models by incorporating a more complete version of the Nernst equation, which enables accurate prediction of the cell potential without the use of a fitting voltage.*
   - RESULT + IMPLICATION: *In animals lacking functional sensory neurons (TRPV1$^{-/-}$), BMP2-mediated increases in SP and CGRP were suppressed as compared to the normal animals, and HO was dramatically inhibited in these deficient mice, suggesting that neuroinflammation plays a functional role.*

6.4. Language

All the language you need for the Abstract can be found in the previous Units. However, because the Abstract needs to be understood very quickly by a wide range of readers, it tends to contain simple, conventional language, and the selection below reflects this. Add to the list from your target article Abstracts.

SIGNIFICANCE OF THE TOPIC/ESSENTIAL FACTUAL BACKGROUND

is assumed to is based on is determined by is fundamental to is influenced by is known to is related to is regarded as it has recently been shown that it is known that it is widely accepted that *Note*: Verbs in the Present Simple tense also communicate the factual background.	a number of studies central common currently dominant emerging frequently generally increasing key many often popular recent typically widely worldwide

Examples from the Abstracts in this Unit:

- The reservoir **lies at** the crest of a high-velocity antiformal chalk section, overlain by about 3000 m of clastics within which a low-velocity gas cloud **produces** a seismic obscured area.
- The sensitivity and frequency selectivity of hearing **result from** tuned amplification by an active process in the mechanoreceptive hair cells.
- Salt sequences **form** an integral part of **many** sedimentary basins worldwide.
- Axial displacement estimation **is fundamental to** many freehand quasistatic ultrasonic strain imaging systems.

- Canopy trees are keystone organisms that create habitat for an **enormous** array of flora and fauna and **dominate** carbon storage in tropical forests.
- The self-assembly of solid particles at fluid–fluid interfaces **is widely exploited** to stabilize emulsions and foams, and in materials synthesis.

THE CHALLENGE/PROBLEM

(an) alternative approach (a) key problem a need for challenge complicated critical debate desirable difficulty disadvantage drawback essential expensive impractical	inaccurate inadequate inconvenient limited little (work) not able to previously problem require risk time-consuming unsuccessful until now

Examples from the Abstracts in this Unit:

- **Despite this, little work has so far been undertaken** to understand magma-salt interactions within the subsurface,…
- The relative contributions of these two mechanisms to the active process in the mammalian inner ear is **the subject of intense current debate**.
- If anisotropy is **not adequately taken into account** during full-waveform seismic inversion (FWI), then inadequacies in the anisotropy model are likely to manifest as significant error…
- …accurate detection of APs from calcium time series **has proved to be a difficult problem**.
- Inferring the times of sequences of action potentials (APs) (spike trains) from neurophysiological data **is a key problem** in computational neuroscience.

WHAT THE PAPER/STUDY DOES (sometimes in the passive)

address	define	extend	propose
analyse	describe	identify	provide
attempt to	discuss	include	report
compare	emphasise	introduce	review
consider	enable	investigate	show
	examine	present	

Examples from the Abstracts in this Unit:

- This paper **presents** the implementation of the first fully integrated pulse oximeter front-end with a power consumption lower than 1 mW.
- The paper **includes** a full description of the hybrid method, in vivo examples to illustrate the method's clinical relevance, and finite element simulations to assess its accuracy.
- In this paper **we investigate** the crushing behaviour, mechanical properties and energy absorption of lattices made by an additive manufacturing process.
- In this study, we **attempt to define** the role of peripheral nerves.
- We **report** herein a rate law analysis of the order of water oxidation as a function of surface hole density on a hematite photoanode employing photoinduced absorption spectroscopy.

METHOD/MATERIALS

Instead of	are/were examined
Rather than	are/were formulated
Unlike	are/were measured
	are/were modelled
are/were analysed	are/were performed
are/were applied	are/were recorded
are/were assembled	are/were selected
are/were calculated	are/were studied
are/were constructed	are/were treated
are/were evaluated	are/were used

Examples from the Abstracts in this Unit:

- At each iteration, **we selected** only a subset of sources, **using** a different subset at each iteration…
- In this study, calcium oxide in the 45S5 bioactive glass composition **was** partially (50%, Sr50) or fully (100%, Sr100) **substituted** with strontium oxide on a molar basis.
- Two types of lattice **were examined**: body-centred-cubic (BCC) and a reinforced variant called BCC_z.
- Samples of uranium containing 600 ppm carbon **were analysed** during and after exposure to water vapour at 19 mbar pressure, in an environmental scanning electron microscope (ESEM) system.
- The two different sets of reaction conditions **involved** alternative reaction times of 1 h and 5 h at 265°C and 350°C, respectively.

RESULTS

cause	are/was achieved
decrease	are/was found
demonstrate	are/was identical
exhibit	are/was identified
increase	are/was observed
occur	are/was obtained
produce	are/was present
reach	are/was unaffected (by)
result in	
reveal	
yield	

Examples from the Abstracts in this Unit:

- Extensive measured results, both electrical and physiological from human subjects are reported, **demonstrating** an estimated SNR of 39 dB…
- Deeper in the section, the FWI velocity model **reveals** a sharper and more intense low-velocity region.
- Statistically significant reductions in cell viability **were observed** with the addition of bioactive glass powders to culture medium.

- The graded structures **exhibited** distinct crushing behaviour, with a sequential collapse of cellular layers preceding full densification.
- Yields of liquid products **reached** up to 40 wt% (on lignin feed basis) in the presence of FA under the less severe reaction condition…

ACHIEVEMENT/VALUE/CONTRIBUTION

accurate	improved	able to
affordable	new	achieve
better	novel	allow
comparable	powerful	confirm
consistent	practical	enable
cost-effective	reliable	enhance
dramatic	robust	ensure
effective	significant	guarantee
efficient	similar	outperform
exact	simple	simplify
fast	suitable	solve
(the) first	superior	validate
good		verify

Most Abstracts contain at least one sentence that makes the achievement/value/contribution of the study clear. Here are some examples from the first five of the Abstracts; continue by identifying sentences with similar functions in the rest of the Abstracts and those in your target articles.

- This paper presents the implementation of **the first fully integrated pulse oximeter front-end with a power consumption lower than 1 mW**.
- **We have developed and implemented a robust and practical scheme** for anisotropic 3D acoustic full-waveform inversion (FWI).
- Within this paper, we detail **the first direct description** of relationships and textures that are developed during intrusive igneous-salt interaction…
- In this paper, **we present a novel estimation method** that combines the strengths of quality-guided tracking, multi-level correlation, and phase-zero search to achieve **high levels of accuracy and robustness**.
- Here, we show that active hair-bundle motility and electromotility can together implement **an efficient mechanism** for amplification that functions like a ratchet:…

IMPLICATIONS

appear to indicate that may/might/could possible	potentially seem to suggest that we conclude that

Examples from the Abstracts in this Unit:

- **We suggest that** heating and transformation of carnallite and other hydrous salts into viscous fluidal horizons during igneous intrusion within a regional salt sequence **may act as a possible trigger for contemporaneous** halokinesis.
- **It was concluded that** strontium-substituted bioactive glasses promoted osteogenesis in a differentiating bone cell culture model.
- The data collectively **suggest that** BMP2 can act directly on sensory neurons to induce neurogenic inflammation, resulting in nerve remodeling and the migration/release of osteogenic and other stem cells from the nerve. Further, blocking this process significantly reduces HO, **suggesting that** the stem cell population contributes to bone formation.
- SND2 **seems to** occupy a subordinate but central tier in the secondary cell wall transcriptional network.
- These findings **indicate that** the chemical diversity of western Amazonian forests occurs in a regionally nested mosaic driven by long-term chemical trait adjustment of communities to large-scale environmental filters…

APPLICATIONS

apply employ enable implement	potential relevant for/in suitable for/in use wide range of

Examples from the Abstracts in this Unit:

- The ratchet mechanism constitutes a general design principle **for implementing** mechanical amplification **in engineering applications**.

- The workflows, inversion strategy, and algorithms that we have used have **broad application** to invert a **wide range of** analogous data sets.
- These results improve the current understanding of additively manufactured lattices and will **enable** the design of sophisticated, functional, lightweight components in the future.
- It was concluded that strontium-substituted bioactive glasses promoted osteogenesis in a differentiating bone cell culture model and, therefore, have considerable **potential for use as** improved bioactive glasses for bone tissue regeneration.
- Geographically nested patterns of forest canopy chemical traits **will play a role in** determining the response and functional rearrangement of western Amazonian ecosystems to changing land use and climate.
- **Our method should find a broad range of applications**, from nanoparticle recycling in sustainable processes to programmable particle delivery in lab-on-a-chip applications.

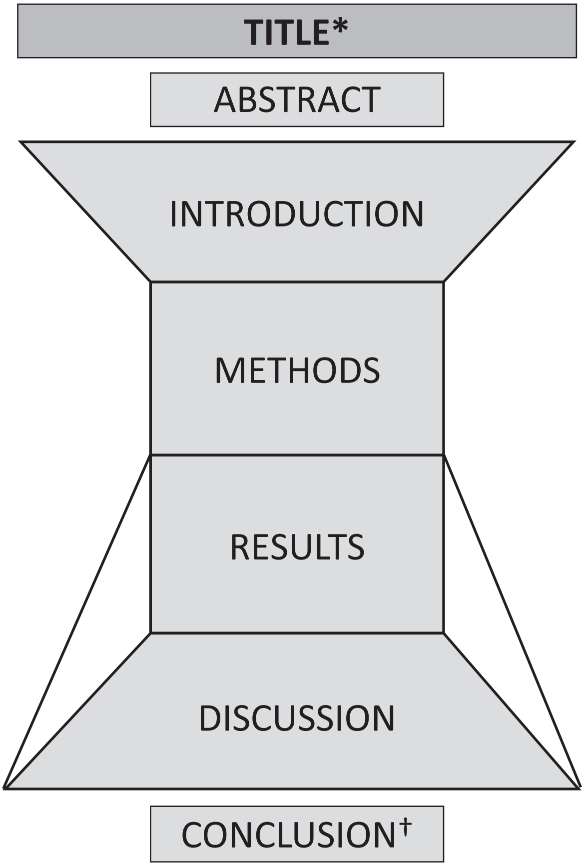
6.5. Summary Abstract Exercise

Analyse the Abstracts of your target articles to determine all of the following:

- The extent to which the structure corresponds to or deviates from the generic Abstract model on page 286.
- The proportion of the Abstract that repeats/revisits the method and the results.
- The function of the first sentence.
- The amount of ‘happy’ language that identifies the value/achievement of the study.
- Whether there is risk-reducing language, including modals such as *may.*
- How the main achievement of the study has been prioritised.
- Which verb tense is used in each sentence, and why.
- Whether there is any ‘ownership’ ambiguity as a result of verb tense or use of the passive.
- Whether there is any ambiguity as a result of reference words such as *this/it*.
- Average sentence length.
- Which acronyms are acceptable.
- **Whether the key take-home message of the study is clear.**

UNIT 7

Writing the Title



*For simplicity, all titles have been standardised with respect to capitalisation.

†Some journals call this section CONCLUSION and others call it CONCLUSIONS but this does not seem to reflect the number of conclusions that are drawn.

Research article titles have undergone a fundamental change and are continuing to develop to meet the needs of the reader. In previous years, researchers accessed developments in their field via hard copies of a carefully-curated — and therefore limited — set of journals. This is no longer the case. The main driver of this transformation has been the changeover to online reading of research, which has had a profound effect on the aim, content and construction of titles. Internet reading means that many more people will read the title than will ever read any other part of the paper, and search engine optimisation means that many do not scroll beyond a few further pages of titles once they have found relevant research. Title scanning is now a constant activity for most scientists, and titles have gained in importance as a result.

Other factors have also played a part in changing the way titles are written, and for whom they are written. For example, there are now many highly specialised research microcommunities within which a great deal of knowledge can be taken for granted, and research articles aimed at these microcommunities often have highly specialised content in the title. In contrast, others are working in fields where there is a need to make their research accessible to an interdisciplinary reader, and this has motivated those researchers to prioritise wide-ranging impact and inclusivity over content when they create titles.

The title will be with the paper forever and will always serve as the entry point for prospective readers. A good title will attract readers and, importantly, will attract all the right readers. The reverse is also true: if the title is poor the research article may not reach the target audience. Before you submit your article, type your title and keyword list into a search engine and check which research articles appear. Are they aimed at the same readership as yours? Is that your target audience?

Despite the importance of the title, advice about what constitutes a 'good' title is sometimes too general to be useful and in some cases may contradict actual practice. You may be told that your title should be 'informative', but exactly what that information should be is not easy to determine. You may be advised to make the title 'as short as possible', but when you look at comparable recent titles in your target journal, they may not be short at all — and in any case, exactly how short is 'as short as possible'? In addition, given the accelerating speed of change in research publication, even useful advice may quickly become out of date. This lack of effective advice means that writers sometimes simply submit the article with the original working title and hope for the best, but in the competitive global research context this is not a good strategy.

What's wrong with using the working title?

The working title is the research topic in the researcher's head before and during the research activity, and crucially, before the results are obtained. It does not tell readers what they can expect to gain from reading the article; instead, it simply tends to reflect the research field, or at best, the research activity. That research activity may be ***an investigation into*** something, but not only is *investigating* a very vague activity, the product — and therefore the value — of the study is unlikely to be the investigation itself but rather the outcome of that investigation.

In addition, a working title sometimes just names the thing you are studying, for example, ***Unsteady flow in pipe networks***, whereas the product or outcome of the study — and therefore the title — might be ***A hydraulic analysis of unsteady flow in pipe networks***. Even when the working title is quite specific, such as ***Mapping single-cell gene expression in the lung***, this is still the research activity; it is not the best or most informative title. Is the article describing a new process for mapping single-cell gene expression, identifying the challenges of mapping single-cell gene expression or simply reviewing the existing literature? If the outcome of the study is expressed in a title such as ***'LungGENS: a web-based tool for mapping single-cell gene expression in the developing lung'*** this will attract readers because they know exactly what they will get as a result of using their very precious time to read it.

Writers can only be really certain of their contribution and decide on the appropriate title when the study is complete and the results have been documented and analysed in relation to current literature and knowledge. This decision is sometimes made very close to the time of submission, and the eventual title often bears little resemblance to the original working title.

Can't I just summarise my findings in a sentence to produce the title?

Sentence titles are acceptable in some research areas, and there is also an increasing tendency to use them as summarising titles for subsections. Sentence titles have a grammatical subject, a verb, and usually an object:

Gamma-range synchronization of fast-spiking interneurons ***enhances*** *detection of tactile stimuli.* Sentence titles that summarise the most important finding/s are acceptable in some journals but they are not common — as always, check your target journal. They are used when the findings are strong, and the sentence simply states the key finding itself, usually in the Present Simple tense. Given the need for speed in research publishing, in some cases journal editors will accept sentence titles even when the implications of the findings are not yet fully established: *Mechanically modulated cartilage growth* ***may*** *regulate joint surface morphogenesis.*

So what strategy should I use to produce a title?

As stated above, titles are changing to meet the way readers access research, so the best strategy is to begin by reverse engineering *current* examples of titles in the journal you wish to publish in and/or titles of research articles that deal with similar subject matter. **Use the following 7 points to analyse recent comparable titles in your target journals.**

7.1. Check Average Length

This is a reasonable starting point, as the average number of words provides some rough-and-ready guidance on the level of complexity in your target journal titles. In many journals, for example, the average number of words is around 12, but as always, averages hide acceptable variation. The actual number is likely to be highly dependent on the specific topic and type of study. In addition, although knowing the average number of words is a good place to start, that number may well change alongside future changes in the online front page of the research article. Some online front pages now include components such as a **Significance Statement**, or a **Research in Context** panel. The number and range of such components is by no means stable or consistent across journals and may eventually impact on the function of the title, which will in turn influence its median length.

7.2. Using Acronyms

It is tempting to use acronyms to reduce the size of the title, but the decision to use an acronym should not be taken lightly. While you are doing your research, you spend most of your time with colleagues who share your knowledge of the concepts and terminology associated with the study, to the point where much of your communication relies on this implicit shared understanding. By the time you write the title of your paper, you have used a shared set of acronyms with colleagues so frequently that the full form seems redundant. This tends to blind you to the reality that those reading your work may not know exactly what your acronym refers to — they may simply find the use of the acronym in the title off-putting and scroll down to the next article.

In addition, although including acronyms in the title is acceptable in highly specific research microcommunities, these acronyms will be completely impenetrable to outsiders, and the outsiders of today may well be the interdisciplinary readers of tomorrow. For example, the potential future readers of a research article on using machine learning to identify malaria vaccine candidates may eventually include a wide range of stakeholders and audiences such as cancer researchers, public health policy makers, clinicians and investors in pharmaceuticals, so the decision of whether to use an acronym in the title depends on correctly gauging the level of knowledge shared by both *current and future* readers.

7.3. Compare the Title Keywords to the Keyword List

Keywords are marketing tools, and journals often request a short *keyword list* that will be displayed on the front page of the article. The list generally contains words or short phrases that enhance the indexing — and therefore the discoverability — of your article. The keyword list is a valuable complement to the title, so creating one which simply repeats the keywords in the title is not a productive strategy.

Comparing the keyword list with the keywords in the title is highly informative. In some cases, the keyword list is more general than the keywords in the title, signalling that the readership could extend more broadly than the title suggests. For example, an article with the title: *A framework for reviewing the trade-offs between renewable energy, food, feed and wood production at a local level* has a keyword list that includes *Ecosystem* and *Landscape* to attract the widest possible audience. In other cases, the title itself may focus on the wider impact and contribution of the study, and keywords that are highly technical are used to attract specialist researchers in the field. For example, an article with the title: *Large igneous provinces and organic carbon burial: controls on global temperature and continental weathering during the Early Cretaceous* has a keyword list that includes *Belemnites; Oceanic Anoxic Events; Late Aptian cold snap*.

Another useful function of the keyword list is that diverting items to the keyword list can thin out an overcrowded title. Including all potential keywords in the title for the sake of search engine optimisation may overload the title with nouns. This tends to scatter the key message, as readers cannot decide where the central focus lies. For example, a title such as *Simultaneous voltage and calcium mapping of genetically purified human induced pluripotent stem cell-derived cardiac myocyte monolayers* does not make it easy for readers to quickly identify the central focus of the study while title-scrolling.

7.4. Check the Grammar of the Title

It may sound obvious, but the title must make sense to the reader. The more nouns and compound nouns there are in the title, the harder it is to convey a clear message. Compound nouns are particularly problematic. They are attractive because they compress meaning and can give the impression of 'ownership' of a new or modified concept, but as they become longer, the overall grammar of the title and the relationships between each of the nouns becomes harder to control. The noun on the right-hand side of a compound noun is the only 'real' noun grammatically; nouns to the left of it have the same function as adjectives in that they modify that noun. As the compound noun becomes longer, the relationship between those nouns becomes harder to unravel:

- *an **oil can** = **a can** whose purpose is to contain oil*
- *an **oil can opener** = **an opener** for cans whose purpose is to contain oil*
- *an **oil can opener repair technician** = **a technician** who is able to repair cans whose purpose is to contain oil*
- *an **oil can opener repair technician training programme** = **a programme** to train technicians to repair openers for cans whose purpose is to contain oil*
- *an **oil can opener repair technician training programme funding problem** = **a problem** with the funding for the training programme used to train technicians to repair openers for cans whose purpose is to contain oil*

Another grammar issue in titles is the number of prepositions. Overloading the title with prepositions can make it grammatically unwieldy. For example, a title such as *A filter **with** a model **for** the contrast sensitivity **of** the visual system **for** modeling human performance **in** detection tasks **with** different viewing angles* is hard for the reader to deconstruct. Including some items in the keyword list instead of the title may resolve the problem.

Prepositions also carry a high risk of ambiguity. Despite their lack of identifiable content, prepositions are not simply a type of glue to hold concepts together; they have a profound effect on meaning (see Section 2.5.2) and ambiguity resulting from careless preposition use is particularly damaging in the title. To minimise ambiguity, consider replacing prepositions with words that have an unmistakable meaning: *Low-complexity domain interactions that control gene transcription* is less ambiguous than *Low-complexity domain interactions in gene transcription.*

How many prepositions are in the titles of articles in your target journals? Which prepositions are most common? Can you identify any ambiguities?

7.5. Map and Model the Structural Content of the Titles in Target Articles

- How many titles begin with A/An to communicate a new offer?
- How many use a colon (:) to split the title?
  - If there is a colon, what is its function? It may be used to separate the general topic area from the focus or contribution of the paper: *Life cycle inherent toxicity: a novel LCA-based algorithm for evaluating chemical synthesis pathways*
  - Alternatively, it may separate a new term from its description or definition: *GridSpice: a distributed simulation platform for the smart grid*
- How many include the method? 3*D reconstruction of SOFC anodes* ***using*** *a focused ion beam lift-out technique*
- How many include purpose or applications? *A random phased array device* ***for*** *delivery of high intensity focused ultrasound*
- How many include 'happy words' that show the value of the contribution? ***Cost-effective*** *multimode polymer waveguides for high-speed on-board optical interconnects*
- How many include acronyms? Would every potential reader know what these acronyms refer to?
- How many are aimed at a highly restricted microcommunity?

7.6. Check that Expectations that the Title Suggests Are Fulfilled in the Paper

The title should attract readers and encourage them to read your article, but it should not overstate or exaggerate the achievement of the study. The expectations set up by the title must be met in the paper itself. Given the need to publish research reasonably fast, it's acceptable to use modal verbs (*may/might/could*) in some cases to suggest the direction of research or the eventual potential contribution: *Diminished circadian rhythms in hippocampal microglia* ***may contribute to*** *age-related neuroinflammatory sensitization*. Look at the titles of your target research articles and predict what you expect to understand or gain from the article. Then check the Conclusion. How correct was your prediction?

Now evaluate the titles below using the following criteria:

- Does the title predict the focus and content of the article?
- How many nouns are there in each title?
- Is the title easy for all targeted readers to understand?
- Is the title grammatically ambiguous?
- Is the contribution or potential application of the study clear from the title?

1. *3D reconstruction of SOFC anodes using a focused ion beam lift-out technique*
2. *A biomimetic, 4.5µW, 120+ db, log-domain cochlear channel with AGC*
3. *A brain controlled wheelchair to navigate in familiar environments*
4. *A computer algorithm for computing the tensile strength of float glass*
5. *A voltage-based STDP rule combined with fast BCM-like metaplasticity accounts for LTP and concurrent "heterosynaptic" LTD in the dentate gyrus in vivo*
6. *A multicommodity Eulerian-Lagrangian cell transmission model for en route traffic*
7. *A new procedure for analyzing the nucleation kinetics of freezing in computer simulation*
8. *Naïve pluripotency and global DNA hypomethylation*

9. *Nanostructured anodes for solid oxide fuel cells*
10. *Pairwise decomposition of image sequences for active multi-view recognition*
11. *Patterns of primary care and mortality among patients with schizophrenia or diabetes: a cluster analysis approach to the retrospective study of healthcare utilization*
12. *A new system for crack closure in cementitious materials using shrinkable polymers*
13. *A novel technique for efficient live migration of multiple virtual machines*
14. *A random phased array device for delivery of high intensity focused ultrasound*
15. *Rapid and reliable assessment of the contrast sensitivity function on an iPad*
16. *Robocasting of structural ceramic parts with hydrogel inks*
17. *A ratchet mechanism for amplification in low-frequency mammalian hearing*
18. *A robust, data-driven methodology for real-world driving cycle development*
19. *A strategy for material supply chain sustainability: enabling a circular economy in the electronics industry through Green Engineering*
20. *Composition-dependent structural properties in ScGaN alloy films: a combined experimental and theoretical study*
21. *Connectivity reflects coding: a model of voltage-based STDP with homeostasis*
22. *Delamination control in composite beams using piezoelectric actuators*
23. *Development of inlaid electrodes for whole column electrochemical detection in HPLC*
24. *A finite rate of innovation algorithm for fast and accurate spike detection from two-photon calcium imaging*
25. *A molecular dynamics study of the Gibbs free energy of solvation of fullerene particles in octanol and water*
26. *Dissociating variability and effort as determinants of coordination*
27. *Electronic structure and local distortions in epitaxial ScGaN films*
28. *Impact and cost-effectiveness of new tuberculosis vaccines in low- and middle-income countries*

29. *Investigating electronic structure and local distortions in epitaxial ScGaN films*
30. *Mathematical modeling of the circulation in the liver lobule*
31. *Penetration resistance of armor ceramics: dimensional analysis and property correlations*
32. *Polarized multispectral imaging in a rigid endoscope based on elastic light scattering spectroscopy*
33. *Population-level impact of active tuberculosis case finding in an Asian megacity*
34. *Sensory components in bacterial nitrogen assimilation*
35. *Treatment of pediatric melanoma patients with lasers*
36. *Unsteady flows in pipes with finite curvature*

UNIT 8

Checklist and Tips

Almost all of the items in this checklist are discussed in detail elsewhere in the book and can be found by using the **Writing Skills Index** on page 345.

The checklist deals with common writing issues and errors, and aligns with the following principles:

- **The aim of writing is not to make it possible for the reader to understand what you have written. *The aim is to make it impossible for the reader not to understand.***
- **Data and information alone have no intrinsic or obvious function for the reader without a narrative.**
- **Knowing WHAT to write is not the same as knowing HOW to write it.**
- **The fact that you and your colleagues understand what you have written makes it harder for you to see potential ambiguities.**
- **Good organisation and good writing can compensate for language errors, but error-free language does not compensate for poor organisation or poor writing.**
- **Everything in the text, whether it is a research article, conference abstract, thesis or other text type, should be consistent with and lead towards the destination point — the 'magnetic south'.**

8.1. Organising the Information

Planning

- As a starting point, list the achievements of the study *in order of importance*, and identify the specific contributions of the study to or its impact on (i) knowledge, (ii) research and (iii) the real world. These will anchor the planning of each part of the research article, including the title.
- Don't let the keyboard force you to start typing before you are ready — getting lost in the middle of a paragraph or subsection wastes time and may result in a muddled, incoherent text. Step away from the keyboard and invest in time to plan the order of each section before you start typing whole sentences, otherwise you'll commit to sentences that may not fit anywhere and waste valuable time trying to find a place for them. Effective, patient planning will increase both the speed and the quality of your writing.

The value of the study: Identifying achievement, contribution, and impact

Results and data do not speak for themselves and the achievement, contribution and impact of the study are not always obvious to the reader.

- Explicitly and consistently identify the achievement/s of the study using 'happy' words (e.g. *a cost-effective method*). Where possible, be specific about the contribution to research or society (e.g. *opening a new direction in research, extending the range of potential applications, modeling epidemics more accurately*), and explicitly state the potential impact of the study on research or society (e.g. *a reduction in the spread of epidemics*).
- The achievement and contribution may overlap or be identical, and some studies have no easily identifiable impact or applications; nevertheless, there should be an explicit and consistent take-home message about the value of the study.

Creating subsections and their subtitles

Check that the way you have divided the text into subsections is helpful to the reader and that the subtitles accurately represent the content of the subsection. Use the keywords in the subtitle as early as possible in the subsection, and lead from those keywords.

Ordering information

Don't jump directly from very general information to very specific/technical information, particularly at the start of a subsection. The space between a full stop and the next capital letter is a dangerous space for you and for your reader. There's thinking time in there, and a desire to move on to the next piece of information without really considering how it relates to the previous sentence. Link information logically and coherently using the **Sentence start-up** suggestions on page 318.

Wrapping the information in a narrative

Make sure that all potential readers know what the information is doing, not just what it is saying. Is its function to introduce a description of a problem/ solution? Is it an example of something positive — or something negative? Consider the magnetic south, i.e. where your text is going, and show the reader the direction of travel by commenting on data and information rather than just stating it. For example, don't just provide data in 'naked numbers'; add evaluative comments such as *only 43%* or *as high as 43%* to show what the data means in the context of the study.

Relevance: Make sure the reader knows why you are writing each sentence

The fact that you know why the sentence is relevant does not ensure that the reader knows. Consider a potential 'so what?' question in the reader's mind at the end of a sentence. These questions can be resolved by adding phrases such as *'suggesting that.../which means that...'.*

Assumptions

As research becomes more interdisciplinary, non-specialist readers may want or need to access your research. Consider the range of potential readers now and in the future and what assumptions you can make about their knowledge of the topic, as well as their recall of earlier parts of your research article (which they may not have even read). If not, your document may remain locked inside your research microcommunity.

Paragraphing

Plan the function of each paragraph and order the paragraphs logically before you start writing.

- Avoid whole-page paragraphs and clusters of short or single-sentence paragraphs. Average paragraph length in research journals is 150–170 words.
- A paragraph which has a single function is more successful and easier to write and read than one with multiple functions. Too many ideas floating about in a paragraph make it hard for the writer to complete the paragraph coherently, and make it hard for the reader to understand what the paragraph is doing.
- Where possible, start the paragraph with a narrative entry statement that communicates the function of the paragraph.
    - Examples: *We now consider the connection between… To address this question, we used… Taken together, these studies suggest that… There are two potential alternatives to such an approach…*
- Avoid making statements early in the paragraph that won't make sense until the reader sees the rest of the paragraph. Consider reversing the order.
- Don't add loose sentences, i.e. sentences that are irrelevant to the function of the paragraph but that you include because they were in your notes or were suggested by a colleague. If a sentence doesn't fit with the function of the paragraph, delete it or create a narrative around it that respects the function of the paragraph.

8.2. Creating Sentences

Ordering the information in the sentence

Known information generally comes first and is used as a platform for launching new/unknown information later in the sentence. This facilitates sentence-to-sentence linkage, as the new information towards the end of the sentence then becomes the known/old information on which to build the next sentence.

Sentence start-up

The way sentences start is crucial to the readability of the text.

- Connect sentences by starting the sentence with an overlapping repeat, a pro-form such as *This/These* + *noun,* or a signalling connector such as *However*.
- Identify important information by beginning sentences with language such as *Interestingly,/Remarkably,/It is noteworthy that/It should be emphasised that/It is important to note that.*
- The way you start a sentence provides a 'frame' that helps the reader to process the content. Avoid beginning sentences with **-ing forms** (see pages 324–325) or prepositions (especially *for* and *with*).

Sentence length and density

The reading speed of the eye should correlate reasonably well with the processing speed of the brain. If the reader frequently needs to re-read over-long and over-dense sentences, this will slow them down. Consecutive long sentences are particularly problematic.

- Average sentence length in most journals is between 20–26 words.
- The longer the sentence, the harder it is for the writer to control the grammar and avoid ambiguity.
- Over-long sentences become 'flat'; the important part becomes submerged in the crowd and the reader cannot see where the principal focus lies.

- Over-long sentences contain so many components that the relationship between each component becomes hard for the writer to manage and hard for the reader to understand.
- Over-dense sentences pack so many nouns and prepositional phrases in that the main verb becomes obscured.
- Risk factors in over-long sentences include more than one **and**, more than one **which**, too many **prepositions**, and too many **nouns**.
    - Error example: *Exploration risk* ***in*** *most inverted rift basins is related to uncertainties* ***which*** *stem* ***from*** *a poor understanding* ***of*** *the structural style* ***and*** *distribution* ***of*** *inversion structures,* ***which*** *are controlled* ***by*** *the presence* ***and*** *orientation* ***of*** *pre-existing structures* ***and*** *the magnitude* ***and*** *orientation* ***of*** *shortening stress.*
    - Error example: *This paper presents the fundamental* ***framework*** *to facilitate* ***transition*** *from traditional deterministic to innovative probabilistic* ***electricity grid*** *operating and design* ***standards****, through the paradigm* ***shift*** *in the* ***provision*** *of* ***security*** *from* ***redundancy*** *in* ***assets*** *to exploiting emerging Smart Grid* ***technologies*** *and advanced* ***control systems****.*
- **and** and **or** can drag things with it that you don't want, or fail to drag things that you do want, creating ambiguity.
    - Error example: *We found an increase in demand and deployment of non-renewable energy sources*. Did the writer find that *demand and deployment of non-renewable energy sources* both increased, or is the writer simply saying that two different things were found: (1) *an increase in demand* and (2) *deployment of non-renewable energy sources* — but the latter did not increase?

Signalling connectors

Signals such as *moreover* and *therefore* are not just glue to join ideas or sentences together; they are emphatic, and have specific and restricted meanings. **The wrong signalling connector means that the reader sets off in the wrong direction and the text becomes unintelligible.**

- When you begin a sentence or clause with **therefore**, ask yourself: is it really a direct consequence or result of the previous sentence or clause? Sometimes the consequence is clear in your head but not on the page.

- Error example: *The most important phenomenon is the breakup length, and **therefore** an electrical conductivity probe technique was used to calculate breakup length.*

- When you begin a sentence or clause with **for example**, does it really illustrate or stand as an example of the general statement in the previous sentence?
- When you begin a sentence or clause with **in other words**, is it really the same thing in other words?

8.3. Grammar and Vocabulary

Verb tense

- Verb tense is a choice made by the writer to communicate the function of the information in the sentence. *We found that x occurred* is simply a report of your findings, whereas *We found that x occurs* means that your findings can be considered as facts; the Present Simple tense is higher risk, but has more power.
- If you switch to a different tense, make sure that you and the reader both know why.

Owning your contribution: Passive use and impersonal/ non-human grammatical subjects

- Agentless passives (*was done, was studied* without 'by X') do not make it clear who actually 'did' the verb. Identify the agent by using words or phrases like *here/in that study/in our model/in their approach.*
- Placing a passive verb at the end of a long sentence requires the reader to wait until the end of the sentence to discover what happened.
    - Error example: *Images and patient data from seventeen patients who were suspected of having PH and who had also undergone cardiac MRI and right-sided heart catheterization between 2002 and 2008 were retrospectively reviewed.*
- The impersonal use of *we/us/our* can refer to 'everyone in my field' or even 'everyone in the world'. This can cause ambiguity if you also use *we/us/our* in other sentences to refer to yourselves as authors. Instead of *We can now design proteins with many functions* to refer to 'everyone in my field', consider *It is now possible to design proteins with new functions.*
- Own your own work and contribution. Sentences with non-human grammatical subjects may risk your work being interpreted as common knowledge or other researchers' contributions. In the sentence *Theoretical modelling suggests formation of these bonds can be strongly reduced by coating the receptors on the nanoparticles* it is not clear whether or not it was the writers who carried out the modelling.

Similarly, in a sentence beginning *It is argued that this rate law is consistent with reaction mechanisms…* it is likely that the authors are referring to themselves, i.e*. We argue that…,* but the sentence could also mean *It is argued by others that…* Note that sentences like this are particularly dangerous in the Abstract.

Indefinite and definite articles

- Watch out for errors that are invisible, i.e. when both **a** and **the** are grammatically correct but the choice will affect the meaning.
  - Example: *The cords should be connected to **ϕ/the** two outlets.*
- Use **the** to communicate shared knowledge.
- Check for uncountable nouns that you are using countably, e.g. *steel, environment, technology* and therefore which potentially need an article.

Prepositions

Prepositions can change the meaning: *evidence **of*** vs. *evidence **for**; improved **up to** 3 times* vs. *improved **by up to** 3 times.*

- Don't use a preposition to do the work of content words; consider replacing it with real words, particularly at the start of the sentence. Instead of ***From** this estimation we changed the temperature of the sample*, try ***Using** this estimation we changed the temperature of the sample.*
- Mine recent research in your field to find subject-specific verb + preposition clusters such as:
  - *normalised FOR exon length*
  - *performed AT quasi-static rates*
  - *performed ON tissue samples*
  - *placed UNDER vacuum*
- *with* has a wide range of meanings and often causes ambiguity. Consider replacing it with one of the following: *using, having, in combination with, together with, as a result of, at the same time as.*
- Strings of prepositional adverb phrases create serious ambiguity.

- Error example: *We apply [**in A**] the concept [**of B**] [**to C**] [**through D**] [**with E**] to constrain the timing [**of F] [for G**]. 'We apply **in** this approach the concept **of** host rock **to** intrusive relationships **through** seismic-stratigraphic analysis **with** conventional biostratigraphic dating to constrain the timing **of** the events **for** the first time.'*

- The location of the prepositional phrase 'for the first time' may make it difficult to identify the real novelty of a study.
  - Error example: *X-ray imaging was used to measure contact angles within oil-bearing rocks at reservoir conditions for the first time*. Is this the first time x-ray imaging has been used to measure contact angles? The first time it has been used to measure contact angles within oil-bearing rocks? The first time it has been used to measure contact angles within oil-bearing rocks at reservoir conditions?

Subject-verb agreement

- Check singular/plural agreement if the subject is not next to the verb.
- Check whether the subject can actually perform the action of the verb, i.e. that the subject-verb agreement is logically possible.
  - Error example: *The nature of the problem **decided** how to resolve it.*

Reference

- Add a noun to *this/these/that/those* (e.g. *this system/model/theory*) so that the reader knows what you are referring to, especially at the start of a sentence or paragraph.
- Replace *it/which/this etc.* with the noun or phrase it refers to if there is more than one possibility.
- Check for ambiguity. Where does the referent of your *it/which/this etc.* begin and end? Is that clear to the reader?

Adverb location

Some adverbs such as *just, only, simply* change the meaning or focus of the information depending on their location. In the table below, match sentences 1–6 with their meanings to see how this works.

1	*Only we analysed models that can simulate the patient's molecular response.*	***A***	The models we analysed were not able to do anything else apart from simulating the patient's molecular response.
2	*We only analysed models that can simulate the patient's molecular response.*	***B***	The models we analysed were able to simulate just one parameter (the patient's molecular response), but not others.
3	*We analysed only models that can simulate the patient's molecular response.*	***C***	No other researchers analysed models that can simulate the patient's molecular response.
4	*We analysed models that can only simulate the patient's molecular response.*	***D***	The patient had just one molecular response, and we analysed models that can simulate it.
5	*We analysed models that can simulate only the patient's molecular response.*	***E***	We didn't analyse any other models apart from those that can simulate the patient's molecular response.
6	*We analysed models that can simulate the patient's only molecular response.*	***F***	We didn't do anything else apart from analysing models that can simulate the patient's molecular response.

(Answer: 1 = C, 2 = F, 3 = E, 4 = A, 5 = B, 6 = D)

-ing ambiguity

- -ing forms are inherently ambiguous in that they exhibit no verb tense or singular/plural marker. In the following sentence it is not clear whether the *deposits* or the *processes* are doing the *producing*. It is also not clear what exactly is doing the *encapsulating*.
  - o Error example: *MTCs are deposits resulting from creep, slide, slump and flow processes producing a variety of rheological units*

and strain sequences encapsulating extensional, translational and compressional domains.

Similarly, in the following sentence it is not clear whether the *small Stokes shift, high fluorescent quantum yields and sharp excitation and emission peaks* are doing the *contributing*, or just the *sharp excitation and emission peaks*… or perhaps just the *emission peaks*.

- Error example: *These dyes are notable for their small Stokes shift, high fluorescent quantum yields and sharp excitation and emission peaks contributing to overall brightness.*

- -ing forms also have a range of possible meanings, adding to their inherent ambiguity.
    - Error example: *Membranes remain flat* ***storing*** *elastic curvature stress.* (by storing? when storing? thereby storing?)

In sentences 1–3 below, consider how many of the meaning options A–J could exist for each -ing:

A	by [verb]ing
B	as a result of [verb]ing
C	on the basis of [verb]ing
D	when [verb]ing
E	thereby [verb]ing
F	therefore verbing
G	which is/are capable of [verb]ing
H	which/that [verb]
I	if we/it/they [verb]
J	because it/they [verb]

1. *The ions are coordinated by the C2 domain and by the phospholipids* ***forming*** *a ternary complex.*
2. *These dyes are notable for their small Stokes shift, high fluorescent quantum yields and sharp excitation and emission peaks* ***contributing*** *to overall brightness.*
3. *The lipids can influence protein functions indirectly* ***altering*** *the biophysical properties of the membrane.*

Avoid over-simple/weak verbs — they have too many possible meanings

have = possess, contain, include
get = obtain, achieve, become
bring = provide, yield, cause
keep = retain, maintain, conserve
spread = distribute, diffuse, scatter, extend

Vocabulary accuracy

Terminology should be used consistently. A *tool* should not become a *strategy* and then a *device* and then an *approach* and then a *methodology* and then a *framework* and then a *technique*.

- The thesaurus is not your friend, and it is the global writer and reader's enemy. No two words have exactly the same meaning in every context so there is no such thing as a perfect synonym. This means that the word you choose as an alternate may have a broader scope than the original word or it may be more negative/positive/neutral than the original word. A non-native writer risks choosing a thesaurus option whose meaning is so distant from the original word that the reader does not recognise it as an alternate. *noticeable* is not the same as *conspicuous*. *famous* is not the same as *well-known.* Don't be afraid to repeat the same word or phrase if that makes reading easier.
    - Example: *Most studies have focused on a deep* ***steady state*** *of general anesthesia and have not used a systematic behavioral measure to track the transition into* ***unconsciousness****. This* ***steady-state*** *approach cannot distinguish between* ***patterns*** *that are characteristic of a deeply anesthetized brain and* ***patterns*** *that arise at the onset of* ***unconsciousness. Unconsciousness*** *can occur in tens of seconds, but many neurophysiological features continue to fluctuate for minutes after induction.*
- Use Google Scholar to check whether your use of technical terms or phrases is accurate and current. First put the term into Google Scholar in quotation marks (") to check where, when and how many times that

exact phrase appears in the literature; then enter the same term again *without* quotation marks and compare the two sets of data.

- New terminology is created very quickly in science, and the term you have been using may have been superseded or steamrollered by an influential research group who are naming it differently. Keep checking.
- *comprise/consist of/be made up of/be composed of* are followed by a list or description of **all** the components, whereas *include* is followed by a list or description of **a selection of** the components.
- *respectively* means **in the same order as just mentioned**: *T helper and T suppressor cells are restricted by the A and E molecules respectively.*
- Joining two or more words with a hyphen makes them act as a single concept to describe the noun that follows them. Thus, *We used five centimetre-wide layers* means that we used five layers, each of which was **one** centimetre wide, whereas *We used five-centimetre wide layers* means that each layer we used was **five** centimetres wide.
- Make sure you know the difference between the following pairs:

alternately and *alternatively*	*alternately = one after the other* or *in sequence* *alternatively = on the other hand, instead* or *as an alternative*
beside and *besides*	*beside = next/close to* *besides = apart from/in addition to*
criterion and *criteria*	*criterion* is the singular form *criteria* is the plural form
different and *various*	*different = not the same* *various = a range of*
e.g. and *i.e.*	*e.g. = for example* *i.e. = in other words*
effective and *efficient*	*effective = it works* *efficient = it works well*
phenomenon and *phenomena*	*phenomenon* is the singular form *phenomena* is the plural form
to adapt and to *adopt*	*to adapt = to modify/adjust* *to adopt = to choose to use/follow*

to affect and *to effect*	*to affect = to influence/to have an effect on* *to effect = to cause/bring about*
to imply and to *infer*	*to imply = to suggest, to indicate* *to infer = to conclude, to deduce*

8.4. General

Ownership: Make sure the reader knows who is 'speaking'

Is this statement your own hypothesis/explanation? Is it a known truth? Will the reader know which of those it is? Is a citation needed?

The certainty continuum and modal verbs

Use language that accurately communicates how committed you are to your interpretation of your results and their implications. You can choose language that tells the reader that you are certain or you can choose language that tells the reader you are merely speculating; what is essential is that the language you choose follows logically from the results or achievements of the study.

Citations

Locate citations at the appropriate place in the sentence. Placing a citation reference at the end of the sentence (or stacking all the citations there) can cause ambiguity about who did what.

Self-edit lexical writing tics such as *indeed/in fact/basically/clearly*

Self-edit punctuation-related writing tics such as *parentheses, dash pairs, multiple commas*

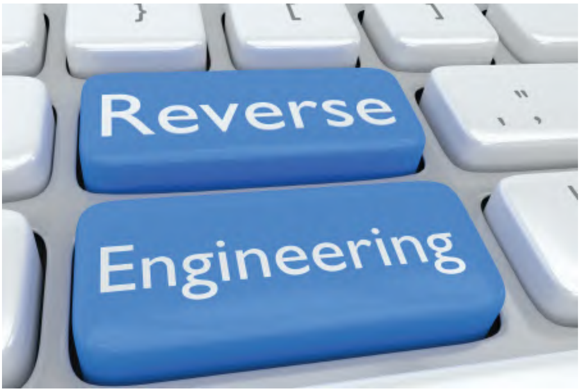
Many writers have a punctuation-related writing tic. Some overuse parentheses, others overuse commas, semicolons or pairs of dashes.

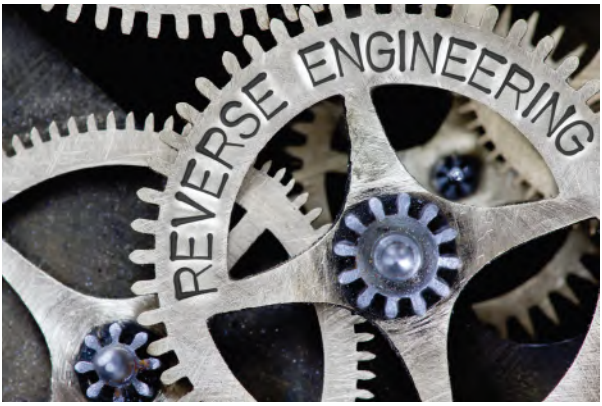
- If your tic is overusing pairs of dashes, note that the meaning of a pair of dashes is not obvious, particularly to international readers. Consider translating what you mean by the dash pairs into language.

- If your tic is overusing parentheses, remember that if something is important enough to include, perhaps it should not be in parentheses...and if it is not important enough to include, perhaps it should not be there at all.
- If your tic is overusing commas, note that using commas to include more information in the sentence may result in an over-long or rambling sentence. Consider breaking the information into separate, well-linked sentences.

Finally, the most important advice of all:

Whatever type of document you are planning to write, **use the strategy in this book to reverse engineer some recently-published examples in order to generate a robust, reliable model**.





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Appendix A: Prefixes Used in Science Writing

PREFIX	MEANING	EXAMPLES
a-	not	asymmetrical, atypical
an-	not	anaerobic, anhydrous
ante-	before	antechamber, antenatal
anti-	against	antimicrobial, antioxidant
auto-	self	autonomous, autocorrect
bi-	two	binary, bicarbonate
cent-	hundred/hundredth	centigrade, centimeter
chrom-	colour	chromatic, chromosome
chron-	time	chronological, chronometer
circ-	around	circulate, circumnavigate
co-	with/together	coauthor, coordinate
contra-	against	contraflow, contraindicate
counter-	against	counteract, counterpoint
crypt-	hidden	cryptocurrency, cryptography
de-	apart/away	decompose, dehydrate
di-	two	dichloride, dioxide
dis-	apart/away	dislocate, disintegrate
dis-	not	dissimilar, disadvantage
equi-	equal	equivalent, equilateral
fore-	before	foreknowledge, forecast
hetero-	different	heterogeneous, heterosexual
homo-	same	homogeneous, homosexual

hyper-	above/more	hyper-heuristic, hypertension
hypo-	under/below	hypoallergenic, hypothermia
il-	not	illogical, illegal
ill-	bad/badly	ill-defined, ill-judged
im-	not	impure, immaterial
in-	not	inaccurate, inconsistent
infra-	under/below	infrared, infrastructure
inter-	between	interdisciplinary, interface
intr-	into/inside	intravenous, introduction
ir-	not	irreversible, irrelevant
iso-	equal	isometric, isotherm
kilo-	thousand	kilogram, kilowatt
mal-	bad/badly	malformed, malfunction
mega-	large/million	megabyte, megadose
meta-	change	metadata, metastasis
milli-	thousandth	millisecond, millimeter
mis-	wrong	miscalculate, misjudge
mono-	one/single	monomer, monotone
multi-	many	multilayer, multicellular
nano-	billionth/very small	nanotube, nanomaterials
neo-	new	neonatal, neoblast
non-	not	nonexistent, non-standard
over-	too/excessively	overheat, oversimplify
para-	similar	paramedic, parapsychology
poly-	many	polysaccharide, polycystic
post-	after	post-processing, postgraduate
pre-	before	preexisting, pretest
prim-	first	primitive, primordial
proto-	first	prototype, protoplasm
re-	again	review, revise
retro-	backwards	retrofit, retrovirus
semi-	half	semiconductor, semicircle
sub-	under/below	subset, subtitle
super-	above/more	superconductor, supersonic

tele-	far/distant	telemetry, telescope
un-	not	unusual, unsuitable
uni-	one/single	unicellular, uniform

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Appendix B: Research Verbs

able to	attach	conclude	demonstrate
accompany	attempt	conclude that	derive
accord with	attribute	conduct	describe
account for	avoid	confirm	design
achieve	be confined to	conflict with	detect
acquire	bisect	connect	determine
adapt	calculate	consider	develop
address	calibrate	construct	deviate from
adjust	carry out	contains	devise
administer	categorise	contradict	differ
adopt	cause	contribute to	discard
affect	challenge	control	discover
align	change	converge	discuss
allow	characterise	convert	display
alter	choose	correlate with	disprove
analyse	claim	correspond to	distribute
appear to	clarify	corroborate	divide
apply	collect	couple	document
argue	combine	create	drive
arise from	compare	deal with	drop
arrange	compare well with	decline	eliminate
ascribe	compensate for	decrease	embed
assemble	complement	deduce	emphasise
assess	compute	define	employ
assume	concentrate on	delay	enable

encase	highlight	maximise	point out
enclose	hypothesise	mean	position
enhance	identify	measure	postulate
ensure	ignore	mention	precede
establish	illustrate	minimise	predict
estimate	immerse	mirror	prepare
evaluate	implement	miscalculate	present
examine	imply	misjudge	prevent
exceed	improve	misunderstand	process
exclude	include	model	produce
exhibit	incorporate	modify	propose
exist	increase	monitor	prove
expand	indicate	mount	provide
explain	infer	neglect	provide a first step
explore	influence	normalise	provide a framework
expose	initiate	note	provide evidence of
extend	input	observe	provide insight into
extract	insert	obtain	provide support for
fabricate	install	occur	purchase
facilitate	interpret	offer	put forward
fall	intersect	operate	quantify
fall short of	introduce	optimise	reach
fasten	invert	organise	recognise
filter	investigate	orient	recommend
find	isolate	originate in	record
fit	join	outline	recover
fix	know	outperform	reduce
focus on	lag behind	overcome	re-examine
formulate	lead	overlook	refine
generalise	lead to	pave the way for	reflect
generate	limit	peak	refute
give rise to	list	perform	regulate
govern	locate	permit	reinforce
guarantee	maintain	place	remain
help to	match	plot	

remove	review	situate	support
repeat	revise	solve	surround
replicate	rise	space	synthesise
report	rule out	speculate	take place
represent	sample	stabilise	test
require	seem to	state	theorise
resemble	select	streamline	track
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