

Unit 1 ⇒ How to Write an Introduction

1.1 Structure

Until now, much of your science writing has focused on writing reports in which you simply described what you did and what you found. Although this will help you write the central ‘report’ sections (Methodology and Results) of a research paper or thesis, it doesn’t prepare you for writing an Introduction to a full-length research article; this is a new task that faces you once you move on to research writing.

In practice, you will find that you need to be certain about what you have done and what you have found in order to write the Introduction, and so the best time to write it will be after you have written, or at least drafted, the report sections. However, in this book, the structure of a research article is presented in the order in which it appears in a paper/thesis so that you can trace the connections between each part and see the sequence in which information is presented to the reader.

You may want to start your Introduction by describing the problem you are trying to solve, or the aim of your work, but as you will see when you examine published work, this is not how most research papers begin — and therefore it is not the best way for you to begin. In order to help you write the Introduction to your own research, the model you build must answer the following three questions:

- How do writers normally start the Introduction?
- What type of information should be in my Introduction, and in what order?
- How do writers normally end the Introduction?

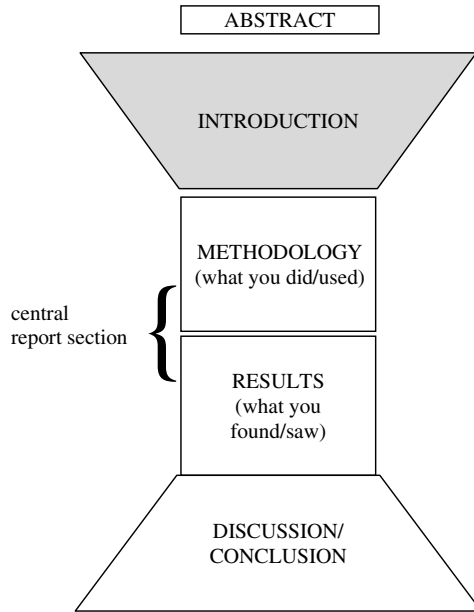


Fig. 1. The shape of a research article or thesis.

The first thing you may notice about Fig. 1 is that it is symmetrical. This is because many of the things you need to do in the Introduction are done — in reverse order — in the Discussion/Conclusion. For example, you need to write an opening sentence which enables you and your reader to ‘get in’ or start your paper/thesis and you also need to ‘get out’ at the end of the Discussion/Conclusion by finding an acceptable way to end the paper/thesis. In addition, you must look for a way to interface with the central report section at the end of the Introduction, and again — in reverse — when you move out of the central section to start the Discussion/Conclusion.

Something else you should notice about the shape of the diagram is that it narrows towards the central report section, and widens after it. This represents the way information is ordered in the Introduction and the Discussion/Conclusion: in the Introduction you start out by being fairly general and gradually narrow your focus, whereas the opposite is true in the Discussion/Conclusion.

Read the Introduction below. Don't worry if the subject matter is not familiar or if you have difficulty understanding individual words, especially technical terms like *polylactide*. Just try to get a general understanding at this stage and familiarise yourself with the type of language used.

The synthesis of flexible polymer blends from polylactide and rubber

Introduction

1 *Polylactide (PLA) has received much attention in recent years due to its biodegradable properties, which offer important economic benefits. 2 PLA is a polymer obtained from corn and is produced by the polymerisation of lactide. 3 It has many possible uses in the biomedical field¹ and has also been investigated as a potential engineering material.^{2,3} 4 However, it has been found to be too weak under impact to be used commercially.⁴*

5 *One way to toughen polymers is to incorporate a layer of rubber particles⁵ and there has been extensive research regarding the rubber modification of PLA. 6 For example, Penney et al. showed that PLA composites could be prepared using blending techniques⁶ and more recently, Hillier established the toughness of such composites.⁷ 7 However, although the effect of the rubber particles on the mechanical properties of copolymer systems was demonstrated over two years ago,⁸ little attention has been paid to the selection of an appropriate rubber component.*

8 *The present paper presents a set of criteria for selecting such a component. 9 On the basis of these criteria it then describes the preparation of a set of polymer blends using PLA and a hydrocarbon rubber (PI). 10 This combination of two mechanistically distinct polymerisations formed a novel copolymer in which the incorporation of PI significantly increased flexibility.*

1.2 Grammar and Writing Skills

This section deals with four language areas which are important in the Introduction:

TENSE PAIRS

SIGNALLING LANGUAGE

PASSIVE/ACTIVE USE

PARAGRAPHING

1.2.1 Tense pairs

Present Simple/Present Continuous

In order to use tenses correctly in the Introduction, you first need to look at the difference between the way the Present Simple tense and the Present Continuous tense are used.

Look at these two sentences:

(a) I live in Beijing.	Present Simple
(b) I'm living in Beijing.	Present Continuous

(a) describes a permanent situation and (b) describes a temporary situation. Because of this, the Present Simple tense is used in science writing to state accepted facts and truths — but what qualifies as an accepted fact or truth is often, surprisingly, your decision. Sometimes the writer considers that research findings have the status of a fact; in that case, s/he can decide to state them in the Present Simple, usually followed by the appropriate research reference. Here is an example from the Introduction in Section 1.1:

5 One way to toughen polymers is to incorporate a layer of rubber particles⁵ and there has been extensive research regarding the rubber modification of PLA.

Later on, in the Results section, you can even decide to state your own findings this way. Look at these two sentences which describe results:

(a) *We found that the pressure **increased** as the temperature **rose**, which **indicated** that temperature **played** a significant role in the process.*

(b) *We found that the pressure **increases** as the temperature **rises**, which **indicates** that temperature **plays** a significant role in the process.*

Which sentence is 'stronger'? In (a), using the Past Simple tense means that your findings are linked only to your own research, and you do not claim your deductions should be considered as accepted or established facts, or even that another researcher will necessarily get the same results. In (b), using the Present Simple tense means that you believe your findings and deductions are strong enough to be considered as facts or truths. The Present Simple communicates this reliability and your readers will respond to your work accordingly. There will be more about this later, in the unit on Results.

Past Simple/Present Perfect

Another tense pair you need in the Introduction is the Past Simple tense and the Present Perfect tense. You will need both, and you need to know when and why to switch from one to the other. Look at 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.
(c) Past Simple: I broke my glasses...	but it doesn't matter/ I repaired them.
(d) Present Perfect: I have broken my glasses...	and so I can't see properly NOW.

You probably learned the difference between (a) and (b) years ago: that one of the differences between Past Simple and Present Perfect is the ‘time’ of the verb, *i.e.* when it happened. The difference between (c) and (d) is harder to understand and more important for you as a writer of science research.

In (c) and (d), ‘time’, *i.e.* when the verb happened, isn’t really what separates the two sentences; it’s possible that both (c) and (d) happened last month, this morning, or one nanosecond ago. What is important is that the event in (d) is considered more relevant to the situation now than the event in (c), which is why it is given in the Present Perfect. Why is this idea of relevance useful when you write an Introduction? Look at these sentences from the Introduction in Section 1.1:

*For example, Penney et al. **showed** that PLA composites could be prepared using blending techniques⁶ and more recently, Hillier **established** the toughness of such composites.⁷ However, although the effect of the rubber particles on the mechanical properties of copolymer systems **was demonstrated** over two years ago,⁸ little* attention **has been paid** to the selection of an appropriate rubber component.*

* *Note: a **little** means ‘a small amount’, but **little** means ‘virtually none’.*

Where does the tense change? Why do you think the writer changes from the Past Simple to the Present Perfect? Could it be because this research article is NOW paying attention to the selection of an appropriate rubber component?

Now look at what happens if the writer forgets to change tense and continues in the Past Simple:

*However, although the effect of the rubber particles on the mechanical properties of copolymer systems **was demonstrated** over two years ago,⁸ little attention **was paid** to the selection of an appropriate rubber component.*

Suddenly, the sentence means that little attention was paid THEN, *i.e.* two years ago. Perhaps attention has been paid to this problem since then; perhaps the problem has even been solved! Tense changes are always meaningful, and they always signal a change in the function of the information — so don't change tense randomly and make sure you remember to change tense when you should.

Now check what you have learned about tenses by looking carefully 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 refer to previous research.

1.2.2 Signalling language

Sentence connection

One of the most common errors in writing is failing to connect one sentence or idea to the next. Every time you end a sentence, your reader has no idea what the next sentence is going to do or say. As a result, the space between a full stop and the next capital letter is a dangerous space for you and your reader. Perhaps you stopped for ten minutes after a sentence, and during that time you thought about your work and your ideas developed. Perhaps you turned off your computer and went home. When you start typing again, if you don't share the link between those sentences with your reader, you create a gap in the text which will cause problems.

One of your tasks as a writer is to make sure that gap is closed, so that your reader is carried carefully from one piece of information to the next. Connecting sentences and concepts is good for you too, as it forces you to develop your ideas logically.

One way to connect sentences is to **overlap**, meaning to repeat something from the previous sentence:

*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.*

*One way to toughen polymers is to incorporate a layer of rubber particles. As a result, there has been extensive research regarding the **rubber** modification of PLA.*

Another way is to use a **pronoun** (*it, they*) or **pro-form** (*this method, these systems*) to glue the sentences together:

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

*On the basis of these criteria it then describes the preparation of a set of polymer blends using PLA and a hydrocarbon rubber (PI). **This combination** of two mechanistically distinct polymerisations formed a novel copolymer in which the incorporation of PI significantly increased flexibility.*

The third way is not to finish the sentence at all, but to join it to the next sentence with a **semicolon** or a **relative clause** (a ‘which’ clause). Joining sentences with a semicolon works well when two sentences are very closely related and one of them is quite short:

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

*It has received much attention over the past few decades due to its biodegradable properties, **which** offer important economic benefits.*

The fourth way is to use a signalling sentence connector to indicate the relationship between one sentence and the next, or one part of a sentence and the next. You know how useful sentence connectors are from your reading; when you see a word like *therefore* or *however*, you are able to process the next piece of information in the sentence correctly even if you don’t understand every word. This is because the sentence connector signals the function of the information in the sentence. The opposite is also true: when the writer does not signal the function of the information with a connector, it is harder for the reader to process the information. Even if the grammar is perfect and every word is correct, the reader still may not be sure what the information is doing (Is it a result of the previous

sentence? An example? A cause?), and may interpret it differently from the way the writer intended.

You already use words like *therefore* and *however* and one aim of this subsection is to make sure that you are using them correctly. Another aim is to expand your vocabulary of signalling words, because you can't spend the rest of your writing life using only *therefore* and *however*! Here are some examples of signalling language arranged according to their function. It is not a long list because only those which are commonly used in science writing have been 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)	as
on account of (the fact that)	because
in view of (the fact that)	since

- Be careful when you use *since*; it is also often used to mean 'from that time', so if there's any possibility of confusion, choose a different connector.
- All these connectors can be used at the start of a sentence, even because (Because the measuring instruments were inaccurate, the experiment was unsuccessful).

RESULT

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

therefore	as a result (of which)
consequently	which is why
hence	so

- Don't start sentences with *so* to communicate a result; it's too informal.

- You can sometimes use *then*, for example in sentences like ‘If x then y’, but it won’t work in every sentence, which is why it has not been included in this list.

CONTRAST/DIFFERENCE

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

<p>however whereas but</p>	<p>on the other hand while by contrast</p>
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- *on the contrary* and *conversely* don’t fit into this category because they don’t only communicate difference; they communicate the fact that ‘exactly the opposite is true’, so 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.*
- Be careful when you use *while*; it is also often used to mean ‘at that/ the same time’, so if there’s any possibility of confusion, choose a different connector.

UNEXPECTEDNESS

- (a) _____ *it was difficult, a solution was eventually found.*
 (b) _____ *the difficulty, a solution was eventually found.*
 (c) *It was difficult; _____ a solution was eventually found.*

<p>(a) Although (a) Even though (a) Though</p>	<p>(b) Despite (b) In spite of (b) Regardless of (b) Notwithstanding</p>	<p>(c) nevertheless (c) however (c) yet (c) nonetheless (c) even so</p>
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- There are other connectors with the same meaning, such as *still* and *anyway*, but they are more informal.

ADDITION

We used a batch processing system because it was more effective; _____ it was faster.

in addition	also
moreover	secondly (etc)
furthermore	in the second place (etc.)
apart from that/which	what is more,

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

Now check what you have learned by looking at the way sentences are connected in the Introductions of your target articles.

1.2.3 Passive/Active

Students often ask whether they can use **we** in their research articles. In the Introduction you usually say what you will be doing or presenting in the research article. You can use **we** to refer to your research group or team, but do not use it to refer to people or humanity in general. If you are referring to people in general, it's better to use a construction with *It* (*It is known/thought that...*) rather than *We know/think that...* It is also common to use the passive instead of **we**, especially in the central 'report' section (*was measured, was added, etc.*).

In a thesis, you are writing as an individual and you don't have a research group or team. Since you cannot write your thesis using **I**, you will probably write in the passive. Use words like *here* and *in this study* to

let your reader know when you are referring to your own work. You can also use a ‘dummy’ subject to take the place of **I** or **we**:

This article describes an algorithm for clustering sequences into index classes.

The present paper presents a set of criteria for selecting such a component.

The problem with using the passive in formal writing is that the agent (the person who performed the action of the verb) is often not mentioned in the sentence. In other words, we say that something *was done* or *was identified etc.* but we don’t say ‘by me’ or ‘by other researchers’, so the reader may not know who *did* it or who *identified* it. This can cause confusion and for that reason it is sometimes clearer to use a dummy subject (*This article/the present paper*) in the Introduction rather than the ‘agentless’ passive (*x is presented*). Now look at the way the passive and dummy subject are used in the Introductions of your target articles.

PARAGRAPHING

Why is paragraphing important?

Paragraphs are an important visual aid to effective reading and writing. Two common errors in paragraphing are clusters of short or single-sentence paragraphs, and paragraphs that are too long. Both errors will confuse readers and are signs of poorly-organised writing.

To understand how paragraphing works, imagine that you have won a 24-hour trip to Paris. You have two options. The first option is to fly to Paris, get off the plane and walk around the city. If you take that option, a friend may ask you later if you saw the famous Louvre art gallery; you say: ‘Well, no, I got lost and spent hours walking around the industrial area by mistake.’ You show your mother the clothes you bought in Paris and she asks if you bought them in the famous Rue de la Paix shopping street, and you say, ‘No, I bought them near my hotel. I didn’t know where the big shopping area was.’ You begin to realise that you wasted a lot of time and missed many important things.

The second option is to take a short helicopter ride over Paris before you leave the airport. It's a difficult decision because you are impatient; you only have 24 hours and you don't want to waste time, but you do it anyway. The helicopter flies over Paris for half an hour in a grid pattern, after which you begin your tour of Paris. You find a well-situated hotel, which you saw from the helicopter. You buy your clothes in the Rue de la Paix — which you saw from the helicopter. You visit the Louvre and you have lunch in one of the big parks near the centre ... which you saw from the helicopter.

What is the connection between this and good paragraphing?

Let's bring that idea to the skills of reading and writing. 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 may finish the book faster. This is because you don't waste time wondering who the murderer is; you know it's the husband, 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.

The more you know about what you are reading, the faster and more effectively you read. So how can you find out about a long article or chapter before reading it? The answer is to skim it quickly before you begin to read. Like the helicopter ride over Paris, skimming is done before reading, not instead of reading. Your aim when you skim through a text is **to find out quickly what it is about and where the various pieces of information are located** so that you can read it faster and more confidently.

How do I skim efficiently and quickly?

Most of the instructions in the box below tell you just to 'look at' or 'check' something. Skimming is a pre-reading technique and should be done very fast; if it takes more than a few minutes you're not skimming, you're reading.

1. READ THE TITLE

and try to predict the type of information you expect to see

2. LOOK AT THE NAME OF THE AUTHOR

What you know about the writer will help you predict and evaluate the content.

3. CHECK THE DATE
and use it to help you assess the content.
4. READ THE ABSTRACT
to find out what the researchers did and/or what they found
5. LOOK QUICKLY AT THE FIRST PARAGRAPH
without trying to understand all the words.
6. LOOK QUICKLY AT THE FIRST SENTENCE OF EACH PARAGRAPH
without trying to understand all the words
7. LOOK QUICKLY AT EACH FIGURE/TABLE AND READ ITS TITLE
to try and find out what type of visual data is included
8. READ THE LAST PARAGRAPH
especially if it has a subtitle like 'Summary' or 'Conclusion'

Skimming may help me read, but how does it help me to write?

Look at number 6 in the box: LOOK QUICKLY AT THE FIRST SENTENCE OF EACH PARAGRAPH. A paragraph in academic writing often starts with a *topic sentence*, which gives the main idea of the paragraph, and tells the reader what the paragraph is about. The other sentences are related to this idea; they discuss it, describe it, define it in more detail, argue about it, give examples of it, rephrase it, *etc.* When the 'topic' or idea moves too far away from the first sentence, the writer usually begins a new paragraph.

You can therefore get a good idea of the various topics covered in an article — or in a chapter of a book — by reading the first sentence of each paragraph. And because it is a conventional way of writing paragraphs, it is a safe way for you to write paragraphs too. The more aware you are of the way other writers structure paragraphs, the easier it will be for you to do it yourself.

As you know, paragraphs are marked either by indentation (starting five spaces in) or by a double space between lines. Over the years, you have developed a very strong response to these visual signals. This means that each time you begin a new paragraph, this conditioned response in your brain prepares for a change or shift of some kind.

Correct paragraphing is essential, but it is easy to get into poor paragraphing habits, either through laziness or carelessness. If you often write one-sentence paragraphs **or** your paragraphs seem to be very long **or** you're not sure when to start a new paragraph, you are making writing harder for yourself. When you are planning your paper, write down each idea/concept that you want to talk about, checking that they are in a logical order and then listing what you want to say about each, using bullet points. This will help you create paragraphs that have a logical and coherent structure.

1.3 Writing Task: Build a Model

1.3.1 Building a model

You are now ready to begin building a model of Introductions by writing a short description of what the writer is doing in each sentence in the space provided. This may be hard, because it is the first time you are doing it, so read the guidelines below before you start. The Key is on the next page. Once you have tried to produce your own model you can use the Key to help you write this section of a research article when you eventually do it on your own.

GUIDELINES: You should spend 30–45 minutes on this task. If you can't think of a good description of the first sentence, choose an easier one, for example, Sentence 7, and start with that. 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 your model to generate Introductions in your own field.

One way to find out what the writer is doing in a sentence — rather than what s/he is saying — is to imagine that your computer has accidentally deleted it. What is different for you as a reader when it disappears? If you press another key on the computer and the sentence comes back, how does that affect the way you respond to the information?

Another way to figure out what the writer is doing in a sentence is to look at the grammar and vocabulary clues. What is the tense of the main verb? What is that tense normally used for? Is it the same tense as in the previous sentence? If not, why has the writer changed the tense? What words has the writer chosen to use?

Don't expect to produce a perfect model. You will modify your model when you look at the Key, and perhaps again when you compare it to the way Introductions work in your target articles.

The synthesis of flexible polymer blends from polylactide and rubber

Introduction

1 Polylactide (PLA) has received much attention in recent years due to its biodegradable properties, which offer important economic benefits. 2 PLA is a polymer obtained from corn and is produced by the polymerisation of lactide. 3 It has many possible uses in the biomedical field¹ and has also been investigated as a potential engineering material.^{2,3} 4 However, it has been found to be too weak under impact to be used commercially.⁴

5 One way to toughen polymers is to incorporate a layer of rubber particles⁵ and there has been extensive research regarding the rubber modification of PLA. 6 For example, Penney *et al.* showed that PLA composites could be prepared using blending techniques⁶ and more recently, Hillier established the toughness of such composites.⁷ 7 However, although the effect of the rubber particles on the mechanical properties of copolymer systems was demonstrated over two years ago,⁸ little attention has been paid to the selection of an appropriate rubber component.

8 The present paper presents a set of criteria for selecting such a component.

In this sentence,
the writer:

1 _____

2 _____

3 _____

4 _____

5 _____

6 _____

7 _____

8 _____

<p>9 On the basis of these criteria it then describes the preparation of a set of polymer blends using PLA and a hydro-carbon rubber(PI). 10 This combination of two mechanistically distinct polymerisations formed a novel copolymer in which the incorporation of PI significantly increased flexibility.</p>	9 _____
	10 _____

1.3.2 Key

In Sentence 1 ‘*Poly lactide (PLA) has received much attention in recent years due to its biodegradable properties, which offer important economic benefits.*’ **the writer establishes the importance of this research topic.**

If you wrote ‘introduces the topic’ for Sentence 1, it won’t really help when you come to write a real research article. How exactly do you ‘introduce’ a topic? You need to be more specific.

Most research articles begin by indicating that the research field or topic is useful or significant. They may focus on the quantity of research in this area, or how useful research in this area can be, or simply how important this research field is. If you look at your target articles, you will probably find something in the first one or two sentences that establishes the significance of the research. Phrases like *much study in recent years* or *plays a major role* are common here, and you’ll find a list of useful vocabulary for this in Section 1.4.

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

Most authors of research articles begin by establishing the significance of their research; if you don’t, it can look as though your research is NOT significant, so don’t be shy about stating why or how your field is important or useful.

What tense should I write in here?

Phrases like much study 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...*). Other ways of establishing significance may use the Present Simple tense (*There are substantial benefits to be gained from...*).

In Sentence 2 ‘*PLA is a polymer obtained from corn and is produced by the polymerisation of lactide.*’ **the writer provides general background information for the reader.**

Sentence 2 is in the Present Simple tense, which is used for accepted/ established facts (see Section 1.1). Research articles often begin with accepted or established facts. This ensures that the reader shares the same level of background information as the writer, and is therefore ready to read the article.

So what kind of facts should I start with?

This depends on how wide your subject — and therefore your readership — is. If the subject of your research is very specific, then many of your readers will have a high level of background knowledge, and you can start with fairly specific information. If your paper is likely to attract a wider audience, then you should start with more general background information. Remember that your background facts may come from research (see Section 1.1), so don't forget to include the research references where necessary.

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

Start with the most general one, the one that many of your readers will already know. This is a ‘meeting place’ fact, a place where all your readers can start together, after which you can move on to more specific information. Always show your readers the general picture before you examine the details: **show them the wall before you examine the bricks!** Also, don't forget to close the gap between these sentences (see Section 1.2.2) so that your readers can move smoothly through the information.

Remember that the background facts to your research are very familiar to you and the people you work with, but they won't be as familiar to all of your readers. Therefore, if the article is to reach a wider audience you need to state background facts which seem obvious or well-known to you.

I'm still not sure where to begin.

If you are still stuck for a first sentence, look at your title. It is helpful to your readers if you define the key words in your title — perhaps you can begin with a definition or a fact about one of those key words.

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

You can, but most authors don't, because it's sometimes difficult to say exactly what the problem is until your readers have enough background 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 down a lot of specific information which your readers aren't ready for because you haven't given them enough background.

In Sentence 3 'PLA has many possible uses in the biomedical field¹ and has also been investigated as a potential engineering material^{2,3}' the writer does the same as in Sentences 1 and 2, but in a more specific/detailed way, using research references to support both the background facts and the claim for significance.

Don't the research references mean that this is part of the literature review?

No, it's still part of the background to general research in this area. The short literature review which is generally found in the Introduction of a research article comes later, and is more likely to deal with individual studies and their methods or results. In a thesis the literature review is much longer and may be a separate chapter.

So why does the author include references if it's only the background?

For three reasons: First, because plagiarism (failing to give others the appropriate credit for their work) is unprofessional; second, referencing gives your reader the chance to find and read the study mentioned.

The third reason is that failing to provide a reference may indicate that you are not familiar with research in your area.

Although Sentence 3 isn't part of the literature review (which comes later in the Introduction) it includes a citation reference. Before you write a research paper, you collect a lot of references, quotations and ideas from journals and the Internet, many of which you will mention at some point in the paper. When you are writing the Introduction, you need to ask yourself three questions:

1. *Which of the research papers I have read should be mentioned somewhere in the Introduction?* The selection of names and references in the Introduction is important, because they draw a research 'map' for the reader by indicating the key players in your field and the progress or achievements so far. These names and references give the reader a clear idea of where your research is located and how it is related to other work in the field.

2. *Which ones should be part of the background to the research (as in Sentence 3 above) and which ones should go in the literature review which comes later in the Introduction?* If the findings are well-known and considered reliable enough to be presented as truths, you can present them in the Present Simple as part of the factual background to your paper (as in Sentence 3) with a research reference. The literature review, which describes recent and current research in your field, usually mentions authors by name, and the sentence is usually in the Simple Past or Present Perfect tense.

3. *What order should I mention them in? Who comes first and who comes last?* These questions about the literature review itself will be discussed after Sentence 6.

In Sentence 4 *'However, it has been found to be too weak under impact to be used commercially.'*⁴ **the writer describes the general problem area or the current research focus of the field.**

Notice that the author is still not describing the specific problem which this research article will deal with; s/he is describing the current focus of the field, a problem which *many* researchers in this field are interested in and which leads to the specific problem which will be addressed in this article. Remember to keep this general description of the problem area

or current research focus brief, or you will find that you begin to give a specific description of what your research is trying to achieve, and it's still too early in the Introduction for that.

As you can see from Sentence 4, you may need a research reference when you describe the problem your paper will deal with; however, if it is a well-known problem (rather than a recent issue, as in Sentence 4), then it is not necessary to provide a reference.

In Sentence 5 *'One way to toughen polymers is to incorporate a layer of rubber particles.'*⁵ **the writer provides a transition between the general problem area and the literature review.**

As a general rule, you should include references to previous or current research wherever it is useful, even in a sentence whose function is primarily to provide a transition. Make sure that the superscript reference number includes all and only the work referred to in the sentence (see the notes on Sentence 6 below for more about this).

In Sentence 6 *'For example, Penney et al. showed that PLA composites could be prepared using blending techniques⁶ and more recently, Hillier⁷ established the toughness of such composites.'* **the writer provides a brief overview of key research projects in this area.**

You can't just 'pour' the literature review onto the page in any order; you should arrange your references and studies so that the reader is able to process them in a logical way. Here are three common options:

- **chronological:** Deal with the research in chronological order. This may be appropriate, for example, if the development of your field is related to political decisions.
- **different approaches/theories/models:** Group projects or studies according to their approach or methodology. Grouping similar projects together helps you avoid the 'tennis match' effect where

you go backwards and forwards, beginning each sentence in the literature review with *However* or *On the other hand!*

- **general/specific:** Start with general research in the field and gradually move to research that is closer to your own.

When should a research reference come in the middle of the sentence?

When it is necessary to avoid confusion, for example if you are referring to more than one study in a sentence or if the citation reference only refers to part of your sentence. You can see examples of this in Sentences 6 and 7.

In Sentence 7 ‘*However, although the effect of the rubber particles on the mechanical properties of copolymer systems was demonstrated over two years ago,⁸ little attention has been paid to the selection of an appropriate rubber component.*’ **the writer describes a gap in the research.**

This is where you begin to introduce the purpose of your paper and the specific problem you will deal with, and in order to do this it is necessary to create a research space. You can do this either by describing a problem in the previous research or by indicating that there is a gap in the research. It is conventional to introduce it with a signalling connector such as *However* or *Although*. In professional writing it is unusual to put it in the form of a question; instead you can state it as a prediction or a hypothesis which you intend to test.

Don’t be shy about pointing out the problems in previous research. In the first place it may be necessary in order to explain why you have done your study, and in the second place, the language used here is usually respectful and impersonal, and is therefore not considered offensive. We will look at the politeness aspect of this language in the vocabulary section at the end of the unit.

You may need more background information at this stage (for example, you may need to give details of the properties of the material which you have chosen to investigate, or describe the specific part of the device which you plan to improve). Research writing requires far more background information than you have previously given in your undergraduate writing, and it is better to offer slightly too much background information than too little.

In Sentence 8 *'The present paper presents a set of criteria for selecting such a component.'* **the writer describes the paper itself.**

At this stage you move to the present work. You can describe it, say what its purpose or focus is, give its structure or a combination of these. Check Section 1.2.3 to see whether to write these sentences in the active or the passive.

You normally use the Present Simple tense to describe the work itself (*This paper is organised as follows* or *This study focuses on*) and the Past Simple tense to talk about the aim of the work (*The aim of this project was...*), because in 'real time', the aim occurred before the work was carried out. It is also possible to state the aim in the Present Simple (*The aim of this work is...*). This is especially true in cases where the aim is only partially achieved in the paper you are submitting and the rest of the work will be done and reported on at a later stage.

In Sentence 9 *'On the basis of these criteria it then describes the preparation of a set of polymer blends using PLA and a hydrocarbon rubber(PI).'* **the writer gives details about the methodology reported in the paper.**

In Sentence 10 *'This combination of two mechanistically distinct polymerisations formed a novel copolymer in which the incorporation of PI significantly increased flexibility.'* **the writer announces the findings.**

Although you can give information about your methodology or findings in the Introduction, be careful not to go into too much detail at this point or you will find that you have nothing to write about in the Methodology or Results sections.

Look at the way the writer begins Sentences 9 and 10. In each case the information is joined to the previous sentence with a pro-form (*On the basis of **these criteria*** in Sentence 9 and ***This combination*** in Sentence 10).

1.3.3 The model

Here are the sentence descriptions we have collected:

- In Sentence 1** the writer establishes the importance of this research topic.
- In Sentence 2** the writer provides general background information.
- In Sentence 3** the writer does the same as in Sentences 1 and 2, but in a more specific/detailed way.
- In Sentence 4** the writer describes the general problem area or the current research focus of the field.
- In Sentence 5** the writer provides a transition between the general problem area and the literature review.
- In Sentence 6** the writer provides a brief overview of key research projects in this area.
- In Sentence 7** the writer describes a gap in the research.
- In Sentence 8** the writer describes the paper itself.
- In Sentence 9** the writer gives details about the methodology reported in the paper.
- In Sentence 10** the writer announces the findings.

We can streamline these so that our model has FOUR basic components:

1	ESTABLISH THE IMPORTANCE OF YOUR FIELD PROVIDE BACKGROUND FACTS/INFORMATION (possibly from research) DEFINE THE TERMINOLOGY IN THE TITLE/KEY WORDS PRESENT THE PROBLEM AREA/CURRENT RESEARCH FOCUS
2	PREVIOUS AND/OR CURRENT RESEARCH AND CONTRIBUTIONS
3	LOCATE A GAP IN THE RESEARCH DESCRIBE THE PROBLEM YOU WILL ADDRESS PRESENT A PREDICTION TO BE TESTED
4	DESCRIBE THE PRESENT PAPER

1.3.4 Testing the Model

The next step is to look at the way this model works in a real Introduction. Here are some full-length Introductions from real research articles. Read them through, and mark the model components (1, 2, 3 or 4) wherever you think you see them. For example, if you think the first sentence of the Introduction corresponds to number 1 in our model, write 1 after it, *etc.*

The height of biomolecules measured with the atomic force microscope depends on electrostatic interactions

INTRODUCTION

Because the atomic force microscope (AFM) (Binnig *et al.*, 1986) makes it possible to image surfaces in liquids, it has become an important tool for studying biological samples (Drake *et al.*, 1989). Recent reports document the observation of protein assemblies under physiological conditions at nanometer resolution (Butt *et al.*, 1990; Hoh *et al.*, 1991; Karrasch *et al.*, 1993, 1994; Yang *et al.*, 1993, Schabert and Engel, 1994; Mou *et al.*, 1995b; Muller *et al.*, 1995b, 1996b). As demonstrated on solids under vacuum conditions (Sugawara *et al.*, 1995) and in liquid (Ohnesorge and Binnig, 1993), the AFM also makes it possible to measure sample heights with subangstrom accuracy. However, the heights of native biological samples measured with the AFM in aqueous solution vary significantly, and may differ from values estimated with other methods (Butt *et al.*, 1991; Apell *et al.*, 1993; Muller *et al.*, 1995b, 1996a; Schabert and Rabe, 1996). For example, the height reported for single purple membranes ranges from 5.1 ± 0 nm to 11.0 ± 3.4 nm (see Table 1). Height measurements on actin filaments (Fritz *et al.*, 1995b), bacteriophage $\phi 29$ connectors (Muller *et al.*, 1997c), cholera toxin (Yang *et al.*, 1994; Mou *et al.*, 1995b), DNA (Hansma *et al.*, 1995; Mou *et al.*, 1995a; Wyman *et al.*, 1995), gap junctions (Hoh *et al.*, 1993), GroEL (Mou *et al.*, 1996), hexagonally packed intermediate layer (HPI) (Karrasch *et al.*, 1993; Muller *et al.*, 1996a; Schabert and Rabe, 1996), lipid bilayers (Mou *et al.*, 1994, 1995b; Radler *et al.*, 1994), and microtubules (Fritz *et al.*, 1995a) exhibit a similar variability. Height anomalies

of soft surfaces have previously been studied and attributed to the mechanical properties of the sample (Weisenhorn *et al.*, 1992; Radmacher *et al.*, 1993, 1995; Hoh and Schoenenberger, 1994). However thin samples such as two-dimensional protein arrays or biological membranes adsorbed to a solid support are not sufficiently compressible to explain such large height variation.

Here we demonstrate that electrostatic interactions between the AFM tip and the sample (Butt, 1991a, b) influence the measured height of a biological structure adsorbed to a solid support in buffer solution. The DLVO (Derjaguin, Landau, Verwey, Overbeek) theory (Israelachvili, 1991) is used to describe the electrostatic repulsion and van der Waals attraction acting between tip and sample (Butt *et al.*, 1995). Experimental results and calculations show that the electrostatic double-layer forces can be eliminated by adjusting the electrolyte concentration (Butt, 1992a, b), providing conditions for correct height measurements with the AFM. In addition, the observed height dependence of the biological structure on electrolyte concentration allows its surface charge density to be estimated.

Optimal location discrimination of two multipartite pure states

1. INTRODUCTION

Entanglement lies at the heart of many aspects of quantum information theory and it is therefore desirable to understand its structure as well as possible. One attempt to improve our understanding of entanglement is the study of our ability to perform information theoretic tasks locally on non-local states, such as the local implementation of non-local quantum gates [2], telecloning [3], the remote manipulation and preparation of quantum states [4] or the recently studied question of the local discrimination of non-local states by a variety of authors. In [1] it was shown that any two orthogonal pure states can be perfectly discriminated locally, whereas in [5] examples of two *orthogonal* mixed states were presented which *cannot* be distinguished

perfectly locally. Another surprising development is that there exist bases of product orthogonal pure states which cannot be locally reliably discriminated, despite the fact that each state in the basis contains no entanglement [6]. Here we discuss the issue of discriminating two non-orthogonal pure states locally, and show that in this regime the optimal global procedure can be achieved.

Inert COD production in a membrane anaerobic reactor treating brewery wastewater

INTRODUCTION

The chemical characterization of wastewaters is commonly undertaken to determine their biological treatability, load on an existing treatment system, or compliance with the final discharge standards. In each case, one of the most important parameters to be measured is the chemical oxygen demand (COD). In general, the COD value of a wastewater mainly represents the biodegradable and non-biodegradable organic components, although inorganic compounds may be significant in certain cases. In biological treatment systems, the biodegradable fraction of wastewater can be removed effectively, but its non-biodegradable fraction passes through the system unchanged. In addition to this, a significant amount of soluble microbial products may be produced by microorganisms within the treatment systems. Some of these will be resistant to biological degradation and will appear in reactor effluents. The factors that affect effluent quality and overall organic matter removal in biological treatment systems are, therefore, the presence of both the inert COD fraction in the influent wastewater and the soluble microbial products which are produced during biological treatment. Although their concentrations may have few practical implications in the treatment of low strength wastewaters, they may have relatively greater significance in the treatment of medium-high strength industrial wastewaters.

There is extensive literature on the determination of inert COD fractions in industrial wastewaters under aerobic conditions (Chudoba, 1985; Ekama *et al.*, 1986; Rittman *et al.*, 1987;

Henze *et al.*, 1987; Orhon *et al.*, 1989; Germirli *et al.*, 1991). However, little has been reported under anaerobic conditions (Germili *et al.*, 1998; Ince *et al.*, 1998). Since medium-high strength industrial wastewaters have been treated efficiently by anaerobic treatment systems, both the inert COD fraction of wastewaters under anaerobic conditions and the soluble microbial products produced within the anaerobic treatment systems should be investigated.

A novel anaerobic reactor system, crossflow ultrafiltration membrane anaerobic reactor (CUMAR) has previously shown great potential for retaining high biomass levels and high biological activity within a fully functioning anaerobic digester (Ince *et al.*, 1993, 1994, 1995a). Since the CUMAR system can be operated at high organic loading rates, the quantification of its efficiency under varying loading rates would be of considerable interest, particularly with regard to the nature and quantity of soluble COD produced in the reactor effluent under various operating conditions.

In this study, formation of soluble microbial products within a 120:1 [is this correct? Should it be 120:1?] pilot-scale CUMAR system treating brewery wastewater will, therefore, be discussed in relation to reactor operating conditions.

Organic vapour phase deposition: a new method for the growth of organic thin films with large optical non-linearities

1. 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 (eg 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.

Limitations of charge-transfer models for mixed-conducting oxygen electrodes

INTRODUCTION

Traditionally, electrochemistry is concerned with charge-transfer reactions occurring across a 2-dimensional interface. Indeed, at any macroscopic two-phase boundary, the magnitude, direction and driving force for current density can be described relatively unambiguously. As early as 1933 [1], workers began introducing the concept of a 'three-phase boundary' (solid/liquid/gas) in order to allow for direct involvement of gas-phase species at an electrochemical interface. However, since matter cannot pass

through a truly one-dimensional interface among three phases, concepts of ‘interfacial area’, ‘current density’, and ‘overpotential’ at a three-phase boundary lack clear definition. For example, where exactly is the current flowing from/to, and what is the local flux density? Also, if we define overpotential in terms of thermodynamic potentials of species outside the interfacial region, what species and region are we talking about? Although the three-phase boundary concept may serve as a useful abstraction of the overall electrode reaction, it does not address these mechanistic questions.

Workers studying gas-diffusion electrodes in the mid-1960s recognized the limitations of the three-phase boundary concept [2, 3]. As an alternative, they began to break down the electrode reaction into individual steps, some that involve charge-transfer across a two-dimensional interface, and some that involve dissolution and diffusion of molecular species in three dimensions or across a chemical interface. These and subsequent studies have demonstrated that electrodes with i - V characteristics indicative of charge-transfer limitations (eg Tafel behaviour) can, in fact, be limited by steps that do not themselves involve charge-transfer [4]. Although the solid-state literature has held on to the three-phase boundary concept more tightly than the aqueous or polymer literature, few examples remain today of solid-state electrochemical reactions that are not partially limited by solid-state reaction and diffusion processes.

One example is the O₂-reduction reaction on a mixed-conducting perovskite electrode, which defies rational explanation in terms of interfacial impedance. In order to incorporate non-charge-transfer effects, workers often apply an empirical Butler–Volmer model (for DC characteristics) or an equivalent-circuit model (for AC impedance) that treat non-charge-transfer processes in terms of an *effective* overpotential/current relationship [5,6]. However, this approach lacks generality and can often be incorrect for treating oxygen absorption and solid-state and gaseous diffusion, which contribute to the impedance in a convoluted manner [7]. Although such models may provide a useful set of parameters to ‘fit’ data accurately, they leave the electrode reaction

mechanism only vaguely or empirically defined, and provide little mechanistic insight.

The purpose of this paper is to provide a framework for defining ‘charge-transfer’ and ‘non-charge-transfer’ processes, and to illustrate how they are different. We investigate why charge-transfer models have difficulty modelling non-charge-transfer effects, and walk through several examples including the ALS model for oxygen reduction on a porous mixed-conducting oxygen electrode. We then review a recent study of linear AC polarization of $\text{La}_{1-x}\text{Sr}_x\text{CoO}_{3-5}$ (LSCO) electrodes on ceria that corroborates the ALS model, and demonstrates the importance of O_2 surface exchange and diffusion. This study shows that the electrode reaction extends up to 20 microns beyond the electrode/electrolyte interface, implying that electrode polarization is better described by macroscopic thermodynamic gradients than as an ‘overpotential’.

Now do the same for the Introductions of your target articles. You should find that most Introductions begin with item 1, that the order of the model components is usually fairly reliable (although items 2 and 3 can occur more than once) and that almost all Introductions finish with number 4. We have, therefore, answered the three questions we set at the beginning of this unit:

- How do I start the Introduction? What type of sentence should I begin with?
- What type of information should be in my Introduction, and in what order?
- How do I end the Introduction?

1.4 Vocabulary

You now need to collect vocabulary for each part of the Introduction model. The vocabulary in this section is taken from over 600 research articles in different fields, all of which were written by native speakers and published in science journals. Only words/phrases which appear frequently have been

included; this means that the vocabulary lists contain words and phrases which are considered normal and acceptable by both writers and editors. We will look at vocabulary for the following areas of the model:

1. ESTABLISHING SIGNIFICANCE

This includes phrases such as *Much research in recent years*. A good list of commonly used words and expressions will encourage you to include this in your first sentences.

2. PREVIOUS AND/OR CURRENT RESEARCH AND CONTRIBUTIONS

This includes all past tense verbs describing what researchers did, *i.e. calculated, monitored, etc.* Instead of just using *did, showed* and *found*, you often need to be more specific about what a researcher actually 'did'!

3. GAP/PROBLEM/QUESTION/PREDICTION

This includes ways to say exactly how previous and/or current research is not yet complete or has not addressed the problem your paper deals with, *i.e. However, few studies have focused on...*

4. THE PRESENT PAPER

This may include your purpose, your strategy and the design of your paper, using language such as *the aims of the present work are as follows*:

VOCABULARY TASK

Look through the Introductions in this unit and the Introductions of your target articles. Underline or highlight all the words and phrases that you think could be used in each of the four areas given above.

A full list of useful language can be found on the following pages. This includes all the appropriate words and phrases from the Introductions in this unit, together with some other common ones which you may have seen in your target articles. Underneath each list you will find examples of how they are used. Read through the list and check the meaning of any you don't know in the dictionary. This list will be useful for many years.

1.4.1 Vocabulary for the Introduction

1. ESTABLISHING SIGNIFICANCE

<p>(a) basic issue</p> <p>(a) central problem</p> <p>(a) challenging area</p> <p>(a) classic feature</p> <p>(a) common issue</p> <p>(a) considerable number</p> <p>(a) crucial issue</p> <p>(a) current problem</p> <p>(a) dramatic increase</p> <p>(an) essential element</p> <p>(a) fundamental issue</p> <p>(a) growth in popularity</p> <p>(an) increasing number</p> <p>(an) interesting field</p> <p>(a) key technique</p> <p>(a) leading cause (of)</p> <p>(a) major issue</p> <p>(a) popular method</p> <p>(a) powerful tool/method</p> <p>(a) profitable technology</p> <p>(a) range (of)</p> <p>(a) rapid rise</p> <p>(a) remarkable variety</p> <p>(a) significant increase</p> <p>(a) striking feature</p> <p>(a) useful method</p> <p>(a) vital aspect</p> <p>(a) worthwhile study</p>	<p>economically important</p> <p>(has) focused (on)</p> <p>for a number of years</p> <p>for many years</p> <p>frequent(ly)</p> <p>generally</p> <p>(has been) extensively studied</p> <p>importance/important</p> <p>many</p> <p>most</p> <p>much study in recent years</p> <p>nowadays</p> <p>numerous investigations</p> <p>of great concern</p> <p>of growing interest</p> <p>often</p> <p>one of the best-known</p> <p>over the past ten years</p> <p>play a key role (in)</p> <p>play a major part (in)</p> <p>possible benefits</p> <p>potential applications</p> <p>recent decades</p> <p>recent(ly)</p> <p>today</p> <p>traditional(ly)</p> <p>typical(ly)</p> <p>usually</p>
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(an) advantage attracted much attention benefit/beneficial commercial interest during the past two decades	well-documented well-known widely recognised widespread worthwhile
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Here are some examples of how these are used:

- A **major current focus** in population management is how to ensure sustainability of...
- **Numerous experiments have established that** ionising radiation causes...
- Low-dose responses to radiation have **generated considerable recent research interest**.
- Analysis of change in the transportation sector is **vital** for two **important** reasons: ...
- PDA accounts for **over 95%** of all pancreatic cancers.
- **It is generally accepted that** joints in steel frames operate in a semi-rigid fashion.
- Nanocrystalline oxide films **are attracting widespread interest** in fields such as...
- **The importance of** strength anisotropy has been demonstrated by...
- Convection heat transfer phenomena **play an important role in** the development of...
- For **more than 100 years** researchers have been observing the stress-strain behaviour of...
- **Much research in recent years has focused on** carbon nanotubes.

2. VERBS USED IN THE LITERATURE REVIEW TO PRESENT PREVIOUS AND/OR CURRENT RESEARCH AND CONTRIBUTIONS

achieve	develop	obtain
address	discover	overcome
adopt	discuss	perform
analyse	enhance	point out
apply	establish	predict
argue	estimate	present
assume	evaluate	produce
attempt	examine	propose
calculate	explain	prove
categorise	explore	provide
carry out	extend	publish
choose	find	put forward
claim	focus on	realise
classify	formulate	recognise
collect	generate	recommend
compare	identify	record
concentrate (on)	illustrate	report
conclude	implement	reveal
conduct	imply	revise
confirm	improve	review
consider	incorporate	show
construct	indicate	simulate
correlate	interpret	solve
deal with	introduce	state
debate	investigate	study
define	measure	support
demonstrate	model	suggest
describe	monitor	test
design	note	undertake
detect	observe	use
determine	prefer	utilise

Here are some examples of how these are used:

- This phenomenon **was demonstrated** by...
- In their study, expanded T-cells **were found** in...
- Initial attempts **focused on identifying** the cause of...
- Weather severity **has been shown to**...
- Early data **was interpreted** in the study by...
- The algorithm **has been proposed** for these applications...
- The results on pair dispersion **were reported in**...
- Their study **suggested** a possible cause for...
- An alternative approach **was developed** by...

Note: You can recycle these verbs at the end of the Introduction when you say what you plan to do in your paper (see 4 below)

3. GAP/QUESTION/PROBLEM/CRITICISM

This is often signalled by words such as however, although, while, nevertheless, despite, but.

ambiguous	(the) absence of
computationally demanding	(an) alternative approach
confused	(a) challenge
deficient	(a) defect
doubtful	(a) difficulty
expensive	(a) disadvantage
false	(a) drawback
far from perfect	(an) error
ill-defined	(a) flaw
impractical	(a) gap in our knowledge
improbable	(a) lack
inaccurate	(a) limitation
inadequate	(a) need for clarification
incapable (of)	(the) next step
incompatible (with)	no correlation (between)
incomplete	(an) obstacle
inconclusive	(a) problem
inconsistent	(a) risk
inconvenient	(a) weakness
incorrect	

<p>ineffective inefficient inferior inflexible insufficient meaningless misleading non-existent not addressed not apparent not dealt with not repeatable not studied not sufficiently + adjective not well understood not/no longer useful of little value over-simplistic poor problematic questionable redundant restricted time-consuming unanswered uncertain unclear uneconomic unfounded unlikely unnecessary unproven unrealistic unresolved unsatisfactory unsolved unsuccessful unsupported</p>	<p>(to be) confined to (to) demand clarification (to) disagree (to) fail to (to) fall short of (to) miscalculate (to) misjudge (to) misunderstand (to) need to re-examine (to) neglect (to) overlook (to) remain unstudied (to) require clarification (to) suffer (from)</p>
	<p>few studies have... it is necessary to... little evidence is available little work has been done more work is needed there is growing concern there is an urgent need... there is growing concern about... this is not the case unfortunately</p>

Here are some examples of how these are used:

- **Few researchers have addressed the problem** of...
- **There remains a need for** an efficient method that can...
- However, light scattering techniques have been **largely unsuccessful** to date.
- The high absorbance makes this **an impractical option** in cases where...
- **Unfortunately**, these methods do not always guarantee...
- **An alternative approach** is necessary.
- The function of these proteins **remains unclear**.
- These can be **time-consuming** and are often **technically difficult** to perform.
- **Although** this approach improves performance, it results in **an unacceptable** number of...
- Previous work has focused **only** on...
- However, the experimental configuration was **far from optimal**.

Note: Some of these words/phrases express very strong criticism. A useful exercise is to put an asterisk (*) next to those you think you could use if you were talking about the research of your professor or supervisor. You can also alter them to make them more polite (*i.e.* instead of *unsuccessful*, which is quite a strong criticism, you could write *may not always be completely successful*).

(to) attempt	(is) organised as follows:	(were/are) able to
(to) compare	(is) set out as follows:	accurate/accurately
(to) concentrate	(is/are) presented in detail	effective/effectively
(on)	(our) approach	efficient/efficiently
(to) conclude	(the) present work	excellent results
(to) describe	(this) paper	innovation
(to) discuss	(this) project	new
(to) enable	(this) report	novel method
(to) evaluate	(this) section	powerful
(to) expect	(this) study	practical

4. THE PRESENT WORK

(to) facilitate (to) illustrate (to) improve (to) manage to (to) minimise (to) offer (to) outline (to) predict (to) present (to) propose (to) provide (to) reveal (to) succeed	(this) work begin by/with close attention is paid to here overview	simple straightforward successful valuable
		aim goal intention objective purpose

Here are some examples of how these are used:

- **This paper focuses on...**
- **The purpose of this study is to describe and examine...**
- **In order** to investigate the biological significance...
- **In this paper we present...**
- New correlations were developed with **excellent** results...
- **In the present study** we performed...
- **This paper introduces** a scheme which solves these problems.
- **The approach we have used in this study** aims to...
- **This study** investigated the use of...
- **In this report** we test the hypothesis that...
- **This paper is organised as follows:...**

Note: In a thesis or a very long research paper, you use these to say what each chapter or section will do. Don't rely on one-size-fits-all verbs such as *discuss*; some chapters/sections do not 'discuss' anything, and even if they do, their main purpose may be to *compare* things, *analyse* things or *describe* things rather than to *discuss* them.

1.5 Writing an Introduction

In the next task, you will bring together and use all the information in this unit. You will write an Introduction according to the model, using the grammar and vocabulary you have learned, so make sure that you have the model (Section 1.3.3) and the vocabulary (Section 1.4) in front of you.

Throughout this unit you have seen that conventional science writing is easier to learn, easier to write and easier for others to read than direct translations from your own language or more creative writing strategies. You have learned the conventional model of an Introduction and collected the vocabulary conventionally used. Your sentence patterns should also be conventional; use the sentences you have read in your target articles and in the Introductions printed here as models for the sentence patterns in your writing, and adapt them for the task.

Follow the model exactly this time. After you have practiced it once or twice you can vary it to suit your needs. However, you should use it to check Introductions you have written so that you can be sure that the information is in an appropriate order and that you have done what your readers expect you to do in an Introduction.

Although a model answer is provided in the Key, you should try to have your own answer checked by a native speaker of English if possible, to make sure that you are using the vocabulary correctly.

1.5.1 Write an Introduction

Imagine that you have just completed a research project to design a bicycle cover which can protect the cyclist 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 of your research paper, to be published in the *Journal of Pedal-Powered Vehicles* (Vol. 3). Your Introduction should be between 200–400 words. You can lie as much as you like, and of course you will have to create fake research references. Follow the model as closely as possible; make sure your Introduction contains the four main components of the model and try out some of the new vocabulary.

The title of your research paper is **A COVER FOR THE SPPPV**

(Single-Person Pedal-Powered Vehicle), and you should write an Introduction of approximately 200–300 words. If you get stuck and don't know what to write next, use the model and the vocabulary to help you move forward. Don't look at the key until you have finished writing.

1.5.2 Key

Here is a sample answer. When you read it, think about which part of the model is represented in each sentence.

A COVER FOR THE SPPPV (Single-Person Pedal-Powered Vehicle)

Concern about global warming and urban air pollution have become central issues in transport policy decision-making, and as a result much research in recent years has focused on the development of vehicles which are environmentally friendly. Air quality in cities is currently significantly lower than in rural areas¹ and this has been shown to be directly linked to the level of vehicle emissions from private cars.² Due to the fact that urban transport policy in the UK is designed to reduce or discourage the use of private cars,³ there has been an increase in the sale of non-polluting vehicles such as the SPPPV (Single-Person Pedal-Powered Vehicle). However, although the number of SPPPV users has increased, 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 aspects of the SPPPV. In 1980, Wang *et al.* responded to the need for increased safety by designing an SPPPV surrounded by a 'cage' of safety bars,⁴ and in 2001 Martinez developed this further with the introduction of a reinforced polymer screen which could be fitted to the safety bars to protect the cyclist's face in the event of a collision.⁵ The issue of comfort has also been addressed by many design teams; in 1998 Kohl *et al.* introduced an SPPPV with a built-in umbrella, which could be opened at the touch of

a button,⁶ and more recently, Martinez⁷ has added a mesh filter which can be placed over the entire cage to reduce the risk of environmental pollution. However, the resulting ‘cage’ or cover is aerodynamically ineffective due to the shape of the umbrella and the weight of the mesh filter.

In this study, we used computer simulation to model the aerodynamic effect of the existing safety and comfort features and we present a new design which integrates these features in an optimally-effective aerodynamic shape.
