Unit 2 ✏ Writing about Methodology

2.1 Structure

The title of this section varies in different disciplines and in different journals. It is sometimes called *Materials and Methods,* or it can be called *Procedure*, *Experiments*, *Experimental*, *Simulation*, *Methodology* or *Model*. This section is the first part of the central 'report' section of the research article (the second part is the Results section), and it reports what you did and/or what you used.

Most journals publish (usually on the Internet) a Guide for Authors. Before you begin to read this unit, access the guide for a journal you read regularly — if you're lucky, it will include a short description of what the editors expect in each section in addition to technical information relating to the figures. Here is a typical sentence from such a guide:

> *The Methodology should contain sufficient detail for readers to replicate the work done and obtain similar results.*

It is true that your work must contain sufficient detail to be repeatable, but the type of writing you will need to do is not just a record of what you did and/or used. One of the most interesting and important changes you need to make in the way you write is that until now, you have probably been writing for people (perhaps your teachers) who know more about your research topic than you do. You have been displaying to them that you understand the tasks they have set and have performed them correctly. However, when you write a research article, people will be learning from you. Therefore you now need to be able to communicate information about a new procedure, a new method, or a new approach so that everyone reading it can not only carry it out and obtain similar results, but also understand and accept your procedure.

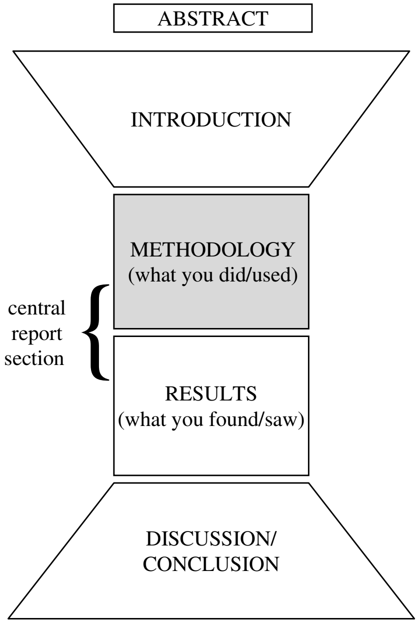

Fig. 1. The shape of a research article or thesis.

When we come to ask our three questions:

- How do I start the Methodology/Experiments section? What type of sentence should I begin with?
- What type of information should be in this section, and in what order?
- How do I end this section?

you already know that the Methodology should contain a detailed description of what you did and/or used, and this helps to answer the second of the three questions. As we will see, however, it is not a full answer; to be effective and conform to what is normally done in a research paper, this section must contain other important information as well.

Read the example below. The title of the paper is **Changes in the chemistry of groundwater in the chalk of the London Basin.** Don't worry if the subject matter is not familiar to you or if you have difficulty understanding individual words, especially technical terms like *ground-water.* Just try to get a general understanding at this stage and familiarise yourself with the type of language used.

Methodology

1 *The current investigation involved sampling and analysing six sites to measure changes in groundwater chemistry.* **2** *The sites were selected from the London Basin area, which is located in the south-east of England and has been frequently used to interpret groundwater evolution.*[2,3,4]

3 *A total of 18 samples was collected and then analysed for the isotopes mentioned earlier.* **4** *Samples 1–9 were collected in thoroughly-rinsed 25 ml brown glass bottles which were filled to the top and then sealed tightly to prevent contamination.* **5** *The filled bottles were shipped directly to two separate laboratories at Reading University, where they were analysed using standard methods suitably miniaturised to handle small quantities of water.*[5]

6 *Samples 10–18 were prepared in our laboratory using a revised version of the precipitation method established by the ISF Institute in Germany.*[6] **7** *This method obtains a precipitate through the addition of* $BaCl_2.2H_2O$*; the resulting precipitate can be washed and stored easily.* **8** *The samples were subsequently shipped to ISF for analysis by accelerator mass spectrometry (AMS).* **9** *All tubing used was stainless steel, and although two samples were at risk of CFC contamination as a result of brief contact with plastic, variation among samples was negligible.*

2.2 Grammar and Writing Skills

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

PASSIVES AND TENSE PAIRS
USE OF 'A' AND 'THE'
ADVERBS AND ADVERB LOCATION

2.2.1 Passives and tense pairs

When a sentence changes from active to passive, it looks like this:

The dog bit the policeman.	*active*
The policeman was bitten by the dog.	*passive*

But in formal academic writing, when you report what you did, you don't write 'by us' or 'by me' when changing the sentence from active to passive. You simply leave the agent out, creating an agentless passive:

We/I collected the samples.	*active*
The samples were collected.	*passive*

Before you begin to write the description of what you did and used, you need to check with the Guide for Authors in your target journal (if you are writing a doctoral thesis in an English-speaking country, check with your supervisor) to find out whether this part of the paper or thesis should be written in the passive or in the active. You can use the active (*we collected*) if you worked as part of a research team. Using the active is not usually appropriate when you write your PhD thesis because you worked alone, and research is not normally written up in the first person singular (*I collected*). In most cases, you will find that in papers and theses, the procedure you used in your research is described in the passive, either in the **Present Simple passive** (*is collected*) or in the **Past Simple passive** (*was collected*). To make that choice, it is useful to explore the advantages and disadvantages of each.

There are two common errors in the way passives are used in this section. First, look at these two sentences:

(a) *A flexible section is inserted in the pipe.*	*Present Simple passive*
(b) *A flexible section was inserted in the pipe.*	*Past Simple passive*

When you write about what you did and what you used, you need to be able to distinguish between standard procedures, *i.e.* what is normally done or how a piece of equipment is normally constructed, and what you did yourself. In the examples above, (a) uses the Present Simple tense to describe what is normally done or to describe a standard piece of equipment used in the research and (b) uses the Past Simple tense to describe what you did yourself. It is conventional in this section to use the passive for both, and the agent of the action is not mentioned in the sentence — we don't add 'by the researcher' or 'by me' at the end.

Passives used in formal writing are normally of this type, *i.e.* agentless passives. However, because the agent is not given, the only way that the reader can separate what is normally done (Sentence (a)) from what you did yourself (Sentence (b)) is if you use the correct tense. Check your target journal, but wherever possible it is clearer to use the Present Simple passive for what is normally done and the Past Simple passive to indicate what you did yourself.

You can see that if you don't pay careful attention to the tense of these sentences, your own work may become confused with the standard procedures you are describing. This is a very common error, even among native speakers, and has serious consequences. If the reader cannot identify your contribution, that is a disaster! Look at this example:

> *Two dye jets* ***are*** *placed in the laser cavity. A gain jet* ***is*** *then excited by an argon ion laser and the pulses* ***are*** *spatially filtered in order to obtain a Gaussian beam. Polarisation* ***is*** *confirmed using a polarising cube. The pulses* ***were*** *split into reference pulses and probe pulses and the reference pulses* ***were*** *carefully aligned into the detector to minimise noise levels.*

In this case, *splitting the pulses into two groups for testing* was the significant innovation of the writer's research team but the only way the reader knows this is because of the change in tense from Present Simple passive to Past Simple passive (***were*** *split*). Here is another example:

> *Samples for gas analysis* ***were collected*** *using the method described by Brown (1999), which* ***uses*** *a pneumatic air sampling pump.*

Another difficulty arises with the passive when you write about the procedure you used and compare it with the work of other researchers. You can use the Past Simple agentless passive to describe the procedure you used (*the samples* ***were collected*** *using a suction tube*) but you may also need to use exactly the same Past Simple agentless passive to describe the procedure used by the other researcher whose work you are citing (*the samples* ***were collected*** *using a suction tube*). This means that unless you are very careful, the reader has no way of separating your work from that of the other researcher. The fact that you are so familiar with what you did means that your own contribution is obvious to you — but it may not be obvious to your reader.

One way to make sure that your own contribution is clear and easy to identify is by marking it with words — perhaps by adding phrases like ***In this study***, *the samples were collected using a suction tube* or ***In our experiments*** *the samples were collected using a suction tube*, and by identifying the procedure used by other researchers with careful references at the appropriate place in the sentence (*In Brown (1999) the samples* ***were collected*** *using a suction tube*).

There are five possible uses that you may need. Note the different tenses.

	What do you mean?	How can you make it clear?
1	*X was (collected/ substituted/ adjusted etc.*) by **me** in the procedure or work that **I** carried out	Either move to the active (*We collected/adjusted/ substituted etc.*) or add words or phrases such as *here/in this work/in our model* or use a 'dummy' subject such as *This experiment/The procedure*
2	*X was (collected/ substituted/ adjusted etc.*) by the person whose procedure or work I am using as a basis for, or comparing with, my own	Give a research reference and/ or add words/phrases such as *in their work/in that model*
3	*X is (collected/substituted/ adjusted etc.*) normally, *i.e.* as part of a standard procedure	You may need a research reference even if it is a standard procedure, depending on how well-known it is. Use phrases such as *as in* [5]

4	*X is (collected/substituted/ adjusted etc.*) as you can see in Fig. 1, but it was collected/ substituted/adjusted *etc.* by me	Move to the active (*We collected/adjusted/substituted etc.*) if you can or make sure that you come out of the Present Simple passive when you stop describing the figure
5	*X is (collected/substituted/ adjusted etc.*) by me in the procedure/work that **I** carried out, but my field requires authors to write procedural descriptions in the Present Simple tense. (This is quite common in pure mathematics)	Either move to the active (‘*We collect/adjust/substitute etc.*) or add words or phrases such as *here/in this work/ in our model* or use a ‘dummy’ subject such as *This experiment/The procedure*

2.2.2 Use of ‘a’ and ‘the’

This is one of the most problematic areas of English grammar and usage. Many languages do not have separate words for **a** and **the**, and even if they do, these words may not correspond exactly to the way in which they are used in English. Students studying English as a second language are often given the following useful, but sometimes confusing, rule:

SINGULAR COUNTABLE NOUNS NEED A DETERMINER

A determiner is a word like **the**, **a**, **my**, **this**, **one**, **some**. It’s a difficult rule to operate successfully because two problems need to be solved before you can use it. Firstly, it’s hard to know exactly which nouns are countable and, secondly, even when you know, how do you decide whether to use **a** or **the**?

Let’s look at the first problem. Deciding which nouns are countable nouns and which aren’t isn’t as easy as it looks. Many nouns which are often considered uncountable can actually be used 'countably'. Nouns like *death* or *childhood*, for example, can occur in the plural:

> *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.*

Even names of materials like *steel* can occur in the plural:

> *Some **steels** are used in the manufacture of medical instruments.*

In the following list of uncountable nouns, mark those which can also be used in the plural, *i.e.* countably. The way you use a noun determines whether it is used in its countable or uncountable form. So when you use a noun like *industry*, stop and think — do you mean industry in general (uncountable) or a particular industry (countable)? Check your answers in the Key.

absence	access	analysis	advice	age
agriculture	cancer	art	atmosphere	beauty
behaviour	duty	capacity	childhood	calculation
concern	economy	death	democracy	depression
design	environment	earth	education	electricity
energy	evidence	equipment	existence	experience
failure	fashion	fear	fire	health
food	freedom	history	growth	independence
heat	help	insurance	ice	knowledge
industry	information	machinery	intelligence	light

life	luck	philosophy	nature	loss
paper	organisation	pollution	physics	oil
power	progress	research	protection	policy
pressure	reality	security	respect	purity
rain	sand	strength	silence	safety
salt	science	time	stuff	sleep
swimming	space	trouble	trade	sunlight
transport	technology	waste	truth	traffic
vision	treatment	water	velocity	violence
wildlife	wind	work	wealth	welfare

KEY

The nouns which can also have a countable meaning appear in italics.

absence	access	*analysis*	advice	*age*
agriculture	*cancer*	*art*	*atmosphere*	*beauty*
behaviour	*duty*	*capacity*	*childhood*	*calculation*
concern	*economy*	*death*	*democracy*	*depression*
design	*environment*	earth	*education*	electricity
energy	evidence	equipment	*existence*	*experience*
failure	*fashion*	*fear*	*fire*	health
food	freedom	*history*	*growth*	independence
heat	help	insurance	ice	knowledge
industry	information	machinery	intelligence	*light*
life	luck	*philosophy*	nature	*loss*
paper	*organisation*	pollution	physics	*oil*
power	progress	research	protection	*policy*

pressure	*reality*	security	respect	*purity*
rain	*sand*	*strength*	*silence*	safety
salt	*science*	*time*	stuff	sleep
swimming	*space*	*trouble*	*trade*	sunlight
transport	*technology*	*waste*	*truth*	traffic
vision	*treatment*	*water*	*velocity*	violence
wildlife	*wind*	work	wealth	welfare

Now look at the second problem: how do you decide whether to use **a** or **the**? You may have been told that **a** is used for general reference and **the** is used for specific reference, but in the following sentence:

*There is **a** book on the shelf above my desk; can you bring it here?*

a *book* clearly refers to a specific book; in fact, that part of the sentence specifies which book the speaker wants. So if the specific/general criterion doesn't help you to select **a** or **the**, what does?

Start by asking yourself this simple question: Why do you use **a** the first time you talk about something, but when you refer to it again you use **the**? After all, it's the same specific item on both occasions. For example, in the sentence below, why does the first reference to the cheese sandwich use **a** and the second reference use **the** if both refer to the same specific sandwich?

*I had **a** cheese sandwich and **an** apple for lunch. **The** sandwich was fine but **the** apple had a worm in it.*

The difference is that the first time the speaker mentions the *cheese sandwich* or the *apple*, only the speaker knows about them — but the second time, both the speaker and listener know. The *worm*, however, is 'new' to the listener, and so is referred to using **a.** Now we can add a new rule:

USE **THE** IF OR WHEN YOU AND YOUR READER BOTH KNOW WHICH THING/PERSON YOU MEAN.

This is true even if the thing or person has not been mentioned before, for example, in the following sentences:

I arrived at Heathrow Airport but ***the*** *check-in was closed.*
I bought a new computer but ***the*** *keyboard was faulty.*

check-in and *keyboard* need **the** because as soon as Heathrow Airport is mentioned, the speaker and listener know about and therefore share *check-in*; as soon as a computer is mentioned, they share *keyboard*. Similarly, in the sentence:

He lit a match but the flame went out.

mentioning *a match* automatically creates the concept of *flame* in the reader's mind — and this shared understanding is marked by the use of **the**. Similarly, if we were in the same room and I told you to look up at **the** ceiling, you wouldn't ask me 'Which ceiling are you talking about?' because it would be obvious; we would share it.

Did she get ***the*** *job?* (the job we both know she wanted)
I'll meet you in ***the*** *library later.* (the library we normally use)

Here are some more useful rules:

USE **THE** IF THERE IS ONLY ONE POSSIBLE REFERENT

We removed ***the*** *softest layer of membrane.*
Cairo is ***the*** *capital of Egypt.*
The opening was located in ***the*** *centre of each mesh.*
Government policy is committed to protecting ***the*** *environment.*
The *sun's altitude is used to determine latitude.*

USE **A** IF IT DOESN'T MATTER *or* YOU DON'T KNOW *or* YOUR READER DOESN'T KNOW WHICH THING/ PERSON YOU ARE REFERRING TO.

A 35 ml brown glass bottle was used to store the liquid. (It doesn't matter which 35 ml brown glass bottle was used.)

The subject then spoke to an interviewer. (It doesn't matter which interviewer/I know which one but you don't.)

It works on the same principle as a combustion engine. (It doesn't matter which combustion engine.)

Sometimes the choice of **a** or **the** changes the meaning of the sentence completely:

(a) *This effect may hide **a** connection between the two*. (There may possibly be a connection between the two but if there is, we cannot see it.)
(b) *This effect may hide **the** connection between the two*. (There is definitely a connection between the two but we may not be able to see it because of *this effect*.)

Here's another pair in which the choice of **a** or **the** has a significant effect on the meaning (∅ is used here to indicate the plural of **a**):

(a) *The nodes should be attached to ∅ two adjacent receptor sites*. (There are many receptor sites and any two adjacent ones will do.)
(b) *The nodes should be attached to **the** two adjacent receptor sites*. (There are only two receptor sites.)

The best way to use the information you have just learned is to take a paragraph from a research article that you are reading and use the information in this grammar section to work out why the writer has chosen each instance of **the** or **a,** or why the writer has not used any determiner before a particular noun.

Another important point to note about the use of **a**, **the** and ∅ is that they can all be used generically, *i.e.* when expressing a general truth:

The electroencephalograph is a machine for measuring brain waves.
An electroencephalograph is a machine for measuring brain waves.
Electroencephalographs are machines for measuring brain waves.

One last note: **a** is used before consonant sounds, while **an** is used before vowel sounds. Sound, not spelling, is important here, so we write ***an*** *MRI scan* because the letter 'M' is pronounced 'em', but ***a*** *UV light* because the letter 'U' is pronounced 'yoo'.

2.2.3 Adverbs and adverb location

When you are communicating complex ideas in another language, an obvious grammatical error is not as bad as an error which is invisible. A proofreader or editor will notice an obvious grammatical error and correct it, but if the sentence is written in grammatically correct English the error is not visible to proofreaders and editors. An example of an invisible error is where the sentence is grammatically correct but the choice of which verb tense to use is inappropriate or does not represent the intention of the writer. These hidden errors are worrying because neither the writer nor the editor/proofreader knows they have occurred and yet the sentence does not mean what the writer intended.

Common hidden errors include mistakes in the use of **a** and **the** (see Section 2.2.2 above), whether or not to use a comma before the word *which* in relative clauses and adverb location errors. Adverb location errors are easy to make and hard to detect.

Adverbs don't always do what you want or expect them to do. In the first place, adverbs needing prepositions can be ambiguous (*Look at that dog* ***with one eye*** can either mean *USING one eye* or *HAVING one eye*) and in the second place, adverbs may attach themselves to unexpected parts of a sentence. Be careful where you put your adverb, and be especially careful if you are using more than one adverb in a sentence. Here is an example of the kind of problem you may encounter:

> *The patient was discharged from hospital after being shot in the back with a 9 mm gun.*

Did the doctors shoot her?

> *He gave a lecture about liver cancer at the hospital last January.*

Was the lecture in the hospital — or the cancer? Did the lecture refer to cancer cases occurring in January or did the lecture itself occur in January?

Although there are rules for adverb location, they are complex and hard to apply when you are writing. Since your aim is to stay safe and write clearly, it is better to avoid adverb clusters like these, and rewrite the information in a different order. If your adverb relates to the whole sentence (*i.e. clearly*, *last January*, *as a result)* then consider putting the adverb at the front of the sentence:

Last January he gave a lecture about liver cancer at the hospital

If you are still left with ambiguous adverb clusters, consider breaking the sentence down into units, each with its own adverb:

Last January he gave a lecture at the hospital; his subject was liver cancer

2.3 Writing Task: Build a Model

2.3.1 Building a model

You are now ready to begin to build a model of the Methodology by writing a short description of what the writer is doing in each sentence in the space provided below. 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 4, and start with that. Remember that your model is only useful if it can be transferred to other Methodology sections, so don't include content words such as *groundwater* or you won't be able to use your model to generate Methodology sections in your 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 — rather than what s/he is saying — 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 Methodology sections in your target articles work.

Changes in the chemistry of groundwater in the chalk of the London Basin	
Methodology	**In this sentence, the writer:**
1 *The current investigation involved sampling and analysing six sites to measure changes in groundwater chemistry.* **2** *The sites were selected from the London Basin area, which is located in the south-east of England and has been frequently used to interpret groundwater evolution.*[2, 3, 4]	1____________________ 2____________________
3 *A total of 18 samples was collected and then analysed for the isotopes mentioned earlier.* **4** *Samples 1–9 were collected in thoroughly-rinsed 25 ml brown glass bottles which were filled to the top and then sealed tightly to prevent contamination.* **5** *The filled bottles were shipped directly to two separate laboratories at Reading University, where they were analysed using standard methods suitably miniaturised to handle small quantities of water.*[5]	3____________________ 4____________________ 5____________________
6 *Samples 10–18 were prepared in our laboratory using a revised version of the precipitation method established by the ISF Institute in Germany.*[6] **7** *This method obtains a precipitate through the addition of $BaCl_2.2H_2O$; the resulting precipitate can be washed and stored easily.*	6____________________ 7____________________

8 *The samples were subsequently shipped to ISF for analysis by accelerator mass spectrometry (AMS).* **9** *All tubing used was stainless steel, and although two samples were at risk of CFC contamination as a result of brief contact with plastic, variation among samples was negligible.*	8__________________ 9____________________

2.3.2 Key

In Sentence 1 '*The current investigation involved sampling and analysing six sites to measure changes in groundwater chemistry.*' the writer **offers a general overview of the entire subsection, including the purpose of the investigation.**

If you wrote 'introduction' or 'introduces the Methodology' here, that won't help you when you come to write your own thesis or research article because it doesn't tell you what exactly to write in that sentence.

Why do I need to introduce the Methodology?

In some cases, writers begin immediately with a description of the procedure or the materials. This is appropriate where the research focus is very narrow and all those who are likely to read it are carrying out similar research. If this is not the case, it is more reader-friendly to start with some introductory material. The aim of providing a short introduction is to make the entry to that section smooth for the reader. There are many ways to introduce the Methodology. Here are three of the most common ways:

- Offer a general overview by outlining the parameters of the work, for example the number of tests, the equipment /material/software used and perhaps also the purpose of the investigation. This helps the reader to get a general idea of this section.
- Provide background information about the materials or about the source of the materials/equipment.
- Refer back to something in the previous section. Common options are restating the aim of the project or the problem you are hoping to address.

If you start with a general overview or even a general paragraph about what was done and used, it can then be broken down to produce the details. However, if you begin with the details, you force the reader to put those details together to create a general picture of what you did and used. This is quite difficult for the reader to do and it is not his/her job; it is your job as a writer to arrange the information in an appropriate order so that it is easy for the reader to process it.

Furthermore, asking your reader to put details together to create a picture of what you did is risky, because each reader may create a slightly different picture of the process if they begin 'bottom-up' with the details, rather than 'top-down' with a general overview. When you write using 'top-down' strategies you are in control. If you begin with general statements about what was done/used (*In all cases, Most sites*), you and your reader share the same framework, so when you fill in the details you are creating the same picture of what was done/used in the mind of each individual reader. Remember: show your reader the wall before you begin to examine the bricks.

In Sentence 2 '*The sites were selected from the London Basin area, which is located in the south-east of England and has been frequently used to interpret groundwater evolution.*[2–4] **the writer provides background information and justifies the choice of location by referring to previous research.**

Why do I need to justify or give reasons for what I did? Isn't it obvious?

Your reasons may be obvious to you, but they are not always obvious to your readers. If you fail to provide justification for what you did, then the reader may not accept the validity of your choices. They 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 did things then readers cannot be expected to accept your methodology, and this will eventually affect the way they evaluate your whole paper.

Many writers believe that this section is just an impersonal description of what was done or used; in fact there is a strong persuasive and communicative element. We see this not only in language such as *thoroughly* or *with care* but also in the frequency of justification. 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 those decisions.** Justification enables the reader to trust the choices you made.

Sometimes background information is given in the Present Simple to justify choices made. For example, you may have chosen a particular material because of its properties; if so, say what those properties are (*This material is able to…*). You may have chosen specific equipment or software because of what it can do; if so, say what that is. In Sentence 2, we understand that the writer chose this geographical area because it had been previously validated as an appropriate location by other researchers.

> **In Sentence 3** '*A total of 18 samples was collected and then analysed for the isotopes mentioned earlier*' **the writer provides an overview of the procedure/method itself.**

If I gave a general overview at the start of this subsection, why should I also give an overview of the procedure itself?

As you saw in Section 1.2.4, the beginning of a paragraph often signals the beginning of a new topic, and providing an introductory sentence is a reader-friendly technique. In addition, the overview in Sentence 3, like the one at the start of the subsection, enables the writer to move in a 'top-down' direction by creating a general framework into which the details can be easily slotted. Because the reader knows from the start how many samples were tested and what was done with them, both reader and writer share the same clear picture. These sentences often start with phrases like *Most of the tests* or *In all cases* (see the vocabulary list in Section 2.4.2).

> **In Sentence 4 '***Samples 1–9 were collected in thoroughly-rinsed 25 ml brown glass bottles which were filled to the top and then sealed tightly to prevent contamination.*' **the writer provides details about what was done and used and also shows that care was taken.**

How much detail do I need to provide?

If you're not certain that all readers are familiar with the precise details of your methodology, it is better to give slightly too much information than too little. By the time you write up your research you will probably have repeated your experiments or simulations many times and so you are very familiar with the materials, quantities, equipment, software, the sequence or steps in the procedure and the time taken for each step. Because of this familiarity, specific details (the size of the bottles in Sentence 5, for example) may seem obvious to you, but those details may not be obvious to every reader. If you want another researcher to be able to reproduce your work and obtain similar results, you should include every specification and detail.

Note that in this sentence, the writer uses *thoroughly*, *filled to the top* and *tightly* to communicate to the reader that the work was carried out with care. Remember that your aim in writing the paper is not only to say what you did and found, but also to make sure that your reader accepts the conclusions at the end of your paper. In order to do this, the reader has to accept your results — but to accept your results s/he must first accept your methodology. For this reason, it is important to present yourself as a competent researcher who carries out procedures accurately and with care.

Notice the use of *25 ml* in Sentence 4. *ml* is the SI (Système International d'Unités) symbol for *millilitre*. Check the SI to make sure that you are using the correct symbol. There is often a space between the quantity/number and the SI symbol; in addition, although SI symbols look like abbreviations they are not, and therefore should not be followed by a period.

In Sentence 5 '*The filled bottles were shipped directly to two separate laboratories at Reading University, where they were analysed using standard methods suitably miniaturised to handle small quantities of water.*[5]' **the writer continues to describe what was done in detail, using language which communicates that care was taken.**

Can you see which words in Sentence 5 communicate to the reader that care was taken? The writer could just have written *The filled bottles were shipped to two laboratories and analysed using standard methods miniaturised to handle small quantities of water*, but including words like *directly, separate* and *suitably* communicates reliability.

In Sentence 6 '*Samples 10–18 were prepared in our laboratory using a revised version of the precipitation method established by the ISF Institute in Germany.*[6]' **the writer describes what was done by referring to existing methods in the literature.**

Why should I refer to other research; why not just describe the method I used?

One reason is that it is unlikely that you created the entire method you used all by yourself. In many cases part of it will be taken from a method used or discovered by someone else and their method may be very well known, so if you give the research reference you do not need to give every detail. Giving the research reference, therefore, provides you with a shortcut. You will find vocabulary for this in **Option 1** in Section 2.4.

But if the reference is available in the literature, why does the writer need to give any details? Why can't readers just go to the library, find the reference and read it themselves?

In this case, the writer provides basic details of the method because some readers may not be familiar with it and it is not always appropriate to send readers to the library or Internet to look up a reference. It's a matter of professional courtesy for writers to describe the procedures, tests, equipment or materials they used even when they are used in a way that is identical to the reference. Remember to use the **Present Simple** for this kind of background information (*This method obtains*) and to switch back to the **Past Simple** when you return to describing what you did.

Comparisons between your materials and methods and those of other researchers in the same field are a legitimate topic for the Methodology section. It is common to keep previous or current research procedures clearly in your readers' view so that they can see how your work is different from other work in the area. Either your method is identical to others you mention (**Option 1** in the vocabulary list in Section 2.4), or it is similar (**Option 2** in the vocabulary list), or it is significantly different, in which case the differences between your materials/method and those of other researchers in the same field may even represent the actual contribution of your paper/thesis itself (**Option 3**).

When you refer to the work of other researchers, be careful about the location of your reference notation in the sentence; you may accidentally credit someone with work they have not done — perhaps even with your own work! Remember that reference notations do not automatically go at the end of a sentence.

It is sometimes appropriate or necessary to mention the effects of the procedures you used. However, it is not a good idea to discuss them or comment at this stage. If you go into too much detail you may leave yourself with nothing to write about in the Results section. Interestingly, it is common to provide further details about the methodology in the Results section. Sometimes the Methodology section just provides basic parameters and the method itself is detailed in the Results section in relation to the results obtained.

In Sentence 7 '*This method obtains a precipitate through the addition of* $BaCl_2.2H_2O$*; the resulting precipitate can be washed and stored easily.*' **the writer provides more detailed information about the method and shows it to have been a good choice.**

Justification is common throughout this section; as before, the aims are to answer possible criticisms or doubts about your choices, to assure the reader that your choices were made on the basis of good reasons and to give those reasons. We often see justification of significant choices and the reason for rejecting alternative options given in full. As mentioned earlier, this is because it is essential that your reader accepts the decisions you made about your methodology.

In Sentence 8 '*The samples were subsequently shipped to ISF for analysis by accelerator mass spectrometry (AMS).*' **the writer provides more details of the method.**

It is interesting to note that, as mentioned earlier, you need to do more than just provide details of what you did and used; this is the only sentence in this section that gives details and nothing more — every other sentence has an additional function.

In Sentence 9 '*All tubing used was stainless steel, and although two samples were at risk of CFC contamination as a result of brief contact with plastic, variation among samples was negligible*.' **the writer mentions a possible difficulty in the methodology**.

Doesn't this discuss a result of what was done?

No, it's actually saying that the problems in the methodology didn't affect the results. Sometimes you do need to mention results in this section, but only if the preliminary results were used to modify or develop the design of the main experiments/simulations.

Why should I mention problems in the methodology? Won't it make me look bad?

In fact the opposite is true. In the first place, if you don't mention the imperfections in your work, it may look as though you are not aware of them, which gives a very poor impression. So you look far more professional if you **do** mention them. If you ignore or try to hide imperfections (such as a data set which was too small, equipment or software that was not ideal) and your readers notice them, they will begin to doubt your legitimacy as a researcher, which affects their acceptance of your results and conclusions.

Second, whenever you finish a piece of research, there is a good chance that you have learned enough from the problems encountered during the project to do it better next time. Should you delay writing it up while you repeat the work and improve your technique? What if you learn more this time too; should you delay again while you do it again? And again? If you do, you may never actually write it up. An acceptable option is to write up the research and acknowledge the problems or difficulties you encountered. In fact, it's not only considered acceptable to mention them in this section, it's much better to do it here rather than wait until the end. It isn't considered appropriate to mention limitations or imperfections for the first time when you are discussing suggestions for future work in the Discussion/Conclusion.

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

Use vocabulary that **minimises the problem**, **minimises your responsibility**, **maximises the good aspects** and **suggests a solution**. In the example above, the writer has acknowledged that there was a problem and then minimised its effects (*variation among samples was negligible*). This is a standard way of dealing with the need to talk about problems. You can find examples of the language needed to refer to problems and difficulties in a conventional, professional way in the vocabulary list in Section 2.4.

2.3.3 The model

Here are the sentence descriptions we have collected:

In Sentence 1 the writer offers a general overview of the subsection.
In Sentence 2 the writer provides background information and justification.
In Sentence 3 the writer provides an overview of the procedure/method itself.
In Sentence 4 the writer provides details about what was done and used and shows that care was taken.
In Sentence 5 the writer continues to describe what was done in detail, using language which communicates that care was taken.
In Sentence 6 the writer describes what was done by referring to existing methods in the literature.
In Sentence 7 the writer provides more detailed information about the method and shows it to have been a good choice.
In Sentence 8 the writer provides more details of the method.
In Sentence 9 the writer mentions a possible difficulty in the methodology.

We can streamline these so that our model has FOUR basic components. Unlike the Introduction model, in which all the items of each component are likely to be used, this is a 'menu' from which you select items appropriate to your research topic and the journal you are submitting to. If you constructed the equipment yourself you won't need to 'give the source of' the equipment used in component 1. If there were no problems, you won't need the fourth component at all.

1	PROVIDE A GENERAL INTRODUCTION AND OVERVIEW OF THE MATERIALS/METHODS RESTATE THE PURPOSE OF THE WORK GIVE THE SOURCE OF MATERIALS/EQUIPMENT USED SUPPLY ESSENTIAL BACKGROUND INFORMATION
2	PROVIDE SPECIFIC AND PRECISE DETAILS ABOUT MATERIALS AND METHODS (*i.e.* quantities, temperatures, duration, sequence, conditions, locations, sizes) JUSTIFY CHOICES MADE INDICATE THAT APPROPRIATE CARE WAS TAKEN
3	RELATE MATERIALS/METHODS TO OTHER STUDIES
4	INDICATE WHERE PROBLEMS OCCURRED

2.3.4 Testing the model

The next step is to look at the way this model works in a real Materials/ Methods section (remember it may not be called Materials and Methods) and in the target articles you have selected. Here are some full-length Methodology sections 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 corresponds to number 1 in the model, write 1 next to it, *etc.*

Effects of H_2O on structure of acid-catalysed SiO_2 sol-gel films

Experimental procedure

Equal volumes of tetraethylorthosilicate (TEOS) and ethanol were mixed and stirred vigorously for 10 min at room temperature.

Then 0.1 M HCl was gradually added to the solutions, until a water to TEOS molar ratio of $R = 2$ was attained. Additional deionised water was added to give solutions with $R = 3$, 4 and 5, so that for all solutions the molecular ration TEOS:HCl was maintained, as summarised in Table 1. 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, while stirring, 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. All the chemicals were obtained from Aldrich Chemicals Ltd.

The sols were dispensed on p-type, 75 mm diameter silicon wafers, through a 0.1 μm filter (PTFE Whatman, obtained from BDH Merk Ltd), and thereafter the substrate was spun at 2000 rpm for 15 s. The coated substrate was baked at 100°C for 5 min, and then cleaved into 10 pieces. Each piece was baked in air at a different temperature, in the range from 100 to 1000°C, for 30 min. The samples were kept in covered petri dishes for a few days in room conditions before the experiments were continued; this allows the completion of surface hydroxylation, and gave reproducible ellipsometer results when water is used as an adsorbate.

The thickness and refractive index of the samples were measured using a Rudolph AutoEl III ellipsometer, with an operating wavelength of 633 nm, and precisions of about ±0.002 and ±3 Å in index and thickness, respectively. For microporous films, the measured index is strongly dependent on relative humidity, because of condensation of water in the pores. By measuring the dependence of index on humidity, information about porosity can be obtained. We have extended this technique to the use of different adsorbate species, in order to probe pore sizes [3]; this, for the sake of brevity, we call molecular probe ellipsometry. In this technique, the film is placed in a sealed chamber on the sample stage of the ellipsometer; first dry N_2 gas is passed through the chamber to empty the pores of any condensed adsorbate, and then N_2 having been bubbled through the liquid adsorbate is passed over the sample to fill the pores; in each case the refractive index is measured. By assuming that all the accessible pores in dry and saturated atmospheres are completely empty or filled with adsorbate, respectively, the pore volume and index of the solid skeleton can be determined by an extension of the Lorentz-Lorenz relation [8] where n_f, n_s and n_p are the refractive indices of the film, solid skeleton and pores, respectively, and v_p is the volume fraction porosity. Measurement of n_f for both the dry and saturated films allows both v_p and n_s to be determined with the assumption that n_p has the same value as that of the bulk adsorbate in the saturated case, and of air ($n_p = 1$) in the dry case.

In order to empty the pores, an initial high flow rate of N_2 was used for a few minutes and the rate was then reduced to 1000 sccm (standard c.c per minute) for 15 min. the flow rate was kept at 100 sccm for 15 min to fill the pores. The low flow rate in this case reduces the likelihood of cooling of the sample surface, which could cause condensation on the external film surface. Comparison of the measured film thickness for wet and dry atmospheres indicated that this did not occur. The temperature inside the chamber was monitored by a thermocouple to ensure that there was no drift or alteration due to gas flow. In each case, the measurement was recorded once repeatable readings were obtained. The adsorbates used are listed in Table 2. Their average diameters were estimated using a combination of bond length data [9] and Van der Waals atomic radii [10]. All were obtained from Aldrich Chemical Ltd, except $C_{24}H_{44}O_8$ obtained from Fluka Chemie AG.

The optical quality of the films was first studied qualitatively by visual examination, and by optical microscopy. The homogeneity of the films was then investigated quantitatively by measuring the intensity of scattered light resulting from oblique reflection of a laser beam from the film-coated silicon substrate. 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 a ×10 microscope objective, and measured using a silicon photodiode and a lock-in amplifier. The position of lens and angle of incidence were fixed during measurements.

The film stress, σ_f, can be determined by measuring the resulting substrate curvature [11], according to Stoney's formula:

$$\sigma_f = (E_s t^2_s / 6(1-\nu_s)t_f)(1/r_s - 1/r_f), \tag{2}$$

where r_s and r_f are the radii of curvature of the bare substrate and substrate with film, respectively; E_s, t_s and ν_s are the Young's modulus, thickness and Poisson's ratio of the silicon substrate, respectively, and t_f is the thickness of the film. Tensile stresses are positive and compressive stresses negative; thus, a positive radius of curvature denotes a convex film surface. Entire 75 mm diameter wafers were used, and curvature was measured from plots of surface profile along 30 mm lines over the central part of the film surface using a Dektak IIA auto-levelling profilometer. To reduce inaccuracy caused by lack of axial symmetry in the wafer curvature, two scans were made, in orthogonal directions, for each measurement, and the inverse radii thus obtained were averaged. Care was taken not to use wafers which had a substantially asymmetric curvature before deposition. Wafer thicknesses, measured with a micrometer, were 390 ± 3 μm. Final film thicknesses were measured by ellipsometry and checked by patterned etching and profilometry, and interim thicknesses were estimated by interpolation. Equivalent single-layer thickness measurements indicate that the assumption that final thickness is proportional to number of layers is sufficiently accurate. For $E_s/(1-\nu_s)$, the value 180 GPa was used [11].

In order to give an indication of the effect of water content on stress, 10 layers were deposited for each R value, using 10 s rapid thermal annealing at 1000°C in all cases.

Infrared imaging of defects heated by a sonic pulse

ii) Experiment

Our experimental setup is shown in Fig. 1. The source of the sonic excitation is a Branson, Model 900 MA 20 kHz ultrasonic welding generator, with a Model GK-5 hand-held gun. The source has a maximum power of 1 kW, and is triggered to provide a short (typically 50–200 ms duration) output pulse to the gun. The gun contains a piezoelectric transducer that couples to the specimen through the 1.3-cm-diam tip of a steel horn. In the laboratory setup, as can be seen in Fig. 1, we use a mechanical fixture to hold the sonic horn firmly against the sample surface. This setup uses a machine slide to provide reproducible alignment of the horn. Typically, a piece of soft Cu sheet is placed between the tip of the horn and the specimen to provide good sound transmission. The location of the source on the sample is chosen primarily for convenience of geometrical alignment, and since it has minimal effect on the resulting sonic IR images, typically is not changed during the course of the inspection. Sound waves at frequencies of 20 kHz in metals such as aluminium or steel have wavelengths on the order of tens of centimetres, and propagate with appreciable amplitude over distances much longer than a wavelength. For typical complex-shaped industrial parts (see, for example, the aluminium automotive part shown in Fig. 1), reflections from various boundaries of the specimen introduce countless conversions among the vibrational modes, leading to a very complicated pattern of sound within the specimen during the time that the pulse is applied. Since the speed of sound in solids is typically on the order of a few km/s, this sound field completely insonifies the regions under inspection during the time that the excitation pulse is applied. If a subsurface interface is present, say a fatigue crack in a metal, or a delamination in a composite structure, the opposing surfaces at the interface will be caused to move by the various sound modes present there. The complexity of the sound is such that relative motion of these surfaces will ordinarily have components both in the plane of the crack and normal to it. Thus, the surfaces will 'rub' and 'slap' against one another, with a concomitant local dissipation of mechanical energy. This energy dissipation causes a temperature rise, which propagates in the material through thermal diffusion. We monitor this dissipation through its effect on the surface temperature distribution. The resolution of the resulting images depends on the depth of the dissipative source as well as on the time at which the imaging is carried out.

The IR camera that we used in the setup that is shown in Fig. 1 is a Raytheon Radiance HS that contains a 256×256 InSb focal plane array, 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 up to 140 Hz with that sensitivity. We have also observed the effects reported here with a considerably less expensive, uncooled, microbolometer focal plane array camera, operating in the long wavelength (7–10 μm) of the IR.

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

MATERIALS AND METHODS

Biological samples

Aquaporin-1 (AQP1) from human erythrocyte solubilized in octyl-f3-glucopyranoside was reconstituted in the presence of Escherichia coli phospholipids to form two-dimensional (2D) crystalline sheets (Walz *et al.*, 1994). The 2D crystals were prepared at a concentration of -0.5 mg protein/ml and 0.25 mg/ml lipid in 0.25 M NaCl, 20 mM $MgCl_2$, 20 mM 2-(N-morpholino) ethanesulfonic acid (MES) (pH 6).

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 (Baumeister *et al.*, 1982). A stock solution (1 mg/ml protein) was stored in distilled water at 4°C.

Purple membranes of Halobacterium salinarium strain ET1001 were isolated as described by Oesterhelt and Stoeckenius (1974). The membranes were frozen and stored at −70°C. After thawing, stock solutions (10 mg protein/ml) were kept 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 (99% purity;

Sigma Chemical Co., St. Louis, MO) at a lipid-to-protein ratio (w/w) of 0.2 and a protein concentration of 1 mg/ml. The mixture was reconstituted as previously described (Hoenger *et al.*, 1993) in a temperature-controlled dialysis device (Jap *et al.*, 1992). The dialysis buffer was 20 mM HEPES, pH 7.4, 100 mM NaCl, 20 mM $MgCl_2$, 0.2 mM dithiothreitol, 3 mM azide.

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.

Layered crystals

$MoTe_2$, a layered crystal of the family of transition metal dichalcogenides (Wilson and Yoffe, 1969), was employed to calibrate the piezo scanner of the AFM. It was prepared by chemical vapor transport (CVT), with chlorine or bromine as carrier gases in a temperature gradient of 100°C across the quartz ampule (Jungblut *et al.*, 1992), and was a kind gift of Y. Tomm.

Muscovite mica (Mica New York Corp., New York) was used as the solid support for all samples. Mica minerals are characterized by their layered crystal structure, and show a perfect basal cleavage that provides atomically flat surfaces over several hundreds of square microns. Their hydrophilicity and relative chemical inertness (Bailey, 1984) make them suitable for the adsorption of biological macromolecules.

Atomic force microscopy

A commercial AFM (Nanoscope III; Digital Instruments, Santa Barbara, CA), equipped with a 120-μm scanner (j-scanner) and a liquid cell, was used. Before use, the liquid cell was cleaned with normal dish cleaner, gently rinsed with ultrapure water, sonicated in ethanol (50 kHz), and sonicated in ultrapure water (50 kHz). Mica was punched to a diameter of –5 mm and glued with water-insoluble epoxy glue (Araldit; Ciba Geigy AG, Basel, Switzerland) onto a Teflon disc. Its diameter of 25 mm was slightly larger than the diameter of the supporting steel disc. The steel disc was required to magnetically mount the sample on to the piezoelectric scanner.

Imaging was performed in the error signal mode, acquiring the deflection and height signal simultaneously. The deflection signal was minimized by optimizing gains and scan speed. The height images presented were recorded in the contact mode. The scan speed was roughly linear to the scan size, at 4–8 lines/s for lower magnifications (frame size 1–25 μm). The applied force was corrected manually to compensate for thermal drift. To achieve reproducible forces, cantilevers were selected from a restricted area of one wafer. The dimensions of one tip were measured in a scanning electron microscope to calculate the mechanical properties of the cantilever (Butt *et al.*, 1993). The 120-μm-long cantilevers purchased from Olympus Ltd. (Tokyo, Japan) had a force constant of k = 0.1 N/m, and the 200-μm-long cantilevers purchased from Digital Instruments had a force constant of 0.15 N/m. All cantilevers used had oxide-sharpened Si3N4 tips.

Sample preparation

To minimize contamination of surfaces during exposure to ambient air, sample supports were prepared immediately before use. All buffers were made with ultrapure water (–18 MDcm^{-1}; Branstead, Boston, MA). This water contains fewer hydrocarbons than conventional bidistilled water and fewer macroscopic contaminants, both of which can influence the imaging process. Chemicals were grade p.a. and purchased from Sigma Chemie AG (Buchs, Switzerland). The buffers used were Tris-(hydroxymethyl)-aminomethane (from pH 10.2 to pH 7.2), MES (from pH 6.5 to pH 5.5), and citric acid (from pH 5.4 to pH 3.0). Macromolecular samples were checked before use by conventional negative stain electron microscopy (Bremer *et al.*, 1992) and/or by sodium dodecyl sulfate-gel electrophoresis.

The samples were diluted to a concentration of 5–10 μg/ml in buffer solution (pH 8.2, 20 mM Tris-HCl, 2100 mM; monovalent electrolyte; except for DPPE, which was not further diluted) before adsorption to freshly cleaved mica. After an adsorption time of 10–60 min, the samples were gently washed with the measuring buffer to remove weakly attached membranes. This allowed height measurements at low electrolyte concentrations, at which samples adsorb sparsely to mica (Muller *et al.*, 1997a and 1997b). Experiments requiring constant pH were performed at pH 8.2. The isoelectric points of bacteriorhodopsin, AQP1, DPPE, and OmpF are 5.2 (Ross *et al.*, 1989), 6.95 (calculated), –10 (Tatulian, 1993), and 4.64 (calculated), respectively. Thus, at this pH, all samples had a net negative charge, except for DPPE, which had a net positive charge.

Now do the same in your target articles. We hope you obtain good confirmation of the model and can now answer the questions in Section 2.1:

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

2.4 Vocabulary

In order to complete the information you need to write this section of your paper you now need to find appropriate vocabulary for each part of the 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.

In the next section we will look at vocabulary for the following seven areas of the model:

1. PROVIDE A GENERAL INTRODUCTION AND OVERVIEW OF THE MATERIALS/METHODS and GIVE THE SOURCE OF MATERIALS/EQUIPMENT USED

This includes phrases such as *In this study, most of the samples were tested using a…* as well as verbs such as *were supplied by.* A good list of commonly-used words and expressions will encourage you to include this in your first sentences.

2. SUPPLY ESSENTIAL BACKGROUND INFORMATION

This list provides words and phrases used to describe instruments, equipment or locations, and includes items such as *parallel to* and *equidistant*. They are essential because the reader needs them in order to visualise or recreate your work.

3. PROVIDE SPECIFIC AND PRECISE DETAILS ABOUT MATERIALS AND METHODS (*i.e.* quantities, temperatures, duration, sequence, conditions, locations, sizes)

This includes verbs which specifically describe what you did/used. Instead of writing only *was done* or *was used*, a more specific verb such as *optimise* or *extract* can save you time by explaining exactly what was 'done'.

4. JUSTIFY CHOICES MADE

This includes phrases that introduce the reasons for the choices you made, such as *in order to*. It also includes a list of verbs that specify the advantages of the choices you made, like *enable* and *facilitate*.

5. INDICATE THAT APPROPRIATE CARE WAS TAKEN

This includes adjectives (*careful*) as well as adverbs (*carefully*), so as to give you maximum flexibility when you are constructing sentences.

6. RELATE MATERIALS/METHODS TO OTHER STUDIES

This provides you with ways to distinguish between procedures/materials/tests which were **exactly the same** as those used by other researchers, procedures/materials/tests which were **similar to** those used by other researchers and procedures/materials/tests which were **significantly different**.

7. INDICATE WHERE PROBLEMS OCCURRED

This list includes ways of minimising the problem, minimising your responsibility, maximising the good aspects and suggesting a solution to the problem.

2.4.1 Vocabulary task

Look through the Methodology sections in this unit and the Methodology or Experimental sections in your target articles. Underline or highlight all the words and phrases that you think could be used in the seven areas above.

A full list of useful language can be found on the next pages. This includes all the appropriate words and phrases you highlighted along with some other common ones. Read through them and check the meaning of any you don't know in the dictionary. This list will be useful for many years.

2.4.2 Vocabulary for the Methodology section

1. PROVIDE A GENERAL INTRODUCTION AND OVERVIEW OF THE MATERIALS/METHODS and GIVE THE SOURCE OF MATERIALS/ EQUIPMENT USED

Some of the vocabulary you need for this is in the Introduction vocabulary list; for example, many of the verbs that describe what you did/used can be found there.

These verbs fall into three categories: the first includes general verbs related to academic research, such as *attempt, consider, conduct, determine, investigate, report, suggest, verify*, and most of these can be found in the Introduction vocabulary list. The second category contains verbs that specify what you did, such as c*alculate, extract, isolate, formulate, incorporate, modify, plot, simulate,* and these can be found in the vocabulary list below. The third category includes verbs which are specific to your field and your research, but which are not useful in other fields, for example *clone, dissect, isotype, infuse*. Also try:

all (of) both (of) each (of) many (of) most (of) the majority(of)	(the) tests (the) samples (the) trials (the) experiments (the) equipment (the) chemicals (the) models (the) instruments (the) materials	is/are commercially available was/were acquired (from/by) was/were carried out was/were chosen was/were conducted was/were collected was/were devised was/were found in was/were generated (by) was/were modified was/were obtained (from/by)

		was/were performed (by/in) was/were provided (by) was/were purchased (from) was/were supplied (by) was/were used as supplied was/were investigated

Here are some examples of how these are used:

- **The impact tests used in this work** were a modified version of…
- **All reactions** were performed in a 27 ml glass reactor…
- **All cell lines** were generated as previously described in…
- **In the majority of the tests,** buffers with a pH of 8 were used in order to…
- **Both experiments** were performed in a greenhouse so that…
- The substrate **was obtained from** the Mushroom Research Centre…
- SSCE glass structures **were used** in this study to perform…
- The cylindrical lens **was obtained from** Newport USA and is shown in Fig. 3.
- **The material investigated** was a standard aluminium alloy; **all** melts were modified with sodium.
- Topographical examination **was carried out** using a 3-D stylus instrument.
- **The experiments were conducted** at a temperature of 0.5°C.

2. SUPPLY ESSENTIAL BACKGROUND INFORMATION

As well as describing standard procedures and techniques you may need to describe the equipment/apparatus or instrument you used or constructed. In order to do this accurately you need good control over the language of spatial location. Make sure you know how to use the words/phrases below. If you are not sure, write down the dictionary definition and use a concordance sampler (which you can find on the Internet) to see how they are used.

opposite	facing		
out of range (of)	within range (of)		
below	under	underneath	
above	over	on top (of)	
parallel (to/with)	perpendicular (to)	adjacent (to)	
on the right/left	to the right/left		
(to) bisect	(to) converge	(to) intersect	
near side/end	far side/end		
side	edge	tip	end
downstream (of)	upstream (of)		
boundary	margin	border	
on the front/back	at the front/back	in the front/back	in front (of)
higher/lower	upper/lower	inner/outer	
horizontal	vertical	lateral	
circular	rectangular	conical	
equidistant	equally spaced		
on either side	on both sides	on each side	
is placed	is situated	is located	occupies
is mounted (on)	is coupled (onto)	is fastened (to)	is positioned
is aligned (with)	is connected (to)	is fixed (to)	is embedded
extends	is surrounded (by)	is fitted (with)	is encased (in)
is attached to	is covered with/by	is joined (to)	

Here are some examples of how these are used:

- Porosity was measured **at the near end and at the far end** of the polished surface.
- The compression axis **is aligned with** the rolling direction…
- The source light was polarised **horizontally** and the sample beam can be scanned **laterally**.
- The mirrors **are positioned near** the focal plane.
- Electrodes comprised a 4 mm diam disk of substrate material **embedded in** a Teflon disk of 15 mm diam.

- The intercooler **was mounted on top of** the engine…
- The concentration of barium decreases **towards the edge**…
- Similar loads were applied to **the front and side** of the box…
- A laminar flow element **was located downstream of** the test section of the wind tunnel…

In which sentence(s) below was the table closest to the wall?

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

In which sentence(s) below was the clock closest to the door?

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

Note that *half as wide (as) = half the width (of); half as heavy (as) = half the weight (of); twice as long (as) = twice the length (of) and twice as strong (as) = twice the strength (of). Also note that with/having a weight of 20 kg = weighing 20 kg and with/having a width/length of 20 cm = 20 cm wide/long.*

3. PROVIDE SPECIFIC AND PRECISE DETAILS ABOUT MATERIALS AND METHODS

These verbs fall into three categories: the first includes general verbs used in academic research, such as *attempt, consider, conduct, determine, investigate, report, suggest, verify*, and these can be found in the Introduction vocabulary list (Section 1.4). The second category contains technical verbs which are specific to your field and your research, but which are not useful in other fields, for example *anneal, calibrate, centrifuge, dissect, fertilise, ionise, infuse*. These will not be given here because they are not generally useful. The third category is a set of less technical verbs that specify what was done or used, such as *calculate, extract, isolate, formulate, incorporate, modify, plot, simulate.* These usually occur in the passive *(was/were isolated)* and can be found in the vocabulary list below.

was adapted	was divided	was operated
was added	was eliminated	was optimised
was adopted	was employed	was plotted
was adjusted	was estimated	was positioned
was applied	was exposed	was prepared
was arranged	was extracted	was quantified
was assembled	was filtered	was recorded
was assumed	was formulated	was regulated
was attached	was generated	was removed
was calculated	was immersed	was repeated
was calibrated	was inhibited	was restricted
was carried out	was incorporated	was retained
was characterised	was included	was sampled
was collected	was inserted	was scored
was combined	was installed	was selected
was computed	was inverted	was separated
was consolidated	was isolated	was simulated
was constructed	was located	was stabilised
was controlled	was maintained	was substituted
was converted	was maximised	was tracked
was created	was measured	was transferred
was designed	was minimised	was treated
was derived	was modified	was varied
was discarded	was normalised	was utilised
was distributed	was obtained	

4. JUSTIFY CHOICES MADE

because* by doing…, we were able to chosen for (+ noun) chosen to (+ infinitive) for the purpose of (+ -ing or noun)** for the sake of (+ -ing or noun) in an attempt to (+ infinitive) in order to (+ infinitive) it was possible to (+ infinitive) offer a means of (+ -ing) one way to avoid... our aim was to (+ infinitive)	provide a way of (+ -ing) selected on the basis of… so as to (+ infinitive) so/such that so (+ -ing) thereby (+ -ing) therefore* thus (+ -ing) to (+ infinitive) to take advantage of which/this allows/allowed *etc.* with the intention of (+ -ing)

*See Section 1.2.2 for other examples of signalling language

**See box below for infinitives, -ing forms and noun forms of useful verbs. ∅ indicates that a noun form is not available or is not common in this type of structure

INFINITIVE	-ING FORM	NOUN FORM
achieve	achieving	achievement
allow	allowing	∅
assess	assessing	assessment
avoid	avoiding	avoidance
compensate for	compensating for	compensation for
confirm	confirming	confirmation
determine	determining	determination
enable	enabling	∅
enhance	enhancing	enhancement
ensure	ensuring	∅
establish	establishing	establishment
facilitate	facilitating	facilitation

guarantee	guaranteeing	guarantee
identify	identifying	identification
improve	improving	improvement
include	including	inclusion
increase	increasing	increase
limit	limiting	limitation
minimise	minimising	∅
obtain	obtaining	∅
overcome	overcoming	∅
permit	permitting	∅
prevent	preventing	prevention
provide	providing	provision
reduce	reducing	reduction
remove	removing	removal
validate	validating	validation

Here are some examples of how these are used:

- **To validate** the results from the metroscale model, samples were collected from all groups.
- The method of false nearest neighbours was selected **in order to determine** the embedding dimension.
- **For the sake of** simplicity, only a single value was analysed.
- **By partitioning** the array, all the multipaths could be identified.
- Zinc oxide was drawn into the laminate **with the intention of** enhancing delaminations and cracks.
- **The advantage of** using three-dimensional analysis was that the out-of-plane stress field could be obtained.
- **Because** FITC was used for both probes, enumeration was carried out using two different slides.
- The LVDTs were unrestrained, **so allowing** the sample to move freely.
- The cylinder was constructed from steel, **which avoided** problems of water absorption.

5. INDICATE THAT APPROPRIATE CARE WAS TAKEN

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

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

Here are some examples of how these are used:

- A mechanical fixture was employed to hold the sonic horn **firmly** in place.
- After being removed, the mouse lungs were frozen and thawed **at least** three times.
- The specimen was monitored **constantly** for a period af 24 hours.
- They were then placed on ice for **immediate** FACS analysis.
- **Frequent** transducer readings were taken to update the stress conditions smoothly.
- The samples were **slowly and carefully** sheared to failure.

6. RELATE MATERIALS/METHODS TO OTHER STUDIES

There are three ways in which you might want to relate your materials/ methods to those used in other studies.

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

according to as described 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 details are given in	given by/in identical to in accordance with the same as that of/in using the method of/in

**by* and *of* are usually followed by the name of the researcher or research team (*by Ross* or *using the method of Ross et al.)* and *in* is usually followed by the work (*in Ross et al. (2003)*). Another option is simply to give the research reference at the appropriate place in the sentence, either in brackets or using a superscript number.

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

a (modified) version of adapted from based in part/partly on based on essentially identical in line with in principle in essence more or less identical slightly modified	(very) similar almost the same essentially the same largely the same practically the same virtually the same with some adjustments with some alterations with some changes with some modifications	(to) adapt (to) adjust (to) alter (to) change (to) modify (to) refine (to) revise (to) vary

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

a novel step was… adapted from* based on* in line with	although in many ways similar although in some ways similar although in essence similar	(to) adapt* (to) adjust* (to) alter* (to) change*

loosely based on partially based on partly based on*	with the following modifications/changes:	(to) refine* (to) revise (to) vary* (to) modify*

*as you can see, 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 if they are not significant. In **Option 3** those differences or modifications are significant and you should say what they were, especially if they were modifications which improved the procedure/material.

Here are some examples of how these are used:

- Developmental evaluation was carried out using the Bayley Scales of Infant Development **(Bayley, 1969)**.
- The size of the Gaussians was adjusted **as in (Krissian *et al.*, 2000)**.
- The centrifuge is a **slightly modified** commercially available model, the Beckman J6-HC.
- The protein was overexpressed and purified **as reported previously.**[10,12]
- **A revised version of** the Structured Clinical Interview (4th edition)[6] was used.
- **We modified** the Du and Parker filter to address these shortcomings and we refer to this modified filter as the MaxCurve filter.
- In our implementation **we followed** Sato *et al.* (1998) by using a discrete kernel size.

7. INDICATE WHERE PROBLEMS OCCURRED

minimise problem	**minimise responsibility**	**maximise good aspects**
did not align precisely only approximate	limited by inevitably	acceptable fairly well

it is recognised that less than ideal not perfect not identical slightly problematic rather time-consuming minor deficit slightly disappointing negligible unimportant immaterial a preliminary attempt not significant	necessarily impractical as far as possible (it was) hard to (it was) difficult to unavoidable impossible not possible	quite good reasonably robust however* nevertheless* **talk about a solution** future work should… future work will…* currently in progress currently underway

*There is an interesting difference between the phrase *future work should* and the phrase *future work will*. When you write *future work should* you are suggesting a direction for future work and inviting the research community in your field to take up the challenge and produce the research. When you write *future work will* you are communicating your own plans and intentions to the research community and it should be understood that these plans and intentions belong to you — you're saying 'hands off!' to the rest of the research community and describing a research plan of your own

Here are some examples of how these are used:

- **Inevitably**, considerable computation was involved.
- 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.
- Continuing research **will** examine a string of dc-dc converters to determine if the predicted efficiencies can be achieved in practice.
- **While** the anode layer was **slightly** thicker than 13 μm, this was a **minor deficit**.

2.5 Writing a Methodology Section

In the next task, you will bring together and use all the information in this unit. You will write a Methodology section according to the model, using the grammar and vocabulary you have learned, so make sure that you have both the model (Section 2.3.3) and the vocabulary (Section 2.4) in front of you.

In this unit you have seen the conventional model of the Methodology and the vocabulary conventionally used has been collected. Remember that when you write, your sentence patterns should also be conventional, so use the sentence patterns you have seen in the Methodology samples in this unit and in your target articles as models for your writing.

Follow the model exactly this time, and in future, use it to check the Methodology of your work 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 this section.

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.

2.5.1 Write a Methodology 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 and obtain exactly the same result as you obtained. Remember that you are expected to show that you carried out your work with due care and that you had good reasons for doing what you did. The message is: **This is exactly what I did, I did it carefully and I had good reasons for doing it in this way.**

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 Materials/Methods section of a research paper.

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 in a hot oven for about an hour and a half*, you should write something like: *The sample was then placed on a 300 × 600 mm stainless steel sheet and heated in a Panasonic E458 × 500 w standard fan-assisted oven for 90 minutes at 350°C.*

Don't worry if you don't know how to cook chicken — it doesn't matter if you report that you cooked it by boiling it in vodka, but you must give the exact quantity and the brand name of the vodka you used, so that your method and results can be replicated by someone else. Remember to use the passive voice and the appropriate tense.

The title of the research paper in which you report the new process is: **AN APPROACH TO THE PREPARATION OF CHICKEN.** The Introduction to your paper looks like this:

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., 1990) 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*[6] *resulting from the consumption of raw meat.*

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 Methodology section of this paper. You should write approximately 250–400 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.

2.5.2 Key

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

Two experiments were carried out using different combinations of seasoning and varying cooking temperatures. A 4.5 kg frozen organic chicken was purchased from Buyrite Supermarket. Buyrite only sell grade 'A' chickens approved by the Organic Farmers Association, thus ensuring both the homogeneity of the sample and the quality of the product. Seasonings were obtained from SeasonInc UK and were used as supplied.

According to the method described by Hanks *et al*. (1998), the chicken was first immersed in freshly boiled water cooled to a temperature of 20°C and was subsequently rinsed thoroughly in a salt solution so as to reduce the level of bacteria on the surface of the chicken.[7] In order to obtain two samples of equal size and weight for testing, the chicken was first skinned using a standard BS1709 Skin-o-matic; the flesh was then removed from the bone with a 4 cm steel Sabatier knife, after which it was cut into 3 cm-cubes, each weighing 100 g.

Two of the cubes thus obtained were randomly selected for testing. The cubes were dried individually in a Phillips R2D2 Dehydrator for 10 minutes. Immediately after removing each cube from the dehydrator it was coated with the selected seasoning mixture[8] and left to stand on a glass plate for 30 minutes at room temperature (16°C) in order to enhance absorption of the seasoning prior to heating. Seasoning quantities were measured used standard domestic kitchen scales and were 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 product was removed from the oven and allowed to come to equilibrium, after which the cubes were assessed according to the TTS test developed by Dundee (Dundee, 1997).
