

On coherence and cohesions in writing

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1. Introduction

In these notes we will go through how to develop paragraphs. As a reminder, paragraphs are not just sequences of sentences. If they were, we could write paragraphs as a collection of simple sentences. But we don't. There are, in fact, two distinguishing features which make paragraphs more than this, namely semantic coherence and linguistic cohesion. What are these things? They are features or aspects of writing greatly aid communicability and readability:

- *Coherence*: This is about developing ideas logically. This is very important for us since we are writing scientific ideas. A coherent idea is one which, broadly speaking, makes sense because the author/speaker has communicated all the necessary elements of the idea in a scientifically logical way, as well as integrating these elements into a whole (i.e. discussing how the sub-ideas are connected to each other).
- *Cohesion*: Cohesion might be said to be the coherence of language. It is about how words, phrases, sentences and paragraphs are developed so as to make one's writing not only semantically correct, but allow for the *flow or development, through language*, of the scientific ideas. Cohesion might be said to be the coherence of language. Or it might be said to be about using language to project the scientific meaning we wish to project.

So we might say that coherence is about the semantic/scientific integrity of ideas, and cohesion is about the linguistic connectivity used to achieve this semantic/scientific integrity. Coherence and cohesion are symbiotically linked. We need to use language in a grammatically correct, and stylistically appropriate, manner in order to pitch and emphasise our scientific ideas the way we want to.

For example, when trying to define, in a simple manner, the term *mechanical stress* (say, the stress in a metal rod) we might say

- 1) The distribution of force across a section is called stress;
- 2) If a force acts across a section, and if this force is distributed, then stress will result;
- 3) Stress is the distribution of force across a section;
- 4) The force of a cross section is the stress of distribution.

As another example consider “While ethane rotates towards eclipsed conformation, electrons in the C-H bonds on two different carbon atoms experience repulsion which introduces the barrier.”, Pophristic and Goodman (2001). I have no idea what this means so I can’t comment on the semantic/scientific coherence, but I can still comment on the linguistic cohesion, as follows:

“While <bla, bla, bla> <something happens> which <bla, bla>

The cohesive words/phrases are therefore “while” and “which”, and the scientific coherence relates to the descriptions given by <bla, bla, bla> and <something happens>.

So in these notes we will focus on the idea of coherence and cohesion as ways of developing paragraphs.

2. Coherence and cohesion

In order to achieve semantic/scientific coherence we will look at semantic/scientific bridges. This relates to

- carrying over the same idea of a topic from sentence to sentence, or across multiple sentences or paragraphs;
- developing general ideas in more detail, or generalising an idea from specific instances.

The following are just some of the different ways in which we can achieve cohesion in language:

- 1) *general lexis*: This simply refers to words such as “and”, “of”, “from ... to”, “hence”, “they”, “so”, “therefore”, “or”, etc. which we use all the time without thinking.
- 2) *referencing* (the technical term for this is anaphoric referencing). This is when we refer to something we stated previously or that we are just about to state. There are two types of referencing: backwards and forward (known technically as anaphoric and cataphoric referencing.). We use backwards referencing all the time in speech and writing.

Examples of this include

- the use of “It” in the second sentence (line 2) of the Cho, Vladimir, Choi (2015) text above. Here, “It” refers back to line 1 where they say “... the procedure for ...”.

- An example of forward referencing is “As medicine leans increasingly on mathematics no clinician can afford to leave the statistical aspects of a paper to the "experts.”” (BMJ (1997)). If we wanted to write the sentence using the standard (backward) referencing it would look something like this:

No clinician can afford to leave the statistical aspects of a paper to the "experts." This is because medicine leans heavily on mathematics.

In both sentences the phrase being *referred to* is “medicine leans increasingly on mathematics”, and the phrase *doing the referring* is “No clinician can afford to leave the statistical aspects of a paper to the "experts." ”. It is just that in the original sentence the “referred to” and the “doing the referencing” are swapped around.

- “What’s wrong with the sentence you are currently reading?” vs “What’s wrong with this sentence?”. Here the word “this” is a reference word which does not referring to anything which was said before. Rather, it refers to what is currently being said. This is called self-referencing. This is what has happened in the Cho, Vladimir, Choi (2015) text above where they say “In this article” in the first sentence.

There are so many cohesive devices, a lot of which we use automatically day-to-day, that it is not worth listing them here (see this week’s folder of material for separate lists). They occur everywhere in writing (re-read this sentence. Which word is the cohesive word, and to what does it refer? And again, re-read this specific last sentence. Which word is the cohesive word, and to what does it refer?)

3) *repeating words or phrases* (but not too often), and also via the *use of synonyms*. For example,

- “Cohesion is an important feature of scientific writing because *such writing* makes reading easier. In this way it makes easier the uptake of scientific meaning.”,
- “Cohesion is an important feature of scientific writing because such writing makes reading easier. *In this way* it makes easier the uptake of scientific meaning.”,
- “Cohesion is an important feature of scientific writing. *Such features* allow readers to more easily understand the science you are writing about.”

4) *transition words/phrases*. These are used to highlight the reader to the fact that we now want to transition to something, such as i) showing examples, ii) comparing /contrasting things (e.g. pros and cons, similarities and differences, etc.), iii) showing results or effects of something, iv) listing items, as in “First we shall examine ... then we shall look at ... Finally, we will see ...”. Even the use of number lists is a type of transition device (in other words the number list I have just used in this paragraph).

- “Cohesion is an important feature of academic writing. It can help ensure that your writing coheres or 'sticks together', which will make it easier for the reader to follow the main ideas in your essay or report.

You can achieve good cohesion by paying attention to four important features. The first of these is reference words. The second key feature is repeated words. The third one is transition signals. And the final one is signposting.”

Note that the sentence “You can achieve good cohesion by paying attention to four important features” acts as a transition sentence. It forewarns the reader that a change in focus is about to occur between the first and second paragraphs.

Another repetition example is:

- The t-distribution is a distribution of sample means. Given a population of size n there can be millions of samples of size 5 or 7 or 9, etc. All of these millions of samples will have a mean, and the t-distribution is a plot of all of these means.

Some example transition terms include the following:

However, ...	Nevertheless ...	Alternatively, ...	Nevertheless,
For example,	Equally important,	Conversely, ...	Similarly, ...
Despite, ...	Firstly, secondly, ...	On the other hand,	In addition ...
Even though ..., it can be seen that ...	While it may be true that ..., we see that ...	Having shown that ... we now move onto ...	In spite of ..., we find that ...

5) *signposting*. This refers to indicating to the reader what is to come in the text. This helps the reader know if you are continuing to focus on a topic but focusing on more detail, or whether you are going to change to a different aspect of the topic, or whether

you are going to give an example, etc... in other words, signposting forewarns the reader in a change in the emphasis of what you are focusing on in the text.

As an example, consider the text below.

“Cohesion is an important feature of academic writing. It can help ensure that your writing coheres or 'sticks together', which will make it easier for the reader to follow the main ideas in your essay or report. *You can achieve good cohesion by paying attention to four important features.* The first of these is reference words. The second key feature is repeated words. The third one is transition signals. And the final one is signposting.”

Notice that the sentence in italics is a signposting sentence because it forewarns us of what is to come. It also changes the focus given by the first two sentences to something new, namely “four important features”. This sentence then acts as a general statement from which will follow by the specifics (texts in 2) – 4) taken, or adapted, from <https://www.eapfoundation.com/writing/cohesion/>).

Other signposting examples include:

We will show that ...	Consider the following ...	For instance,	Furthermore,
For example,	In particular, ...	Conversely,	On the other hand,
As previously mentioned ...	As an example, consider, ...	Nevertheless,	Contrary to ...
However, not all research shows that... Some evidence agrees that ...		The strength of such an approach is that ...	By performing /analysing/... we will show/demonstrate/... that

Note that semantic/scientific coherence is more difficult to achieve than linguistic cohesion. The latter is simply the use of appropriate keywords or phrases given how you want to project the development of your idea. The former requires you to know that each subsequent development or explanation of an idea follows on directly and immediately in a scientific way from a prior/previous idea you have explained. Writing is always about coherence and cohesion.

Important note 1: The English language doesn't just contain four types of cohesive devices. There are many others. We can't go through all of them in these notes. When reading, analysing, and writing text you should recognise, and be familiar with, the various different ways language is used to achieve cohesion so as to carry scientific ideas.

Important note 2: The difficulty as a writer lies in coherently developing a scientific idea in a cohesive manner. This is the real test of you as a writer when it comes to communicating science of any type.

This is because all STEM texts are loaded with scientific meaning. Each text has what I call a density of meaning, and it is this density of meaning which the reader does not understand. It is your job to write in a way that carries them through your idea such that they are able to understand the details of scientific concepts.

To this end we use cohesion for clarity of language, and coherence for comprehensibility of ideas.

3. Examples of coherence and cohesion

3.1. Example 1: Chemistry – Chemical bonding

Below is a text from Özmen (2004). Each relevant linguistic cohesive device has been superscripted by a number. You can find an analysis of each particular number item below the text.

1 “Chemical bonding is one of the most important topics in undergraduate
2 chemistry and^a the topic^b involves the use of a variety of models varying from^c
3 simple analogical models to^c sophisticated abstract models possessing
4 considerable mathematical complexity (Coll and Taylor, 2002; Coll and
5 Treagust, 2003; Fensham, 1975). It^d is also^e a topic that students' commonly
6 find problematic and^f develop a wide range of misconceptions. The concepts of
7 electron, ionization energy, electronegativity, bonding, geometry, molecular
8 structure, and stability are central to much of chemistry, from^{g-h} reactivity in
9 organic chemistry to^{g-h} spectroscopy in analytical chemistry (Nicoll, 2001). And
10 alsoⁱ, it is important for students to grasp these concepts in understanding why
11 and^j how chemical bonds occur. Chemical bonding has been classified into a
12 series of three target systems]^k; metallic, ionic, and covalent bonding.”

Analysis

In line 2, item a: General lexis: The standard and most used of cohesive devices. This can be used to join two separate ideas or two separate sentences, each containing one idea: “Chemical bonding is one of the most important topics in undergraduate chemistry” and “the topic involves the use of a variety of models varying from simple analogical models to ...”. Also notice my use of ‘and’ in this previous sentence!

Be careful when using “and” to join two separate ideas or sentences. The ideas of each sentence have to cohere. In other words, the final (enlarged) sentence has to be coherent in terms of the idea it is describing. The following is an incorrect use of the word “and”: “Gravity has the effect of bending starlight and weighs less than 1kg”. The “and” refers to gravity, but we don’t talk of gravity as weighing anything. (notice my use of “In other words”, second sentence of this paragraph. This is also a cohesive device. What does it do?)

In line 2, item b: Referencing: “the topic”. Which topic? Chemical bonding. So, “the topic” acts as a referencing.

In line 2-3, item c: General lexis: Another standard cohesive device. This can be used to show direction, time, place, location, relationship, amongst other things. Here “from” is used to show different examples. In this case it is used in the sense of “from ... to”.

In line 5, item d: Referencing and general lexis: Another standard cohesive device (see how these pop up everywhere), the word “it” helps us to not repeat, otherwise we would be writing “Chemical bonding is one of the most important topics in undergraduate chemistry ...” and “Chemical bonding is also a topic that students’ commonly find problematic ...”. Using the word “it” is efficient and makes the reading lighter compared to regularly repeating “Chemical bonding”

In line 5, item e: Transition: “Chemical bonding is one of the most important topics in undergraduate chemistry ...” and “It is also a topic that students’ commonly find problematic ...”, so the word “also” here acts to transition to another aspect of chemical bonding which the author wants to address.

The word “also” is also used here as a connecting device. The author wants to connect another an additional aspect which relates to the main focus of chemical bonding. So if we were to write “Chemical bonding is one of the most important topics in undergraduate chemistry ...” and then “It is a topic that students’ commonly find problematic ...”, we would

have missed out on relating the two issues of importance and problematicness: “Chemical bonding is important to learn but is also problematic to teach”.

In line 6, item f: General lexis: Another “and”.

In line 8-9, item g-h: general lexis: Another “from ... to”.

In line 10, item i: Signposting: “And also, it is important for”. This acts as signposting signifying that the author is going to introduce something else. “And also” could also be read as a transition. Look at the sentence before “and also” then look at the “And also” sentence. Do they refer to the same idea or theme? If they do, then “And also” would not act as transition. If they don’t, “And also” would act as a transition.

In line 11, item j: General lexis: Another “and”.

In line 11-12, item j: Signposting: “Chemical bonding has been classified into a series of three target systems:” suggests signposting because we only tend to write in this form when we want to list the three specific items.

The last sentence also has general lexis to make it cohesive. Can you find these? To help you find them consider the altered version below of the last sentence. Does it make sense language-wise?

Chemical bonding has been classified series three target systems; metallic, ionic, covalent bonding.

This is why cohesive language is imperative.

3.2. Example 2: Mechanical engineering – Vibrations

The following text is from Liew, K. M., Xiang, Y., Kitipornchai, S., (1995).

1 “Mindlin et al. [41] investigated the free flexural vibration of rectangular Mindlin
2 plates with^a simply supported edge conditions and with^b one pair of parallel edges
3 free and^c the other pair simply supported. Analytical solutions for these^d plates
4 were obtained. They^e found that three independent families of modes are possible
5 when the plate edges are simply supported. The coupling of the modes has also^f
6 been studied for the case of one pair of parallel edges free and the other pair
7 simply supported.”

Analysis

There is very little variety in the use of cohesive devices in the text above, and the ones that are used are basic. These are

In line 2, item a, b: General lexis: with”, “and”, “of”.

In line 3, item c: General lexis: “and”

In line 3, item d: Referencing: What does “these” refer to?

In line 4, item e: Referencing: “They” refers to “Mindlin et al. [41]”

In line 5, item f: General lexis: Here the authors uses the word “also” to include an additional aspect which relates to how the edges of the plate are supported.

Note that the beginning of the first sentence (“Mindlin et al. [41]”) does not count as referencing in a linguistic sense. This is referencing of a source, not referencing as a cohesive device.

3.3. Example 3: Palaeontology

The following text is from Elias (1950). Each relevant linguistic cohesive device has been superscripted by a number. You can find an analysis of each particular number item below the text.

1 “This^a paper is an attempt to outline]^b, in a subjective way]^c, the present status of
2 paleontology, chiefly^d that of the invertebrates, illustrated by^e certain examples
3 taken mostly from some recent studies of late Paleozoic invertebrates from the
4 Mid-Continent region with which]^f I am familiar. However^g, the conclusions
5 reached seem to apply, with certain reservations, to the contemporary state of
6 knowledge of other fossil organisms, here and elsewhere.”

Analysis

In line 1, item a: Referencing: This is what is called self-referencing. It is a linguistically shorter version of something like “The paper you are about to read is an attempt ...”, or worse “The paper you are about to read is a paper which attempts to ...”. Self-referencing makes reading more effective and efficient.

In line 1, item b: Signposting: The whole phrase notifies the reader about what is to come in the paper. Phrasing such as “This paper ...” is standard in this context. For example, “This paper explains/proves/demonstrates/presents ...”.

In line 1, item c: Signposting: The phrase “in a subjective way” can be seen as informing the reader ahead of time that the paper may be more of a personal take on the topic rather than an objective, evidence-based presentation of the science. If you read the first sentences as a whole (lines 1-4) you will see that this is indeed the case.

In line 2, item d: Signposting. Why?

In line 2, item e: General lexis and signposting: See what happens to the cohesion of the sentence if we remove “by”. Consider the simplified sentence with “by”

- i) “This paper is an attempt to outline the present status of paleontology, illustrated by certain examples taken mostly from...”

and the simplified sentence without “by”:

- ii) “This paper is an attempt to outline the present status of paleontology, illustrated certain examples taken mostly from...”

We can rewrite i) as

- iii) “This paper is an attempt to outline the present status of paleontology, illustrated *by means of* certain examples taken mostly from...”

So here “by” acts to inform the reader how it is that the author will outline the present status of paleontology. But we can rewrite ii) as

- iv) “This paper is an attempt to outline the present status of paleontology, *which* illustrated certain examples taken mostly from...”

This doesn’t make sense. There is no coherence of ideas between the phrase before “which” and the phrase after “which”. There seems to be something missing.

Hence, “by” is a cohesive device used to make the sentence as a whole coherent in its idea.

In line 4, item f: General lexis: Things like “with which”, “by which”, “in which”, “of which”, attribute something to something else. In this case “I am familiar” to “recent studies of late Paleozoic invertebrates from the Mid-Continent region”. A heavier form of writing would look something like “taken mostly from some recent studies of late Paleozoic invertebrates from the Mid-Continent region. I am familiar with this region.” The use of such type of lexis /attribution is an advanced form of writing.

In line 4, item g: Transition: “However” is one of the most used of cohesive devices. It is designed to signal a change or shift. Here the shift is from “Paleozoic invertebrates” to “other fossil organisms”.

3.4. Example 4: Mechanical engineering

Consider the two texts below:

1. A spring-mass system is configured as a viscously damped system. A force $F(t)$ acts on this system. We can use Newton's laws to obtain the equations of motion of this system.
2. "If a force $F(t)$ acts on a viscously damped spring-mass system [...], the equation of motion can be obtained using Newton's second law [...]." (Rao (###))

In terms of semantic/scientific coherence we would be the experts who would know the hierarchy of meaning of the text above. As such we would know to consider

- Force;
- Viscous;
- Viscously damped;
- A spring-mass;
- A spring-mass system;
- A force acting on a viscously damped spring-mass system,

etc. And as experts we also know not to consider

- Viscous spring-mass;
- A system of viscous damping;
- Viscous equations;

or

- The motion of a viscous law obtained from spring-force damping.

3.5. Exercise: A continuation of example 4

The following text is my own description, in layman's terms, of the text of example 4.

- a) Identify the cohesive devices used in this text. If you find other types language you consider cohesive, apart from the five main ones listed in section 2, p3 then list these also.
- b) If possible, identify any lack of coherence. The aim of my description below is to explain the meaning of Rao's technically dense text. So, have I to be able to keep the scientific meaning of Rao's text. Do I do this?

My text

Suppose you are driving along a road which has potholes in it, and you drive over one of these potholes. Some shock absorbers tend to have two aspects which cushion the reaction of the car driving over the pothole. One is a coiled

spring made of some suitable material (metal, carbon fibre, or other), and the other⁵ is some kind of oil inside the cylinder part of the shock absorber.

Now, suppose the coiled spring is made of metal. The type of metal used, and the number of coils in the spring, will determine how springy the shock absorber is. Using one type of material and/or a certain number of coils, will give you a soft, spongy reaction when you drive over the pothole. This means that after you have driven over the pothole you could keep bouncing down the road for ages.

Using another type of metal, and a different number of coils in the spring, may mean that there is no bounce at all as you drive over the pothole. It is as if you had no suspension at all on the car, and this would make for very uncomfortable drive.

The viscosity of this oil relates to how “thick” it is. The more viscous it is, the “thicker” it is, and therefore the “harder” it reacts against impact, the more quickly it acts to absorb or stop any rebound, and the more quickly it will stop the car bouncing up and down. This then makes it less comfortable for the driver.

The less viscous the oil is, the less quickly it acts to absorb or stop rebound, and the less quickly it will stop the car bouncing up and down. In other words, the car will bounce up and down for longer, and will make for a more spongy feeling for the driver.

The degree of viscosity of the oil then determines the degree of springiness of the oil. Taken together, the coiled spring and the oil are considered as one single spring-mass system, this having one overall, total, springiness.

We want to study the way the car bounces up and down as a result of the type of shock absorber used. The equations which relating to the car’s bouncing up and down can be found from Newton’s second law of motion. This says that when a force acts on an object, the object accelerates in the direction of the force. If the mass of an object is held constant, increasing force will increase acceleration.

Here the fall of the car into the pothole is the acceleration being referred to. What force causes this acceleration? Gravity, pulling the car down into the pothole. Since gravity is (more or less) constant, the heavier the car, the more it will affect driving comfort.

End of exercise.

One way to describe what we are doing when we are writing scientifically is to say that we are wrapping the English language around the technical language of the topic. We are wrapping the way we express ourselves in English around the scientific content of the source material. For example,

- For the text “If a force $F(t)$ acts on a viscously damped spring-mass system [...], the equation of motion can be obtained using Newton’s second law [...].” we can see the way in which the English language wraps around the scientific language:
 - *English language:* “If a force $F(t)$ acts on a viscously damped spring-mass system [...], the equation of motion can be obtained using Newton’s second law [...].”
 - *Scientific language:* “If a force $F(t)$ acts on a viscously damped spring-mass system [...], the equation of motion can be obtained using Newton’s second law [...].”

Using a colour coded way of communicating the above idea I might say:

<my vocabulary> <typical technical terminology> <my phrasing> <standard scientific collocation> <my linguistic feature> <fixed technical expression> <my linguistic expression> <accepted technical name>

4. Lack of cohesion – Lack of cohesion results in text difficult to read

Depending on how much or how little cohesion there is, a text may simply read as a disparate collection of information, where each piece of information seemingly unconnected to any other piece.

4.1. Example 1: Mechanics

We will look at a text from Adler (1980), cumulatively adding more sentences as we go along.

“In the standard Newtonian formulation of mechanics, the second derivative of position with time, _____ the acceleration of an object, has special significance.”

The blank relates to cohesive language. What could this be? Anything which makes sense within the context of the sentence. Which of the following would make sense?

in which	for	in the case of
specifically	in other words,	for example
and	but not	by which we mean
which is to say	therefore	instead of
in this respect	then	Thus
it	hence	a consequence being

We might continue the sentence above as follows:

“This follows from the fact that in Newton's Second Law, acceleration is directly proportional to force; and force, as conceived by Newton, is a first principle' (that is, real and directly experienced). _____, in the Newtonian approach, the equation: $F(X) = ma$, or $F(X) = m\ddot{x}$ is more than a differential equation that describes the motion of the particle whose position is x in an environmental configuration described by X .”

What cohesive language could take the space of the blank above? You can find an appropriate one in the table above. Hint: look at “is more than a” and decide what cohesive device might fit with this latter phrase.

Continuing directly from the above we have

“ ___ is a statement that (real) forces produce accelerations.”

What cohesive language could take the space of the blank above? You can find an appropriate one in the table above. Hint: the missing language refers to “the equation” and does so without having to repeat the phrase “this equation”.

4.2. Example 2: Plasma physics

The following text is taken from Palmroth (2018). It illustrates what a large amount of text looks like when there is a significant lack of cohesion. How easy is it to read the flow of ideas as you read through the text? The full version of the text is given in appendix 7

“ ___ physical understanding is inherently based on empirical evidence, numerical simulation tools have become an integral part ___ the majority ___ fields within physics. ___ tested against observations, numerical models can strengthen or invalidate existing theories ___ quantify the degree ___ the theories have to be improved. Simulation results ___ complement observations by giving ___ a larger context. In space physics, spacecraft measurements concern only one point at one time in the vast volume of space, ___ that discerning spatial phenomena from temporal changes is difficult. ___ shortcoming that has ___ led to the use of spacecraft constellations, ___ the European Space Agency’s Cluster mission (Escoubet et al. 2001). ___, simulations are considerably more cost-effective compared to spacecraft, and ___ can be adopted to address physical systems that cannot be reached by in situ experiments, ___ the distant galaxies. ___, and most importantly, predictions of physical environments under varying conditions are always based on modelling. Predicting the near-Earth environment ___ has become increasingly important, ___ because the near-Earth space hosts expensive assets used to monitor our planet, [but also because ...]”

4.3. Example 3: Palaeontology

The following text is taken from Elias (1950). It illustrates what a large amount of text looks like when there is a significant lack of cohesion. This time I haven't even included the gaps where the cohesive language should be located. See how difficult it is to read, and see if you spot where, and which, cohesive language, could be used. The full text is given in appendix 7.

“present state of our knowledge fossil organisms to be a bewildering mixture well established facts, stubbornly perpetuated errors, naive notions. comparatively few observations conclusions survived the test of time, some established sequences of fossils [...] have been proved reasonably constant, usually within more or less limited provinces, constancy other observed changes merely is taken for granted, our science does not seem to recognize the necessity repeated verification fundamental observations.”

(as a side note, the above text is actually one single sentence. As such this is too long. We will deal with such an issue in the topic dealing with simple and complex sentences later this week or next week).

5. Lack of coherence – The non-redundancy of technical discourse

As a reminder, coherence refers to way in which scientific ideas are presented in a logical and meaningful way. another way of saying this is that scientific ideas need to be developed in a methodical and conceptually ordered fashion.

5.1. Example 1: Mathematics.

When defining a mathematical function, such as $f(x) = x^2 + 1$, we need to state two things, namely a domain and a range (note here that “such as” and “namely” are cohesive language, specifically signposting). The domain is defined as the set of valid input value, i.e. the set of value of x . The range is defined as the set of valid output value, i.e. the set of value of $f(x)$. So, a mathematically coherent sentence using these terms would be something like

“the domain of the function is $x \in \mathbb{R}$ ”,

or

“any value of x is a domain value for $f(x)$.”

Students often use the word “range” instead of “domain” because they interpret “range” as a general English language word instead of the mathematical word.

So they might say:

“the range of the function is $x \in \mathbb{R}$ ”,

or

“the range of values of x which are valid for $f(x)$ ”.

So, although the sentences above are grammatically correct they are semantically incorrect. They are mathematically incoherent (note that the word “interval” can sometimes be substituted for the word “range”, since the former terminology applies to a span of x values as it does to a span of $f(x)$ values. However, this cannot be done above since $x \in \mathbb{R}$ means $-\infty < x < \infty$, and the word “interval” applies only to finite domains and ranges).

End of example.

It should be clear from our experience that scientific texts have a great density of meaning. In other words, many scientific words are wrapped with a few normal English words, the whole sentence being scientifically coherent (i.e. having a coherent scientific meaning).

What this means is that every scientific term, compound term or phrases is necessary for the correct description of the object or phenomenon we are trying to describe. None of these terms or phrasings can be omitted. This is what I mean by “non-redundancy”. Redundancy means that we have information which is either unnecessary or does not add anything new to the meaning of the text. Such information can be left out without affecting the accuracy, correctness, precision, etc. of the meaning of the text (the most basic form of redundancy is repetition). Mathematical/scientific text is non-redundant discourse because (99% of the time) we cannot omit any technical language without affecting the accuracy, correctness, precision, etc., of the meaning of the text.

Let us see what happens if we do omit technical language from a scientific text.

5.2. Example 2: Mechanical stress

Consider the text “The distribution of force across a section is called stress”. What happens if we omit one of more terms of this text?

- “Force across a section is called stress”. The key term omitted is “distribution”, implying that stress might exist on a section when the force is applied only at one point or location of the section, not across the whole of the section.
- “The distribution across a section is called stress”. The key term omitted is “force”. The question then is, “the distribution of what?” Force can be said to be an action of

some kind, so the altered sentence is clearly missing the type of action which is to be distributed. It is the particular action of a force which relates to stress, since some other action may not be related to stress.

- “The distribution of force is called stress”. The key terms omitted is “across a section”. Here we can ask, Where is the force applied? Force is always applied somewhere to something, and this has to be specified.

This brings up the question of the extent to which we describe the scientific meaning of the text. We have to get across the essential scientific meaning of the text, but how much detail should we go into?

- Do we explain everything the text describes?
 - i.e. the use of force? The fact that it is distributed? Where the force is applied?
- How much detail do we go into?
 - What is the true nature of forces? What is the difference between constant forces or variable forces in terms of stress?
 - Does the distribution of force have to be homogeneous (i.e. evenly spread across the section)? Or can there be parts of the section where there is no force and other parts where there is a force?
- Do we explain only what we consider the basics and leave out the more subtle aspects or alternative aspects?
 - What could subtle aspects of mechanical stress be? I cannot answer this since this is not my area of expertise.

This is where writing becomes a skill and an art: the ability to pitch a description at a level of simplicity or complexity without compromising scientific meaning.

5.3. Example 3: Mechanics

Consider the text “If a force $F(t)$ acts on a viscously damped spring-mass system [...], the equation of motion can be obtained using Newton’s second law [...].” What happens if we omit one of more terms of this text?

- Consider omitting the term “viscously damped”: Since viscous damping refers to effects of friction, omitting “viscously damped” suggests that we are referring to a spring-mass system which is frictionless. This would be a serious scientific error if the system we are studying happens to undergo friction.

- Consider omitting the term “system”: In this case we are referring only to one single spring-mass, and not a system of these. If, for example, you are studying the vibration characteristics of a car then you are making a serious scientific error in not considering the car as multiple spring-masses, i.e. as a spring-mass system.
- Consider omitting the terms “using Newton’s second law”: In this case we are not specifying how the equations of motion can be obtained. In fact, there is at least one other way of obtaining equations of motion, this being using Lagrangian mechanics (i.e. using something called the *Lagrangian*) which is a method based on the energy of the system. Newton equations of motion are not based on the energy of the system but on the forces acting on the system. This is something very different to Lagrangian mechanics. So there could be a confusion as to which approach is being used here.

Again, we can ask how much detail should we go into in order to get across the essential scientific meaning of the text:

- Do we explain everything the text describes?
 - i.e. the use of force? The meaning of spring-mass and a spring-mass system? The fact that spring-masses are idealised representation of the object under study? do we explain what viscous means? What damping means? Do we present the equation for Newton’s second law?
- How much detail do we go into?
 - Do we elaborate on damping by explaining over-damped, critically damped or underdamped systems?
 - Does we elaborate on the nature of viscosity?
 - Do we give an example of deriving the equations of motion using Newton’s laws?
- Do we explain only what we consider the basics and leave out the more subtle aspects or alternative aspects?
 - Do we ignore viscosity and/or damping?
 - What subtle effects are there to viscously damped systems? I cannot answer this since this is not my area of expertise.

This is where writing becomes a skill and an art: the ability to pitch a description at a level of simplicity or complexity without compromising scientific meaning.

5.4. Example 4: Advanced Mathematics (optional. For mathematicians only?)

Consider the text “Each non-empty set of real numbers that is bounded above and has a supremum”. What happens if we omit one or more terms of this text?

- Consider omitting the terms “real numbers”: Sets are collections of objects. Numbers are just one type of object which we group together in sets. But we could group together other things. And even with numbers we can ask, what type of numbers are you grouping? Whole numbers? Positive integers? Rational numbers? Etc. If we don't specify which type of objects we want to study we don't know how to manipulate them, operate on them or otherwise analyse them.
- Consider omitting the term “above”: This is just a standard English word but its use is crucially important because we can also talk of numbers bounded below. And when we omit the word “above” or “below” and just say “bounded” we mean that the object is bounded both above and below. Also, for the word “supremum” to make sense we have to use the word “above” otherwise there would be a significant error in accuracy of description.
- Consider omitting the term “supremum”: This word is also crucially important. Mathematically speaking, without a supremum there is no such thing as a real number! There would only be upper bounds (any upper bound we care to choose), not the least or smallest upper bound.

Again, we can ask how much detail should we go into in order to get across the essential scientific meaning of the text:

- Do we explain everything the text describes?
 - i.e. all the individual mathematical terms, and the phrasing of these terms?
- How much detail do we go into?
 - Do we develop the idea of sequences of numbers (this being relevant to the idea of boundedness)?
 - Do we go into the idea of convergence and limits (this being relevant to the definition of real numbers)?
- Do we explain only what we consider the basics and leave out the more subtle aspects or alternative aspects?
 - Do we ignore the idea of sets (it is possible to talk about real numbers without referring to sets).

- Do we discuss the subtle difference between upper bounds and least upper bounds? It looks like we have to since “supremum” means the same thing as “least upper bound” and without a supremum there is no real number.
- Do we talk about Dedekind cuts (which is a different definition of real numbers)?

This is where writing becomes a skill and an art: the ability to pitch a description at a level of simplicity or complexity without compromising scientific meaning.

6. A definition

Based on everything done above I might define paragraph building as

**the coherent development of an idea, using cohesive language and linguistic features
(such as continuation, transitioning, signposting, referencing, etc.)
where the paragraph has a specific focus and a sufficient degree of detail.**

7. Appendix: Full texts for section 4 examples

Example 1

“While physical understanding is inherently based on empirical evidence, numerical simulation tools have become an integral part of the majority of fields within physics. When tested against observations, numerical models can strengthen or invalidate existing theories and quantify the degree to which the theories have to be improved. Simulation results can also complement observations by giving them a larger context. In space physics, spacecraft measurements concern only one point at one time in the vast volume of space, indicating that discerning spatial phenomena from temporal changes is difficult. This is a shortcoming that has also led to the use of spacecraft constellations, like the European Space Agency’s Cluster mission (Escoubet et al. 2001). However, simulations are considerably more cost-effective compared to spacecraft, and they can be adopted to address physical systems that cannot be reached by in situ experiments, like the distant galaxies. Finally, and most importantly, predictions of physical environments under varying conditions are always based on modelling. Predicting the near-Earth environment in particular has become increasingly important, not only because the near-Earth space hosts expensive assets used to monitor our planet.”

Example 2

“The present state of our knowledge of fossil organisms seems to be a bewildering mixture of well established facts, stubbornly perpetuated errors, and naive notions. Only comparatively few observations and conclusions survived the test of time, and some established sequences of fossils, or some orderly temporal changes in them, have been proved reasonably constant, though usually within more or less limited provinces, while constancy of other observed changes merely is taken for granted, and as yet our science does not seem to recognize the necessity of repeated verification of fundamental observations.”

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