

Writing

If you have learned the basics of journalistic writing, you already have a pretty good idea of what to keep in mind when writing about science. Journalistic writing should be clear, concise and informative. Same for science writing.

But that doesn't mean that science journalism is just as simple as, say, writing about fires or floods. Writing about science poses some particularly tough problems. Being clear, concise and informative about scientific subjects requires more skill and harder work than writing about more familiar topics.

Sadly, there is no magic formula for writing clearly about scientific subjects, no sure-fire short-cuts to getting the message across. But there is one fundamental principle to keep in mind: Use Plain English. When you're communicating about science to a general audience, you need to use the language your readers already possess, *not* the language used by scientists.

Turning science into Plain English can be pretty challenging, but not impossible. It helps to keep a few important principle to keep in mind. I have often given talks about this, and when I do I like to start out with a "Top 10 List" of rules for clarifying complexity. I hate to call them "rules" because I don't like rules, and some people think rules should never be broken. (Hah!) So let's call them guidelines, or perhaps tips. Observing them most of the time will be helpful when communicating complex subject matter.

Here they are:

10. Value Clarity

9. Use short words

8. Stay low on the ladder (of abstraction)

7. Use familiar words (avoid jargon)

6. Describe rather than define

5. Relate the unfamiliar to the familiar

4. Use short sentences

3. Evoke images (turn ideas into actions)

2. Watch your grammar

1 . Know your subject

If you like, you can sum all these rules up concisely with one rather short sentence: Use simple, clear, familiar language that evokes images. Or just “Use Plain English!” Most of the tips in my Top 10 list are really just strategies for achieving that Plain English goal.

Many of those strategies, you should notice, focus on the notion of brevity. Brevity, both of sentences and of words, is at the root of mathematical measures of readability, once popular ways of testing how easy (or hard) something was to read. It is certainly true that, on average, shorter sentences and words correlate with easier reading. It is not enough, though, just to write short sentences containing short words. Formulas emphasize brevity not only because short words and sentences are inherently easier to read, but also because brevity correlates with other important things, such as familiarity and low levels of abstraction. Understanding the reasons why brevity enhances clarity is essential for making sound judgments when writing about science, and that’s what my Top 10 tips are all about.

10. Value Clarity

The importance of valuing clarity should be so obvious that it doesn't really need to be on the list. Or so I would have thought. But a lot of writers don't value clarity as much as they value showing off their flair for flowery prose. Consider this passage from a science writer at a major Eastern newspaper:

In the physics of human emotions, love may be thought of as the strong force, binding together friends, family and couples with the tight, private energy of an atom's core. But the emotion most akin to gravity, the sensation that keeps the affairs of humanity on track as surely as the Earth wheels around the Sun, is empathy: the power to recognize the plight of another and to take on that burden as though it were built to order.

After the fists of hell had punched a hole through the center of Oklahoma City, the city recovered its wits with a thousand acts of empathy and compassion. Empathy allows one to sit in a movie theater and blubber over a death that never happened to a character who never lived; it keeps charities breathing...; and it is the reason why, if you stand in the middle of a sidewalk with a map in hand, looking bewildered, someone is bound to ask you if you are lost. . . .

Some people think this is wonderful writing. I read it and want to be sick. I would be willing to agree that writing of this nature might be fine in, say, a novel. But read through it and try to find any information. There isn't much. Journalistic writing, especially science-journalistic writing, is supposed to communicate information, concisely. That means there should be a high ratio of information to words. The above passage flunks that test.

I prefer the attitude toward science writing expressed by Isaac Asimov, who was certainly one of the 20th century's most successful explainers of science. Asimov was not concerned with literary pretension. Or literary critics.

"I made up my mind long ago to follow one cardinal rule in all my writing — to be clear," he wrote in introductory comments to *Nemesis*, one of his last science

fiction novels. “I have given up all thought of writing poetically or symbolically or experimentally, or in any of the other modes that might (if I were good enough) get me a Pulitzer prize. I would write merely clearly and in this way establish a warm relationship between myself and my readers, and the professional critics — well, they can do whatever they wish.”

He adopted this attitude following an exchange with an editor commenting on the draft of an early novel, in which the young Asimov worked hard to make his writing as flowery and literary as possible. (He thought that sort of thing would establish his reputation as a good writer.) One day the editor asked him, “Do you know how Hemingway says ‘the sun rose the next morning’?”

“No,” said Asimov. “How does he say it?”

“He says ‘the sun rose the next morning.’”

Asimov learned the lesson and learned to write to be clear. He used Plain English.

9. Use short words

One of the defining features of Plain English is its relative lack of long words. Fortunately, for most long words in the English language there is a shorter word that means roughly the same thing. Here’s a chart with some examples:

12 *Presenting Science to the Public: General Principles*

TABLE 3. *Examples of using shorter, more common words*

Long word	Short word(s)	Long word	Short word(s)
approximately	about	necessary	needed
attempt	try	numerous	many
complicated	complex	opportunity	chance
concerning	about	optimal	best
consequently	thus	perform	do
construct	build	possess	have; own
currently	now	previously	before
demonstrate	show	primarily	mainly
elucidate	explain	principally	mainly
essential	needed	provide	give
fabricate	make	subsequently	later
fundamental	basic	sufficient	enough
illustrate	show	superior	better
indicate	show	technique	method; way
initial	first	terminate	end
initiate	begin	uncommon	rare
instrument	tool	unnecessary	needless
manually	by hand	utilize	use
modify	change	verify	prove
multiple	many		

From Barbara Gastel, *Presenting Science to the Public*

Keep in mind that some of these replacement words will work only in certain contexts and not others. And sometimes the longer word conveys a shade of meaning that the shorter word doesn't. If that's important, go ahead and use the long word — in any isolated instance. An occasional long word is not a disaster. But a steady polysyllabic diet will send your readers elsewhere.

You are not insulting the reader by using short words — you are making his or her life easier. Shorter words are inherently easier to read; they require less mental effort. But there's more to it than that. Short words tend to be familiar words; they tend to be specific and concrete, not abstract, and therefore are more likely to communicate successfully.

8. Stay Low on the Ladder (of abstraction)

Communicating clearly requires specificity, and short words are usually specific words. Longer words are typically vague and abstract, and abstract words are often ambiguous, forcing a reader to figure out just what the intended meaning is.

The problem of abstraction in communicating was dealt with extensively by S.I. Hayakawa in his famous book on semantics, *Language in Thought and Action*. Hayakawa used the illustration of what he called a "ladder of abstraction." Ordinarily, words lower on the ladder of abstraction are better for communicating than words high on the ladder.

Hayakawa illustrated the idea by talking about Bessie the Cow. "Bessie," the name of the specific cow, is on the bottom rung of the abstraction ladder. Plain old "cow" is pretty concrete, but one level more abstract than Bessie. As you climb the ladder, you can refer to Bessie as "livestock," "farm asset," "asset," or simply "wealth." All those words refer to Bessie, but if you just said wealth, your reader would really not have any idea what you were talking about.

Here's another example (not from Hayakawa, but from a scientific journal):

Collectively, these *rodent, primate* and *human* findings suggest that instances of prolonged glucocorticoid exposure should be associated with *cognitive impairments*.

Many long words, not very familiar to most people, and some that are familiar aren't very specific. You could write instead:

These studies on *rats, monkeys* and *people* suggest that long-term steroid exposure should be linked to *memory loss*.

Note that sometimes it is necessary to choose between a familiar word and more concrete word. "Glucocorticoid" is a more specific (and hence, lower on the ladder of abstraction) word than "steroid." But steroid is by far the more familiar word, and easier to read. If, in the context of the story, the distinction is important, it would be a good idea to add an additional sentence explaining that difference. But keep in mind that concrete, specific words are good because they evoke images and reduce ambiguity. When the concrete word is not familiar enough to achieve these benefits, then it is usually better to use a less concrete but more familiar term. "Neurotransmitter" is more concrete and specific than "brain chemical," but in many contexts, reading will be easier and the message will be clearer by moving up the ladder a little.

The results can be influenced by the presence of neurotransmitters such as serotonin, dopamine and norepinephrine.

Various brain chemicals can influence the results.

7. Use familiar words (avoid jargon)

Short words tend to be familiar words. Familiar words communicate more effectively than unfamiliar words. When explaining complicated subjects, it is always unwise to try to teach the reader a new vocabulary. (Remember, your job is informing, not educating!) And you need to inform the readers using the vocabulary they already have. Don't expect to keep readers on board with words they never heard of before they read your story.

In other words, eliminate jargon! Specialists in most fields communicate with a common set of words and

phrases that leave outsiders clueless. Your job as a science writer is to turn the jargon of a specialty into the vernacular of your audience.

For example:

Engineer on solar power:

"All solar thermal systems suffer from diurnal transients and rapid transients because of cloud passage during daily operation.

Translation:

Solar power plants have to be turned off and on a lot because it gets dark at night and clouds block the sun sometimes.

But beware. Replacing a precise technical term with a common word can sometimes render a sentence senseless.

Force is equal to mass times acceleration

IS NOT THE SAME AS

Force is equal to stuff times increasing speed.

Acceleration of particles in a ring gives off radiation

IS NOT THE SAME AS

Increasing speed of particles in ring gives off radiation.

You have to know your subject.

6. Relate the unfamiliar to the familiar

Sometimes novice writers object to the idea of using only familiar words. And scientists-turned-science-writers often will point out that they are trying to inform their readers about unfamiliar things, so unfamiliar words are necessary.

Well, maybe in some cases. When you can't avoid all the unfamiliar words, here's the rule: Restrict yourself to one technical term, the technical term that is most central to the topic you're writing about. You can't very well write an article about how chlorofluorocarbons destroy the ozone layer without using the term chlorofluorocarbons. But don't lapse into talking about photodissociative catalytic cycles. Don't write to educate!

Now, by prohibiting more than one technical term, I don't mean that no other technical words can appear in the story. Other technical terms can be mentioned when necessary. But they should not become your tools for telling the story.

In writing about the embryonic development of the brain, for example, you might want to describe what a growth cone is and then use that term as you outline what happens in the developing brain. You might mention other important words, too — just not too many of them, and not repeatedly.

As the growth cone embarks on its journey, tiny feelers on its surface called filopodia sense the area for clues on how to proceed.

It's perfectly OK to use filopodia here, but subsequently you should just refer to them as the "feelers" if you need to refer to them again at all.

Of course, just because you shouldn't write to educate, that doesn't mean you can't make use of some tricks of educators. A study I noticed several years ago from science education researchers suggested that people subjected to a scientific lecture found it hard to follow because they had no frame of reference, no previous knowledge to use to give order to the new information. Good science writing provides such a frame of reference. I think it's fair to say that the key to communicating about science is to inform the readers about things they don't know by relating the new information to things they do know. If you can explain some complex theory by relating it to a house or a car or baseball or food or the weather, do it. Suppose you're writing about the early universe, explaining how some original primordial fundamental force differentiated into the common forces known today, such as gravity and electromagnetism, as the universe expanded and cooled. You can relate that process to something as familiar as the way water and then ice forms from steam as steam cools.

Most physicists hold the view that nobody can say what a subatomic particle is doing unless somebody is looking at it. Furthermore, the particle may at times behave like a wave, depending on the type of observation made. And light, ordinarily thought of as a wave, can appear to be made of particles if viewed in a certain way.

Resolving this dilemma is not as simple as explaining why water is sometimes found in the form of waves and at other times is packaged as ice cubes. It is as if anytime you poured from a pitcher, liquid water flowed smoothly into the cup. But if you then stuck your hand into the same pitcher, you would find only ice cubes — no liquid.

5. Describe, rather than define

There's an implication to what I've been saying that I probably should elaborate on a little because it contradicts a common belief, especially among inexperienced writers, that the key to science writing is carefully defining your terms so the reader will know what you're talking about. Thus many beginning science writers try to write articles like textbooks — defining all technical terms before going on to tell the story, freely using those technical words as if they had become old friends.

I would like to emphasize that this is a very bad idea. One, because you shouldn't be using words that need defining. Two, definitions are boring. Three: You're not trying to prepare the reader to pass a vocabulary test. And you don't want a science story to read like an encyclopedia article or a textbook.

What about that one technical term that I said it's OK to use? The secret here is not to define, but to describe. If you look up catalytic converter in the dictionary, you'll find something like "a device for reducing pollutant emissions from automobile exhaust systems." I think in a newspaper story you're much better off saying it's "a small stainless steel box filled with tiny metallic beads that clean up car exhaust." You can then go on to provide clarifying details, because there's a chance the reader will still be reading.

In some cases, the description can be short and simple:

Lithium

Definition: A metallic chemical element of the alkali group, atomic number 3 and atomic weight 6.941.

Description: Lithium: A light, silvery-white metal soft enough to be cut with a table knife.

Sometimes the description might take up a little more space. And you can often choose from various possible approaches, as with these examples about how to describe fractals:

Fractal

Definition:

A geometrical or physical structure having an irregular or fragmented shape at all scales of measurement between a greatest and smallest scale such that certain mathematical or physical properties of the structure, as the perimeter of a curve or the flow rate in a porous medium, behave as if the dimensions of the structure (fractal dimensions) are greater than the spatial dimensions.

—Random House Unabridged Dictionary, Second Edition

Descriptions:

Fractals are those repetitive shapes that look the same whether shrunk or magnified. Nature is full of such irregular patterns. A small piece of a coastline, greatly enlarged, looks just like a big coastline, for example. Fractals are like Rorschach tests designed for mathematicians, who can see simple mathematical patterns hidden in the complex squiggles and swirls.

OR

... the mathematical curiosities known as fractals.

Fractals are famous in the math world for their ability to represent a large structure with a tiny piece of the whole. The standard example is a coastline. Take a small piece of a coastline and then enlarge it dramatically, and it looks like a whole coastline. Basically, a fractal is something that looks the same no matter what scale you view it on.

A common way of expressing this is to say that the coastline is similar to itself, or “self-similar.”

OR

Fractals are patterns. They are patterns that repeat themselves, so as to appear similar whether viewed close up or from far away. Some wallpaper has this property, as do the tile patterns in the floors of certain ancient cathedrals. Coastlines are commonly cited as the typical example of a fractal.

4. Use Short Sentences

Explaining complicated stuff requires distilling the essence out of every sentence and then re-presenting it to the reader in chewable bites — that is, short sentences. If you understand the subject thoroughly enough, you should be

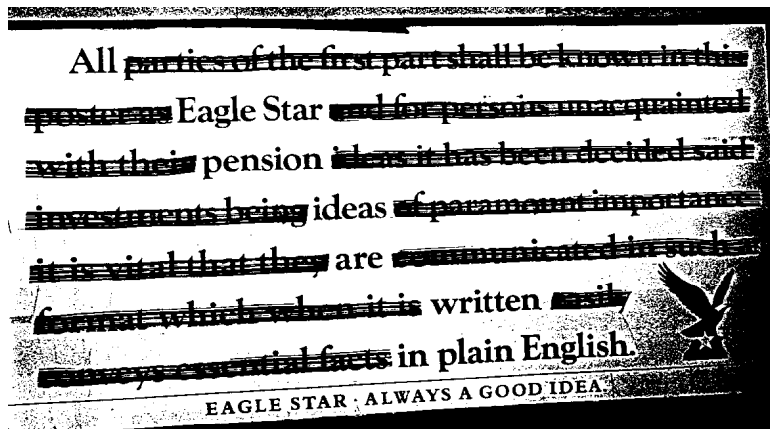
able to take the raw material straight from the specialist's word processor and translate it into the plain English needed to communicate.

We've already talked about the first step — replacing jargon with short, concrete, familiar words. Often, though, that's not enough. The sentences also need to be short and simple.

Achieving short sentences involves obvious things like using subject-verb-object constructions without a lot of modifying clauses and prepositional phrases. But there are some other specific points to keep in mind that will help as well.

Remove unnecessary words

Remember, you want to distill the essence out of each sentence. For starters, that means getting rid of unneeded words that clutter the core meaning. This billboard at a London subway station gets the idea across pretty well.



You can do much the same thing with complicated sentences composed by specialists.

“The induction of eukaryotic heat shock genes in response to a temperature upshift is mediated by the binding of a transcriptional activator, heat shock factor, to a short highly conserved DNA sequence known as the heat shock element.”

The induction of heat shock genes is mediated by binding of an activator to DNA.

Of course, it isn't always immediately obvious how you can go from the long convoluted sentence to the shorter, clearer one. Sometimes it takes a lot of work. It helps, I think,

if you try to do it one step at a time. Here's a passage from a journal article that starts out long and unwieldy. Watch how the core point gradually emerges in the course of some careful pruning.

Under conditions of prolonged stress, these same adrenal steroids, acting in concert with excitatory amino acid neurotransmitters, can, depending on the extent and level of exposure, cause either reversible dendritic alterations or permanent neuronal loss, particularly in the aging brain.

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Under conditions of prolonged stress, these ~~same adrenal~~ steroids, ~~acting in concert with excitatory amino acid neurotransmitters~~, can, ~~depending on the extent and level of exposure~~, cause either reversible dendritic alterations or permanent neuronal loss, ~~particularly in the aging brain~~.

Under conditions of prolonged stress, these steroids can cause either reversible dendritic alterations or permanent neuronal loss.

Under conditions of prolonged stress, these steroids can alter or kill nerve cells.

~~Under conditions of prolonged stress, these steroids~~ can alter or kill nerve cells.

Prolonged stress can alter or kill nerve cells.

= = = = = = = =

One idea to a sentence

Now you might complain that the nice short sentence left over from the pruning does not really contain all the information in the original. So you have to ask yourself, is the lost information really important. Depending on the context and the purpose of the story, the missing information may not be really necessary. But in case it is, that doesn't mean you should make the sentence longer again. The main reason that short sentences are a good idea is that a short sentence is unlikely to contain more than one idea. When presenting unfamiliar ideas, it is essential to present them one at a time, and keeping your sentences short helps make sure you do that. And if that means the sentence you are left with leaves out some important ideas from the original sentence, the solution is simple: write more sentences.

Prolonged stress can alter or kill nerve cells. Certain steroids conspire with other brain chemicals to do this damage. The extent of the damage depends on the amount of steroid exposure. The problem is particularly bad in old brains.

Or this long sentence:

“The induction of eukaryotic heat shock genes in response to a temperature upshift is mediated by the binding of a transcriptional activator, heat shock factor, to a short highly conserved DNA sequence known as the heat shock element.”

could be rewritten this way:

An activator turns on heat shock genes by binding to DNA. The activator is called heat shock factor. It attaches to a short segment of the DNA molecule called the heat shock element.

3. Evoke images (turn ideas into actions)

Brevity is not the only thing to value in sentences. Active, positive constructions are also easier to read, because they help evoke images. And often turning abstract ideas into actions shorten the sentence as a beneficial side effect. Instead of discussing “the acceptance of,” just say “accepting.” Rather than say the results “are illustrative of,” say the results “show.”

The induction of heat shock genes is mediated by binding of an activator to DNA.

An activator turns on heat shock genes by binding to DNA.

Sometimes sentences are perfectly clear and short, but lifeless. In situations like this, making the sentence longer may be advisable.

If the radio waves are properly tuned, the charged particles can gain energy from the moving radio waves, just as a surfboard gains energy from a water wave.

... capturing the rapidly moving antiprotons from the cloud of debris emanating from the tungsten target would be as impossible as trying to catch the queen bee in the swarm of bees emanating from a kicked-over hive.

Science claims to understand a lot, but in fact, the depth of scientific understanding of the universe is limited. Here and there, scientists have been able to glimpse portions of a fundamental reality.

Science claims to understand a lot, but in fact, the depth of scientific understanding of the universe amounts to little more than a thin layer of ice covering an ocean of which we are ignorant.

Here and there, scientists have been able to punch a few holes in the ice, making it possible to glimpse portions of a fundamental reality.

Notice that these sentence are perfectly clear and understandable without the illustrative additions. But the additional phrase calls forth images — creates pictures in readers' minds. It makes reading more like watching TV — faster and easier.

2. Watch your Grammar

Grammar is supposed to be a friend of understanding, but too often it turns into an enemy because too many editors think rules of grammar are laws of physics. Whereas in fact, it is in perfect accord with the historical foundations of grammar to insist that grammar rules should always be subordinate to clear communication.

In fact, teaching grammar in school often has the effect of misleading good students into thinking that a grammatically correct sentence is a good sentence. Scientists in particular are often sticklers about grammar. But it is essential for a science writer to recognize that a sentence can be perfectly correct, grammatically, and still be a sorry excuse for a sentence.

Nevertheless, there are a few grammar “rules” worth observing. At least, observing them helps improve the prospects for clear communication. (These are not necessarily grammar book rules, but are my personal rules. They may or may not be endorsed by grammarians, but I don't care.)

Don't use a pronoun unless it refers to the nearest noun of same number. (Weak pronoun principle)

Don't use a pronoun unless preceding sentence has only one possible referent. (Strong pronoun principle)

“Which” should always refer only to the immediately preceding word.

Never use “this” at the beginning of a sentence without a noun immediately following.

Don't be afraid to repeat a word.

Is it really necessary to observe all of these rules rigorously for the rest of your life? NO. If you know what you're doing, you can break them whenever you like. But it's usually not a wise thing to do. Following these rules will force you to make your sentences more immediately comprehensible. You can always argue that a reader will be able to figure out what the referent is supposed to be for a vague pronoun. But your job is to do that sort of work for the reader — not to make the reader figure things out.

1. Know Your Subject

Rule Number One does not at first glance seem to be about writing. Nevertheless it is probably the most important rule of all for a science journalist. No amount of writing skill or tricks for simplification will succeed unless you know what you're talking (or writing) about. You have to know the background to the story, the history, the scientific principles involved and the scientific questions being investigated. If you don't know these things, you need to find them out.

The old worry that you can know too much about a subject to communicate it clearly is nonsense. True, you have to guard against forgetting how much your audience does NOT know once you've learned a lot about a subject. But the only way you will be able to communicate complex subject matter clearly is to understand it first yourself.