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LINGUISTICS

Defining Definitions: The Importance of Chain Definitions in Online Popular Science Articles

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This article discusses the different types of definitions and how writers use them in online popular science articles. The work breaks definitions down into six different types: prototypical, procedural, delayed, zero, figurative, and chain. Looking at different types of definitions, this article focuses the importance of definitions. It also discusses why specific definitions found in popular science articles are categorized under the different definition types. It undertakes an in-depth analysis of 74 definitions and explains why they belong in the category they were given. As a result, the article highlights the importance of chain definitions— combinations of multiple definitions working together to provide an explanation of a term or concept. Overall, each type of definition is unique and helpful in the process of popularizing science. They give the author freedom to create connections between the scientists and the readers. These connections, in turn, allow for greater understanding between the two. The current project examined 10 articles (roughly 10,600 words analyzed) and 74 definitions.

Introduction

This project examines online popular science articles and how the use of definitions allows the reader to gain a greater understanding of the topic being discussed. While reading *The Language of Popular Science* by Dr. Pilkington (2019), I became curious as to whether the definitions she found in popular science books would remain true in popular science articles online. As such, this is a confirmation study, and the types of definitions discussed will be the types she coined in her book: prototypical, procedural, delayed, zero, figurative, and chain.

While almost all types of definitions were found within the online popular science articles, this article will focus on how chain definitions are used to provide greater understanding to the reader. Before we can focus on that, though, we must explain the different types of definitions.

When you think of a definition, the first thought that comes to mind is what is called a prototypical definition. This type of definition is when "a definition references the *what-it-is-to-be* that kind of thing – its principal features or structure – in order to delimit it from other kinds and to make possible a systematic study of it and its connections" (Hibberd, 2019, p. 31). For example,

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"black phosphorus is composed of many layered sheets of an atom-thick material called phosphorene" (Timmer, 2020, para 3). Basically, it is a standard dictionary definition. This definition narrows down the object to the "essential or defining features ... without which that kind could not be the kind it is, i.e., the kind has them necessarily" (Hibberd, 2019, p. 32). Generally, it is the simplest form of a definition, but depending on the object, it can become complex.

Then we have a procedural definition. This definition explains what an object does (Pilkington, 2019, p. 125). In the article "What is Scientific Definition?" Fiona Hibberd claims this is not a proper definition but that "there is nothing wrong with a functional definition as long as what the kind *does* is not muddled with what the kind *is*" (Hibberd, 2019, p. 36). Therefore, a procedural definition might only have merit if it does not subtract from the original prototypical definition. However, this idea could be true of basically any definition that is not prototypical and does not mean that the other types of definitions are useless. Instead, it signifies the importance of having many ways to explain a concept of an idea so that a broader audience can understand the term being defined. Here is an example of a procedural definition: "the inhibitory neurons block out background noise and allow long term learning to take place" (McGill University, 2020, para 1). It is telling the reader what the inhibitory neurons do, mainly "blocking out background noise and allowing long term learning to take place" (McGill University, 2020, para 1). What the inhibitory neurons do is different than what they are. Meaning this definition does not follow the pattern of A=B and cannot fall under the category of a prototypical definition.

Two other types of definitions that do not fall into the prototypical definition category are delayed and zero definitions. Delayed and zero definitions are similar to each other. A delayed definition is when the author introduces a term but informs the reader that the term will be discussed later (Pilkington, 2019, p. 128). A zero definition is when there "is an acknowledgment of the lack of endorsement by the scientific community or, in some cases, the lack of scientific knowledge on the subject" (Pilkington, 2019, p. 129). Because science is a discipline of discovery, when a new discovery is made, it takes time to verify. This means that "within the scientific community, efforts to formulate unequivocal definitions are challenging and often controversial" (Piciocchi & Martinelli, 2016, para 4). It is not a simple matter of one scientist discovering something new and getting to define it.

When dealing with a new discovery, scientists often rely on a figurative definition as a starting point. "A figurative definition is a definition that relies on analogies, metaphors, and other expressive means..." (Pilkington, 2019, p. 131). Without the ability to compare to other already known objects, scientists would struggle to explain any new phenomenon. Indeed, "many new terms come into being as metaphors..." (Tanghe et al., 2016, p. 609). This means that

the starting point of a definition is often not creating a prototypical definition. Instead, it is creating a metaphor so the idea can be understood and then refined:

> The essence of a live metaphor is precisely the juxtaposition of similarity and difference, the manifest untruth of equating source and target. And what gives it its value in the logic of scientific discovery is precisely the instability it generates by virtue of its insistence on both similarity *and* difference, its insistence that, at one and the same time, man both *is* and *is not* a wolf. Lose this duality, and one loses the vitality of the metaphor. (Keller, 2020, p. 250)

A figurative definition allows for more flexibility in understanding and can provide easier understanding for those who do not intensely study the topic being discussed. Definitions give the reader a look behind the curtain to understanding what scientists are discovering. Consider, for example, the following: "cadavers decay, like how the microbiomes inside us go haywire after death" (Simon, 2020, para 1). This figurative definition paints a picture in the reader's mind and allows for a greater understanding of the topic.

Each of these types of definitions can provide new insight into the same term. When prototypical, procedural and figurative definitions are used together, they create a chain or string definition (Pilkington, 2019, p. 123). This study did not find any full chain definitions. However, there were many examples of mini-chain definitions, which only combine prototypical and procedural definitions. An example is, "this process, called memory consolidation, requires the synthesis of new proteins in brain cells" (McGill University, 2020, para 3). The process is memory consolidation and what it does is it "requires the synthesis of new proteins in brain cells" (McGill University, 2020, para 3). By combining two or more of the previous types of definitions, the writer can reach multiple audiences within one piece of writing. This ability to create chain and mini-chain definitions is invaluable to popular science writers.

Methods

To find the popular science articles for this analysis, I turned to the search engine Google to identify popular science websites. I then examined Ars Technica, Atlas Obscura, Chemistry World, Smithsonian, and Science Daily. (For a full list see Appendix A.) From these websites, I randomly selected 10 articles covering the subjects of technology, astronomy, genetics, and marine biology. I then analyzed each article for the presence of the above-explained definition types.

For the course of this paper, I will be using the terms coined by Pilkington (2019) in her book *The Language of Popular Science*. These terms are prototypical, procedural, delayed, zero, figurative, and chain definitions (p.

Table 1: The Break Down of the Different Types of Definitions by Pilkington (2019)

Definition Type	Structure
Prototypical	Subject+hinge+descriptor (subject and descriptor interchangeable)
Procedural	Subject+hinge+descriptor (Subject and descriptor not interchangeable)
Delayed	Subject introduced with instructions on where to find descriptor elsewhere.
Zero	Subject not fulled defined by scientific community.
Figurative	Subject defined with use of metaphor or simile.
Chain	The use of prototypical, procedural, and figurative definitions in a row to define one subject.

Source: Pilkington, 2019.

123-133). Each of these terms relates to the form and meaning of the definition it introduces. The following structural requirements from Pilkington (2019) guided my parameters for labeling a text fragment a definition. See Table 1.

The subject refers to the term being defined. The hinge is a word(s) or typographical mark that connects the subject to the descriptor. The descriptor is the explanation of what the subject is or does.

With the previous types of definitions mentioned in mind, I calculated the total number of definitions found in the popular science articles I found online. The total number of definitions collected and analyzed for this study is 74. The total number of words examined is roughly 10,600. My goal was to determine if the terms Dr. Pilkington coined for definitions found in popular science books would transfer to popular science articles found online.

Results

Within the ten articles I reviewed in search of definitions, only one piece contained no definitions. Of the definitions found in the 10 articles, 11% combined to make chain definitions, all of which were mini-chain definitions, which I will discuss in greater detail later in this article. Of the articles reviewed, 90% had at least two definitions, and 70% of the articles contained four or more definitions. Of the 74 definitions I found, 54% were prototypical, 28% were procedural, 4% were delayed, 0% were zero, 3% were figurative. (See Appendix B for a full list.) The chart below (see Figure 1) breaks down the number of definitions in each article. Each article is labeled by color and last name of the author providing a breakdown of each article and the combined data.

The only article that did not have a definition in it was Durrani's article "How Does Hair Blunt Steel Blades?" It was by far the shortest article, consisting of only 199 words. It was also seemingly simpler than the other pieces. There was no need to define any words because the author did not use terms that the average science enthusiast would not understand.

Prototypical Definitions

The prototypical definition was overwhelmingly the most popular type of definition. Forty out of the 74 definitions found were prototypical. They were instrumental in their articles because they were able to define new terms quickly. For example, in Simon's (2020) article "Could a Tree Help Find a

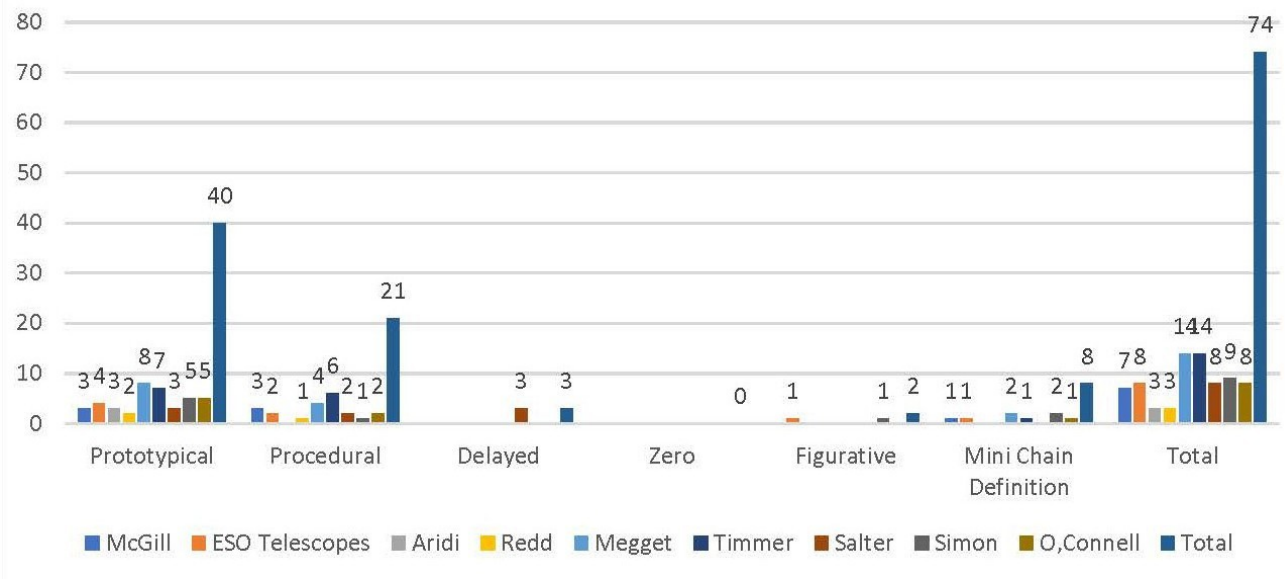

Figure 1: Definitions in Use

Decaying Corpse Nearby?" he states, "phenotype – its physical characteristics" to quickly provide the reader with a definition of phenotype without distracting from the overall story (para 2). It is easy to see why the prototypical definition is a favorite of popular science authors. This type of definition uses the subject, a hinge, and a descriptor, just as most do. In this example, the subject is "phenotype," the hinge is the emdash, and the descriptor is "its physical characteristics" (Simon, 2020, para 2). However, what makes this special is the hinge used creates an equal relationship between the subject and the descriptors. This means A=B. If A is your subject and B is your descriptor, the two are interchangeable.

A hinge can be as simple as a punctuation mark. McGill University (2020) provided a concise prototypical definition when they wrote: "short-term memories (which last just a few hours)" and "long-term memories (which may last years)" (para 3). With the parenthesis being used as the hinge, the reader finds a precise definition. Short-term memories equal just a few hours, and long-term memories equal years. Repeatedly different authors used similar hinges to create multiple prototypical definitions. Within the 40 prototypical definitions found, 23 used typographical marks as a hinge.

A hinge, however, does not have to be a typographic mark. In fact, it is most often a verb. For a prototypical definition, all the hinge needs to do is make sure the relationship between the subject and descriptor is A=B. For example, "Graphite is a form of carbon that's just a large collection of graphene sheets layered on top of each other" (Timmer, 2020, para 3). In this case, the verb "is" is being used as the hinge, the subject: "Graphite" and the descriptor: "a form of carbon that's just a large collection of graphene sheets layered on top of each other" (Timmer, 2020, para 3). Nine of the prototypical definitions used a "to be" verb as their hinge. Another example is, "graphene is essentially

flat" (Timmer, 2020, para 4). In this example the descriptor provides a qualifier. This definition is still prototypical because the author is still saying A=B, but they are amending that equation slightly to provide greater clarity.

While the hinge in a prototypical definition is often a "to be" verb or punctuation, that is not always the case. In the case of "the former [meaning communication] broadly refers to the transmission of information," the word "refers" is the hinge being used in this definition (O'Connell, 2020, para 8). The term "refers" still provides the implication of equality between the subject (communication) and the descriptors "the transmission of information" (O'Connell, 2020, para 8). When Simon (2020) wrote, "an amino acid like phenylalanine," he used the word "like" as the hinge in his definition, which once again, created the pattern of A=B (para 7). All 40 of the prototypical definitions found in the articles followed this pattern.

Procedural Definitions

The next most used were the procedural definitions. They were used 21 out of the 74 times a definition was present in an article. While it is a drastic drop between the prototypical definitions and the procedural definitions, the procedural definitions still outnumbered the other types of definitions combined. Delayed, zero, figurative, and chain definitions only made up 13 of the total 74 combined.

A procedural definition uses a verb as its hinge, just like prototypical definitions. However, instead of creating equality between the subject and the descriptors, a procedural definition describes what the subject does, not what it is. Consider an example:

> This technique [meaning gravitational microlensing] can reveal objects too dark to discover through other means, objects such as black holes or planets. When an object, like a planet, passes in front of a star, its gravity causes a very slight brightening to the stellar light. The faint magnification, predicted by the theory of general relativity, can provide insights into the passing magnifier. Unlike most other planetary discovery techniques, microlensing can find worlds cast off from their star, drifting through the darkness of space. (Redd, 2020, para 6)

This definition talks about what gravitational microlensing does. Verbs like "reveal," "causes," "magnification," and "find" all indicate what gravitational microlensing is doing, not what it is (Redd, 2020, para 6). Something that might cause confusion is when there is a "to be" verb present in a procedural definition, such as when McGill University (2020) introduces a definition for the excitatory neurons: "the excitatory neurons are involved in creating a memory trace" (para 1). While the verb "are" is present, it is not the hinge verb in this sentence. Instead, that function is performed by the verb "creating," which then indicates that the reader is finding out what excitatory neurons do, mainly "creating a memory trace" (McGill University, 2020, para 1).

While many definitions follow the pattern of the subject, then hinge, then descriptors, that is not the only way a definition can be structured. "ESO Telescopes" (2020) structures the following definition quite interestingly: "during this spaghettification process a bright flare of energy is released" (para3). This definition has the structure of the subject, then descriptors, and then hinge. The subject is the "spaghettification process." The descriptors are "a bright flare of energy," and the hinge is "released" (ESO, 2020, para 3). It is easy to see that this is a procedural definition by slightly rearranging the words. Instead of the original quote, the author could have written, "the spaghettification process releases a bright flare of energy." With this change, the definition is brought back into the familiar pattern of the subject, then hinge, and then descriptors. However, this pattern creates a slightly less exciting sentence because its form is more common. The ability of authors to move around the parts of a definition allow for more creativity and a more compelling reading experience for the audience.

Delayed Definitions

Delayed definitions introduce the term and then tell the reader where in the text they can find more information on that topic. In the articles analyzed, delayed definitions were presented slightly differently than what Pilkington (2019) observed in popular science books. Instead of directing the reader to another part of that article, the author embedded hyperlinks to take the reader to a new article altogether if they desired more information. This type of definition was found only in one article by Salter (2020). He put a hyperlink on the words "Wireguard," "Nebula," and "Revit," each one of which was a different type of computer product (Salter, 2020, para 24 and 27). They were used as potential examples of products businesses could use to help them better support their employees to work from home (Salter, 2020, para 24 and 27). Because these particular products were only there to support the original topic of the article, there was no reason for Slater to give a full definition. They were hence providing a delayed definition for the readers who wanted to know more.

Zero Definitions

A zero definition generally is when the scientific community as a whole agrees that they do not fully understand a phenomenon, such as dark matter. As such, there were no zero definitions found within the popular science articles reviewed for this paper.

Figurative Definitions

Figurative definitions were not frequent in the ten articles reviewed. Only 2 of the 74 definitions found were figurative definitions. The authors of these articles did not appear to need figurative language to get their point across to the reader. One of the figurative definitions found was a direct quote from the scientist being interviewed. "'The idea of a black hole 'sucking in' a nearby star sounds like science fiction. But this is exactly what happens in a tidal disruption event,' says Matt Nicholl" (ESO, 2020, para 2). This quote appears to be a figurative and procedural definition rolled up into one. Nicholl uses imagery to

help define a tidal disruption event as well as tying the event to a common genre of fiction with the use of a simile. This description allows the reader to picture what is happening during that event. However, with the very next sentence, Nicholl turns that figurative definition into a procedural definition by saying, "this is exactly what happens in a tidal disruption event" (ESO, 2020, para 2). No longer is it just "like" science fiction. The tidal disruption event happens the same way science fiction described it. This situation creates a definition that is not entirely figurative but is also not fully procedural in nature.

Chain Definitions

A chain definition is typically created of a prototypical, procedural, and figurative definition (Pilkington, 2019, p. 123). A chain can be as simple as a sentence or two with multiple definitions provided, or it can take up numerous paragraphs. Within the ten articles studied, there were no chains found with all three elements. There were, however, eight, what I shall call, mini-chains, which only provided a prototypical and a procedural definition. Six of those mini-chains were no more than a sentence or two. I observed the following mini-chain: "an amino acid like phenylalanine, which is released from a dead body" (Simon, 2020, para 7). Both a prototypical and procedural definition are present in this quote. "An amino acid like phenylalanine" is the prototypical definition because the author is stating that phenylalanine is an amino acid. The procedural definition is "which is released from a dead body" because the author is showing what phenylalanine does. Mainly it is "released from a dead body" (Simon, 2020, para 7). The same article has an even longer mini-chain:

> The chlorophyll in plant leaves fluoresces, reemitting light that special optics can pick up. This signature is invisible to the human eye but not to existing technologies. It's known as hyperspectral sensing. These devices can actually see across the electromagnetic spectrum, including visible and infrared light. (Simon, 2020, para 7)

This chain is interesting because it uses the same sentence as the subject for both the prototypical and procedural definitions. The sentence "it's known as hyperspectral sensing" provides a connection between the prototypical definition "the chlorophyll in plants leaves fluoresces" and the procedural definition "these devices can actually see across the electromagnetic spectrum, including visible and infrared light" (Simon, 2020, para 7). By connecting the describers in such a way Simon is reducing redundancy and allowing the reader to connect these definitions together in an interesting manner. It will enable them to see what hyperspectral sensing is while also indicating how the process is done through a machine.

While these smaller mini chains are fascinating, what stood out was how Megget (2016) used an incredibly long mini-chain. In her article, she dedicates an entire section called "What is Crispr" to define this technology. Using prototypical (bold) and procedural (italicized) definitions, she wrote:

> **scientists found DNA sequences that were repeated and interspersed with unique sequences, becoming known as Crispr**. Further research identified the unique sequences as viral DNA, which had come from phage viruses that infect bacteria. The bacteria were essentially keeping a record of viral infection, forming part of their nifty microbial immune system. The other part was located near to the **Crispr sequence; genes coding for enzymes known as Cas (Crispr-associated proteins)**, *which have DNA-cleaving ability*.
>
> *The viral DNA sequences are copied into an RNA strand and linked with a Cas enzyme. The resulting molecules float through a bacterial cell on the lookout for viral DNA that specifically matches their RNA strands. A match results in the RNA and viral DNA pairing, allowing the Cas enzyme to whir into action and snip the viral DNA up, stopping the viral infection in its tracks.*
>
> This bacterial satnav and scissor combo has been exploited to become a genome-editor extraordinaire, targeting specific genes in any organism with the ability to delete, repair or replace them. *All scientists need to do is synthesise a guide-RNA (gRNA) molecule of about 20 bases that matches the target gene sequence and link it to a Cas enzyme, of which there are many.* The Cas enzyme most commonly used is **Cas9 – from the bacteria that cause strep throat** – *because of its high efficiency and ability to create a double stranded DNA break*. This gives rise to the Crispr–Cas9 nomenclature, though this system is often just referred to as Crispr.
>
> *The gRNA–Cas9 complex then targets the specific gene to be edited through RNA–DNA base pairing and Cas9 makes the cut. One cut deactivates the gene. Two cuts, with two gRNAs, remove the gene.* If the gene was faulty, it can then be repaired by adding a normal copy of the gene to the cell, which pairs up with the cut DNA ends to form one DNA molecule again. New genes can also be inserted into the genome in this way. *Multiple gRNAs can also induce multiple cuts simultaneously, editing more than one gene at the same time*. (Megget, 2016, para 5-8)

Within the first paragraph, there are a few instances of a prototypical definition, such as "Crispr sequence; genes coding for enzymes known as Cas (Crispr-associated proteins)" (Megget, 2016, para 5). However, the rest of the paragraphs, as shown above, are basically one long extended procedural definition. Megget (2016) spends four paragraphs explaining just what Crispr does, and she goes into detail to give the most precise image possible. She uses words such as "cut," "copied," "cleaving," and "targets" to create a procedural definition that gives clear images to the reader (Megget, 2016, para 5-8). This

clarity allows them to picture what exactly Crispr is doing in their mind—providing the reader with a more significant in-depth learning experience.

Because of its length, one might wonder if this example is a chain definition and not a mini-chain. However, Megget (2016) does not use a figurative definition to help in the explanation, thereby leaving it squarely in the category of a mini-chain. While the use of such descriptive language such as "bacterial satnav and scissor combo" might lead one to argue that there is a figurative definition present, there is not (Megget, 2016, para 7). A figurative definition uses figurative language normally in the form of a simile or metaphor to help explain to a reader what the subject does. The verbs used in these passages literally describe what Crispr is doing. Figurative language is not involved.

Another lengthy mini-chain was found in the article written by Timmer (2020). He wrote a chain comprising of prototypical (bold) and procedural (italics) definitions which says:

> So, what is black phosphorus? The easiest way to understand it is by comparisons to **graphite, a material that's already in use as an electrode for lithium-ion batteries**. **Graphite is a form of carbon that's just a large collection of graphene sheets layered on top of each other. Graphene, in turn, is a sheet formed by an enormous molecule composed of carbon atoms bonded to each other, with the carbons arranged in a hexagonal pattern.** In the same way, **black phosphorus is composed of many layered sheets of an atom-thick material called phosphorene.**
>
> But there are key differences between the materials. To begin with, **phosphorus is a larger atom with more electrons than carbon**, and so *it can interact with more lithium atoms, an essential feature for battery electrodes*. The other key difference is that the bonds formed by carbon atoms ensure that **graphene is essentially flat**, no thicker than the atoms of carbon it's formed from. The **phosphorene sheets, as you can see above, are most clearly not flat**. Neighboring atoms are bound at angles that give the sheet a series of ridges or channels.
>
> It's that feature that drew the researchers' interest, since those angles form an avenue to get lithium ions into and out of the material quickly. And, because *each phosphorus atom can interact with multiple lithium ions*, we only know of two materials with higher theoretical electrode capacities—one of them being lithium metal itself. Finally, *black phosphorus conducts electricity well*, an important feature for a battery electrode.

> So, why isn't everyone already using black phosphorus? Well, mostly because it doesn't work. Like other electrode materials, the *black phosphorus expands as lithium ions get packed in, increasing the risk of a structural failure during charge/discharge cycles. And at the edges of sheets, chemical bonds can form between the different layers, sealing off some of the channels.* To get it to work as a battery material, these issues need to be fixed. (Timmer, 2020, para 3-6)

This example has the mini-chain in the form of prototypical and procedural definitions. However, unlike the example above, this chain has utilized prototypical definitions to a greater magnitude. The Megget (2016) chain has more procedural definitions present, while the Timmer (2020) chain has about equal prototypical and procedural definitions. Even with these differences, they both create mini chains due to their inclusion of both the prototypical and procedural definition and their lack of figurative definitions. With a greater understanding of the different types of definitions, one can see how each type could be useful.

Discussion

By learning these specific types of definitions, popular science writers can create a greater connection between scientists and the general population. It is not enough to only have procedural definitions at their disposal. While prototypical definitions are found most often, as seen by how 54% of all the definitions in this study were prototypical, it alone cannot fully explain complex scientific discoveries. If the mini-chain above regarding Crispr (Megget, 2016, para 5-8) had stopped with only the prototypical definition, readers would be left with no greater understanding of the process than before reading the article. Just reading, "scientists found DNA sequences that were repeated and interspersed with unique sequences, becoming known as Crispr" does not help the average reader at all (Megget, 2016, para 5). By adding as much detail as possible with procedural definitions, Megget can take a complicated process and make it understandable for the masses. This example also shows the incredible value of chain definitions or, in this case, a mini-chain definition. Without the ability to combine multiple types of definitions, the author would have difficulty expressing their ideas, and the reader would struggle to comprehend the article. However, with this ability, Megget is able to provide different types of definitions interwoven together that create greater comprehension for the reader.

Each instance of a chain definition provides the reader greater insight into the topic being discussed. A chain definition also allows the author to discuss simultaneously what the subject is and what the subject does with the added benefit of a metaphor for the more visual learner. A mini-chain definition, in contrast, only provides what the subject is and what the subject does. However, those two aspects discussed are invaluable to the reader because they provide substance and context together.

Each type of definition brings its personal flavor to a piece of popular science. These types of definitions give the writer space to be creative and to connect to different readers. Some readers may find prototypical definitions most helpful. Others may enjoy a procedural definition more. Most people are probably thankful for delayed definitions, especially in the form of hyperlinks. Those hyperlinks prevent the article from being bogged down with too many unnecessary definitions. Each reader is different; therefore, providing as many variations of definitions is vital to reaching a larger audience. By reaching larger audiences, popular science authors connect scientists to the average reader. These connections allow for greater understanding, which in turn leads to the public wanting more information. This desire enables scientists to continue their research. Therefore, the more ways a popular science writer can define what scientists are doing, the more scientists can get done. By having access to multiple forms of definitions, popular science writers help create an upward spiral of progress.

Conclusion

After examination, there is confirmation that popular science articles online use the same kinds of definitions defined by Pilkington (2019). While there is some slight variation, it is not enough to warrant entirely new categories with the exception of a subcategory to chain definitions, i.e., mini-chain definitions. Overall, each of the definitions present was useful in its own unique way. Whether they were prototypical, procedural, delayed, zero, figurative, or chain definition, they all had a purpose. Prototypical definitions were used when the author wanted a quick and more dictionary-like definition. Procedural definitions were used to explain what the science term did and brought more clarity of its function to the audience. Delayed definitions gave readers an opportunity to learn more if they wanted. Zero definitions were present when there could have been a definition, but it was not needed for the article to make sense. Figurative definitions provided colorful connections, and chain definitions (or more specifically, mini-chain definitions) brought multiple definitions to create one larger and more well-rounded definition.

These mini-chain definitions provide greater flexibility to the author as they write online popular science articles about current scientific achievements. They combine prototypical and procedural definitions to provide a more well-rounded and complete definition to the reader. This use of mini-chain definitions allows the reader to understand the topic being discussed on a deeper level, which in turn allows for greater conversations with others about the current science or technology.

These authors used definitions to explain just enough to avoid confusing the reader without giving them too much unneeded knowledge. The definitions allowed writers to maintain the flow of the article while still including as many people as possible in their audience. The fact that there are so many ways to convey a definition allows writers to have more freedom in their writing process. It is one of the many ways they can show their creativity as an author

while still maintaining the integrity of a popular science article. Indeed, part of the beauty of definitions is that they can be as simple or complicated as the writer needs or wants.

- "So, what is black phosphorus? The easiest way to understand it is by comparisons to graphite, a material that's already in use as an electrode for lithium-ion batteries. Graphite is a form of carbon that's just a large collection of graphene sheets layered on top of each other. Graphene, in turn, is a sheet formed by an enormous molecule composed of carbon atoms bonded to each other, with the carbons arranged in a hexagonal pattern. In the same way, black phosphorus is composed of many layered sheets of an atom-thick material called phosphorene.

  But there are key differences between the materials. To begin with, phosphorus is a larger atom with more electrons than carbon, and so it can interact with more lithium atoms, an essential feature for battery electrodes. The other key difference is that the bonds formed by carbon atoms ensure that graphene is essentially flat, no thicker than the atoms of carbon it's formed from. The phosphorene sheets, as you can see above, are most clearly not flat. Neighboring atoms are bound at angles that give the sheet a series of ridges or channels.

  It's that feature that drew the researchers' interest, since those angles form an avenue to get lithium ions into and out of the material quickly. And, because each phosphorus atom can interact with multiple lithium ions, we only know of two materials with higher theoretical electrode capacities—one of them being lithium metal itself. Finally, black phosphorus conducts electricity well, an important feature for a battery electrode.

  So, why isn't everyone already using black phosphorus? Well, mostly because it doesn't work. Like other electrode materials, the black phosphorus expands as lithium ions get packed in, increasing the risk of a structural failure during charge/discharge cycles. And at the edges of sheets, chemical bonds can form between the different layers, sealing off some of the channels. To get it to work as a battery material, these issues need to be fixed." (para 3-6)

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References

Aridi, R. (2020, September 30). How Human Y Chromosomes Replaced Those of Neanderthals in a Quiet Genetic Takeover. *Smithsonianmag*. https://www.smithsonianmag.com/smart-news/how-human-y-chromosomes-replaced-those-neanderthals-quiet-genetic-takeover-180975944/

Durrani, J. (2020, August 6). How Does Hair Blunt Steel Blades? *Chemistryworld*. https://www.chemistryworld.com/news/how-does-hair-blunt-steel-blades/4012245.article

ESO. (2020, October 12). ESO Telescopes Record Last Moments of Star Devoured by a Black Hole. *ScienceDaily*. https://www.sciencedaily.com/releases/2020/10/201012115956.htm

Hibberd, F. J. (2019). What is Scientific Definition? *Journal of Mind & Behavior*, *40*(1), 29–52. http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=136794017&site=ehost-live

Keller, E. F. (2020). Cognitive Functions of Metaphor in the Natural Sciences. *Interdisciplinary Science Reviews*, *45*(3), 249–267. https://doi.org/10.1080/03080188.2020.1794384

McGill University. (2020, October 7). New Key Player in Long-term Memory: Long-term Memory Controlled by Protein Synthesis in Inhibitory Cells. *ScienceDaily*. https://www.sciencedaily.com/releases/2020/10/201007123121.htm

Megget, K. (2016, January 21). The Cutting Edge of Gene Editing. *Chemistryworld*. https://www.chemistryworld.com/features/the-cutting-edge-of-gene-editing/9371.article

O'Connell, R. (2020, October 12). Pandemic Quiet Means We Can Eavesdrop on Rare Australian Dolphins. *Atlasobscura*. https://www.atlasobscura.com/articles/pandemic-silence-dolphin-communication

Piciocchi, C., & Martinelli, L. (2016). The Change of Definitions in a Multidisciplinary Landscape: The Case of Human Embryo and Pre-embryo Identification. *Croatian Medical Journal*, *57*(5), 510–515. https://doi.org/10.3325/cmj.2016.57.510

Pilkington, O. A. (2019). *The Language of Popular Science: Analyzing the Communication of Advanced Ideas to Lay Readers*. McFarland.

Redd, N. T. (2020, September 30). How NASA's New Telescope Will Help Astronomers Discover Free-Floating Worlds. *Smithsonianmag*. https://www.smithsonianmag.com/science-nature/how-nasas-new-telescope-will-help-astronomers-find-hundreds-planets-without-stars-180975922/

Salter, J. (2020, October 12). Yesterday's Corporate Network Design Isn't Working for Working from Home. *Arstechnica*. https://arstechnica.com/gadgets/2020/10/future-of-collaboration-01/

Simon, M. (2020, October 12). Could a Tree Help Find a Decaying Corpse Nearby? *Atlasobscura*. https://www.atlasobscura.com/articles/body-farm-tree-colors

Tanghe, K. B., De Tiège, A., & Blancke, S. (2016). Linguistic Reference in Science: Problems and Progress. *International Multidisciplinary Scientific Conference on Social Sciences & Arts SGEM*, 603–610. http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=128318819&site=ehost-live

Timmer, J. (2020, October 11). Engineering a Battery Fast Enough to Make Recharging Like Refueling. *Arstechnica*. https://arstechnica.com/science/2020/10/engineering-a-battery-fast-enough-to-make-recharging-like-refueling/

Appendices

Appendix A: Primary Sources

Aridi, R. (2020, September 30). *How Human Y Chromosomes Replaced Those of Neanderthals in a Quiet Genetic Takeover*. Smithsonianmag. October 13, 2020, from https://www.smithsonianmag.com/smart-news/how-human-y-chromosomes-replaced-those-neanderthals-quiet-genetic-takeover-180975944/

Durrani, J. (2020, August 6). *How Does Hair Blunt Steel Blades?* Chemistryworld. Oct 12, 2020, from https://www.chemistryworld.com/news/how-does-hair-blunt-steel-blades/4012245.article

ESO. (2020, October 12). *ESO Telescopes Record Last Moments of Star Devoured by a Black Hole.* ScienceDaily. Retrieved October 13, 2020, from www.sciencedaily.com/releases/2020/10/201012115956.htm

McGill University. (2020, October 7). *New Key Player in Long-term Memory: Long-term Memory Controlled by Protein Synthesis in Inhibitory Cells.* ScienceDaily. Retrieved October 12, 2020, from www.sciencedaily.com/releases/2020/10/201007123121.htm

Megget, K. (2016, January 21). *The Cutting Edge of Gene Editing.* Chemistryworld. October 12, 2020, from https://www.chemistryworld.com/features/the-cutting-edge-of-gene-editing/9371.article

O'Connell, R. (2020, October 12). *Pandemic Quiet Means We Can Eavesdrop on Rare Australian Dolphins.* Atlasobscura. October 13, 2020, from https://www.atlasobscura.com/articles/pandemic-silence-dolphin-communication

Redd, N. T. (2020, September 30). *How NASA's New Telescope Will Help Astronomers Discover Free-Floating Worlds.* Smithsonianmag. October 13, 2020, from https://www.smithsonianmag.com/science-nature/how-nasas-new-telescope-will-help-astronomers-find-hundreds-planets-without-stars-180975922/

Salter, J. (2020, October 12). *Yesterday's Corporate Network Design Isn't Working for Working from Home.* Arstechnica. October 13, 2020, from https://arstechnica.com/gadgets/2020/10/future-of-collaboration-01/

Simon, M. (2020, October 12). *Could a Tree Help Find a Decaying Corpse Nearby?* Atlasobscura. October 13, 2020, from https://www.atlasobscura.com/articles/body-farm-tree-colors

Timmer, J. (2020, October 11). *Engineering a Battery Fast Enough to Make Recharging Like Refueling.* Arstechnica. October 13, 2020, from https://arstechnica.com/science/2020/10/engineering-a-battery-fast-enough-to-make-recharging-like-refueling/

Appendix B: List of Definitions

Prototypical Definitions

Aridi (2020)

- "*Homo-sapiens* – the modern-day human –" (para 1)

- "two archaic human species: the famous Neanderthals and their lesser know cousins, the Denisovans" (para 1)
- "deleterious – or harmful –" (para 7)

ESO (2020)

- "a rare blast of light from a star being ripped apart by a supermassive black hole. The phenomenon, known as a tidal disruption event" (para 1)
- "But these tidal disruption events, where a star experiences what's known as spaghettification as it's sucked in by a black hole" (para 2)
- "the thin strands of stellar material fall into the black hole during this spaghettification process" (para 3)
- X-shooter and EFOSC2, powerful instruments on ESO's VLT and ESO's NTT" (para 8)

McGill University (2020)

- "short-term memories (which last just a few hours)" (para 3)
- "long-term memories (which may last years)" (para 3)
- "this process [meaning short-term memories becoming long term memories], called memory consolidation" (para 3)

Megget (2016)

- "The technique, known as Crispr (clustered regularly interspaced short palindromic repeats), is an advance on previous gene-editing techniques." (para 2)
- "it is more precise, faster, easier, and cheaper [than previous gene-editing techniques]" (para 2)
- "scientists found DNA sequences that were repeated and interspersed with unique sequences, becoming known as Crispr. Further research identified the unique sequences as viral DNA, which had come from phage viruses that infect bacteria." (para 5)
- "Crispr sequence; genes coding for enzymes known as Cas" (para 5)
- "Cas (Crispr-associated proteins)" (para 5)
- "[earlier gene-editing techniques] zinc finger nucleases (ZFN) and transcription activator-like effector nucleases (Talens)" (para 10)
- "the blood disorder β-thalassaemia" (para 24)
- "the germ line (the sex cells, eggs and sperm)" (para 27)

O'Connell (2020)

- "the Burrunan [is] a unique species of bottlenose in 2011." (para 4)
- "'signature whistle'—a unique greeting to other dolphins, akin to them saying their own names." (para 6)
- "The former [meaning communication] broadly refers to the transmission of information" (para 8)
- "Language, by comparison, is communication using complex systems of symbols, words, or other signals." (para 8)
- sound traps, passive acoustic monitoring stations placed on the bottom" (para 11)

Redd (2020)

- "Jupiter-sized (read: large)" (para 1)
- "optical light, the part of the spectrum that humans can see with their eyes" (para 10)

Salter (2020)

- "telework (which, if you're not in the IT biz, is just a fancy word for"working from not in the office")" (para 1)
- "Traffic shaping – i.e., prioritizing packets based on what protocol they're using, or where they're going" (para 12)
- "Wireguard, a newer, faster VPN technology" (para 24)

Simon (2020)

- "phenotype – its physical characteristics" (para 2)
- "necrobiome – all the bacteria that was already in it when it was alive" (para 3)
- "the chlorophyll in plant leaves fluoresces, reemitting light that special optics can pick up. This signature is invisible to the human eye but not to existing technologies. It's known as hyperspectral sensing." (para 7)
- "Fluorescence specifically is an indicator of what's in a plant leaf's cell walls." (para 7)
- "an amino acid like phenylalanine" (para 7) which is released from a dead body, could cause leaves to fluoresce in a distinct way.

Timmer (2020)

- "graphite, a material that's already in use as an electrode for lithium-ion batteries." (para 3)
- "Graphite is a form of carbon that's just a large collection of graphene sheets layered on top of each other." (para 3)
- "Graphene, in turn, is a sheet formed by an enormous molecule composed of carbon atoms bonded to each other, with the carbons arranged in a hexagonal pattern." (para 3)
- "black phosphorus is composed of many layered sheets of an atom-thick material called phosphorene." (para 3)
- "phosphorus is a larger atom with more electrons than carbon" (para 4)
- "graphene is essentially flat" (para 4)
- "the phosphorus sheets... are most clearly not flat" (para 4)

Procedural Definitions

ESO (2020)

- "during this spaghettification process a bright flare of energy is released" (para 3)

McGill University (2020)

- "the excitatory neurons are involved in creating a memory trace" (para 1)
- "the inhibitory neurons block out background noise and allow long-term learning to take place" (para 1)
- "[memory consolidation] requires the synthesis of new proteins in brain cells" (para 3)

Megget (2016)

- "with the ability to delete, repair or replace genes." (para 2)
- "The bacteria were essentially keeping a record of viral infection, forming part of their nifty microbial immune system. The other part was located near to the Crispr sequence; genes coding for enzymes known as Cas (Crispr-associated proteins), which have DNA-cleaving ability.

  The viral DNA sequences are copied into an RNA strand and linked with a Cas enzyme. The resulting molecules float through a bacterial cell on the lookout for viral DNA that specifically matches their RNA

strands. A match results in the RNA and viral DNA pairing, allowing the Cas enzyme to whir into action and snip the viral DNA up, stopping the viral infection in its tracks.

This bacterial satnav and scissor combo has been exploited to become a genome-editor extraordinaire, targeting specific genes in any organism with the ability to delete, repair or replace them. All scientists need to do is synthesise a guide-RNA (gRNA) molecule of about 20 bases that matches the target gene sequence and link it to a Cas enzyme, of which there are many. The Cas enzyme most commonly used is Cas9 – from the bacteria that cause strep throat – because of its high efficiency and ability to create a double stranded DNA break. This gives rise to the Crispr–Cas9 nomenclature, though this system is often just referred to as Crispr.

The gRNA–Cas9 complex then targets the specific gene to be edited through RNA–DNA base pairing and Cas9 makes the cut. One cut deactivates the gene. Two cuts, with two gRNAs, remove the gene. If the gene was faulty, it can then be repaired by adding a normal copy of the gene to the cell, which pairs up with the cut DNA ends to form one DNA molecule again. New genes can also be inserted into the genome in this way. Multiple gRNAs can also induce multiple cuts simultaneously, editing more than one gene at the same time." (para 5-8)

- "Crispr, he says, could accelerate plant breeding, protect plant health, increase crop yields and 'allow us to create better solutions that could result in less environmental impact – for example, improved crops that use less water or more efficiently use fertilisers.'" (para 13)
- "stem cells (which can turn into other types of body cells)" (para 19)

O'Connell (2020)

- "... [communication] can be as simple as an animal baring its teeth to convey aggression." (para 8)
- "sound traps ... let the MMF team"eavesdrop on the dolphins 24 hours a day," Robb says." (para 11)

Redd (2020)

- "This technique [meaning gravitational microlensing] can reveal objects too dark to discover through other means, objects such as black holes or planets. When an object, like a planet, passes in front of a star, its gravity causes a very slight brightening to the stellar light. The faint magnification, predicted by the theory of general relativity,

can provide insights into the passing magnifier. Unlike most other planetary discovery techniques, microlensing can find worlds cast off from their star, drifting through the darkness of space." (para 6)

Salter (2020)

- "That means all of the bits you're moving around on your laptop while you're at work are transiting through your office's Internet connection via that VPN." (para 4)
- "A globally routed VPN requires a connected home user to send all traffic across the VPN" (para 21)

Simon (2020)

- "phenylalanine, which is released from a dead body" (para 7)

Timmer (2020)

- "black phosphorus, which forms atom-thick sheets with lithium-sized channels in it" (para 2)
- "it [meaning phosphorus] can interact with more lithium atoms" (para4)
- Black phosphorus conducts electricity well" (para 5)
- "red phosphorus, which forms a disordered mesh rather than layered sheets" (para 9)

Delayed Definitions

Salter (2020)

- "Wireguard" (para 24)
- "Nebula" (para 24)
- "Revit" (para 27)

Zero Definitions

None

Figurative Definitions

ESO (2020)

- "'The idea of a black hole 'sucking in' a nearby star sounds like science fiction. But this is exactly what happens in a tidal disruption event,' says Matt Nicholl" (para 2)

Simon (2020)

- "cadavers decay, like how the microbiomes inside us go haywire after death." (para 1)

Mini-Chain Definitions

ESO (2020)

- "the thin strands of stellar material fall into the black hole during this spaghettification, process a bright flare of energy is released" (para 3)

McGill University (2020)

- "this process, called memory consolidation, requires the synthesis of new proteins in brain cells" (para 3)

Megget (2016)

- "it is more precise, faster, easier, and cheaper, with the ability to delete, repair or replace genes." (para 2)

- "scientists found DNA sequences that were repeated and interspersed with unique sequences, becoming known as Crispr. Further research identified the unique sequences as viral DNA, which had come from phage viruses that infect bacteria. The bacteria were essentially keeping a record of viral infection, forming part of their nifty microbial immune system. The other part was located near to the Crispr sequence; genes coding for enzymes known as Cas (Crispr-associated proteins), which have DNA-cleaving ability.

  The viral DNA sequences are copied into an RNA strand and linked with a Cas enzyme. The resulting molecules float through a bacterial cell on the lookout for viral DNA that specifically matches their RNA strands. A match results in the RNA and viral DNA pairing, allowing the Cas enzyme to whir into action and snip the viral DNA up, stopping the viral infection in its tracks.

  This bacterial satnav and scissor combo has been exploited to become a genome-editor extraordinaire, targeting specific genes in any organism with the ability to delete, repair or replace them. All scientists need to do is synthesise a guide-RNA (gRNA) molecule of about 20 bases that matches the target gene sequence and link it to a Cas enzyme, of which there are many. The Cas enzyme most commonly used is Cas9 – from the bacteria that cause strep throat – because of its high efficiency and ability to create a double stranded DNA break. This gives rise to the Crispr–Cas9 nomenclature, though this system is often just referred to as Crispr.

  The gRNA–Cas9 complex then targets the specific gene to be edited through RNA–DNA base pairing and Cas9 makes the cut. One cut deactivates the gene. Two cuts, with two gRNAs, remove the gene. If the gene was faulty, it can then be repaired by adding a normal copy of the gene to the cell, which pairs up with the cut DNA ends to form

one DNA molecule again. New genes can also be inserted into the genome in this way. Multiple gRNAs can also induce multiple cuts simultaneously, editing more than one gene at the same time." (para 5-8)

O'Connell (2020)

- "sound traps, passive acoustic monitoring stations placed on the bottom that let the MMF team"eavesdrop on the dolphins 24 hours a day," Robb says." (para 11)

Simon (2020)

- "the chlorophyll in plant leaves fluoresces, reemitting light that special optics can pick up. This signature is invisible to the human eye but not to existing technologies. It's known as hyperspectral sensing. These devices can actually see across the electromagnetic spectrum, including visible and infrared light." (para 7)
- "an amino acid like phenylalanine, which is released from a dead body, could cause leaves to fluoresce in a distinct way." (para 7)

Timmer (2020)