Revealing "the stories behind the words" of chemistry.

On a cold and damp evening during the Christmas holidays of 1860 an expectant crowd gathers in the gas lit gloom outside the Royal Institution in London. They shuffle into the steep banked seating of the auditorium and an excited hush descends over the room as Michael Faraday enters and begins the first of his six lectures on "The Chemical History of a Candle". As he commences his exploration and ignites the audience's curiosity he remarks:

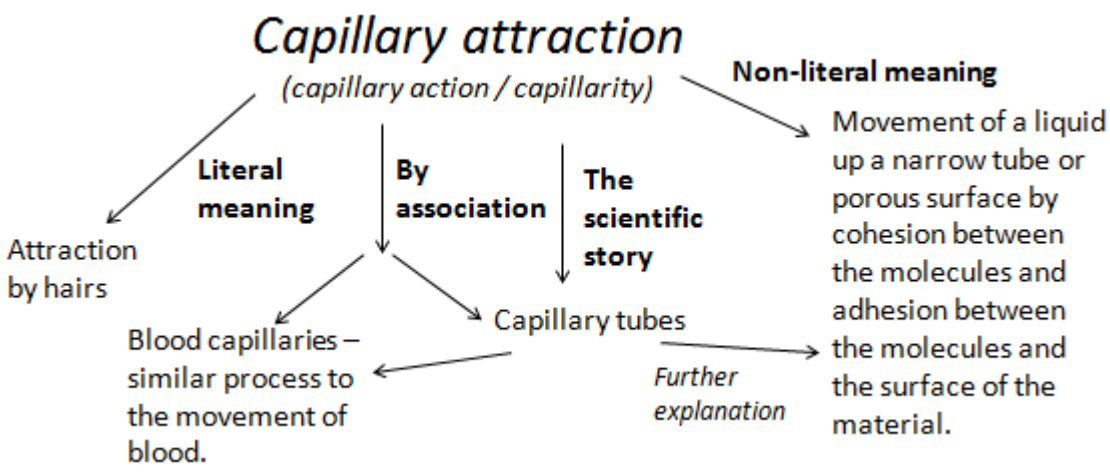
"But how does the flame get hold of the fuel? There is a beautiful point about that – capillary attraction, 'Capillary attraction!' you say – 'the attraction of hairs'. Well never mind the name; it was given in old times, before we had a good understanding of what the real power was."

(Faraday, 1861, paragraph 12)

With this remark about "capillary attraction", Michael Faraday has provided a flicker of illumination on the theme of this article; the potential for words in science to promote understanding or to confuse and obfuscate. I shall use this example to illustrate several potential routes for developing understanding of a scientific term (Box 1).

When Faraday introduces this term to the audience he immediately dismisses it as misleading because of its reference to hairs (*capillaris* – Latin word for *hairs*). He states that this name was assigned when the true "power" (another interesting choice of word) or mechanism was not known. This suggests that he thought the original assigning of this term was due to a view that the movement of the liquid was indeed caused by attraction of tiny hairs on the surface. This is our first route via literal meaning (see Box 1) and knowledge of the Latin origins of the English word. Often this is a successful route; in this case, however, it can lead to an incorrect conclusion as Faraday demonstrates.

Box 1. *Capillary attraction – the different routes to meaning.*



To understand the origin of this word and the process it represents, one needs to be aware of our second route to meaning via the story of science (Sutton 1992). The term was ascribed after the observation in the 17th Century of water rising within a capillary tube (so called as it is a tube with an internal diameter of "hair-like" thinness) and hence attraction to the walls of the tube (Boyle, (1660). An apparently logical term to ascribe to the observation in this context and can then lead on to an explanation of the mechanism involved.

Two hundred years on, when knowledge and usage of Latin was more prevalent than today, Faraday recognised its potential to cause confusion. His response, somewhat disappointingly, was to dismiss the term and expect his audience to simply accept it. As such he is tending towards our third route – non-literal meaning. The original meaning of the word has been lost and one is simply expected to learn the explanation. This common route removes the potential for the term to provide insight and explanation of the process and encourages rote learning.

One hundred and fifty years later and has anything changed? Capillary attraction is a term still used but perhaps is more frequently referred to as *capillary action*; this, in itself, does not seem to be an improvement as it implies the action of hairs rather than attraction. Alternatively, there is *capillarity* which also retains the "hair" root of the word. Nowadays, however, fewer people have the knowledge of Latin to be immediately confused by this. Natural curiosity, though, leads one to wonder why it has acquired this term and the mind may seek to make links with other similar words. This is our fourth route to meaning – by association. In this instance, one may link to a capillary tube and find a way to the correct explanation but more likely is to think of the tiny blood vessels, *capillaries*. Is there a connection? Does capillary action occur in capillaries? Is it the action of capillaries? They both relate to the movement of fluids after all!

Language itself is fluid and changes over time and is it not time that we reflected on some of the terms that we use and whether there are more accessible and appropriate alternatives? Do we actually need a term for this? Would it be sufficient to simply explain the phenomenon in terms of cohesion and adhesion (two further challenging words) of water molecules? Is it an artefact of science that specific names have been assigned excessively to phenomena and processes which only serve to isolate the scientific community from the public at large?

As chemistry educators, it is essential that we imagine ourselves in the position of someone sat in the auditorium at the Royal Institution with little knowledge of science and ask ourselves whether the language and words we use help or hinder understanding of the fascinating phenomena we are seeking to explain. Indeed, if I could go back in time and be Michael Faraday's scriptwriter then I would have liked to have suggested a couple of alternatives (see Box 2).

Box 2. *The Faraday alternative scripts!*

1. Exploring the scientific story.

"But how does the flame get hold of the fuel? There is a beautiful point about that – capillary attraction, 'Capillary attraction!' you say – 'the attraction of hairs'. I say 'no – certainly not!' This name was given by the eminent scientist Robert Boyle two hundred years ago when he observed water rising against the force gravity within glass capillary tubes as fine as a hair on your head."

2. Removing unnecessary terms.

"But how does the flame get hold of the fuel? There is a beautiful point about that – the candle wax molecules are attracted to each other and to the wick such that they are able rise against the force of gravity."

Words as more than labels

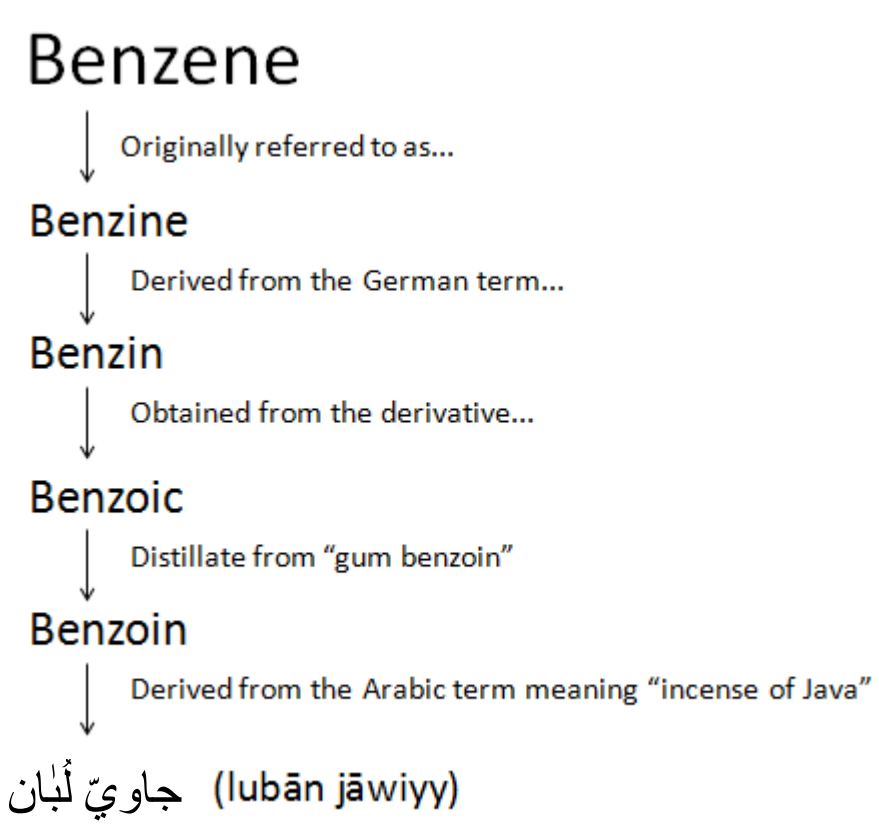
Capillary attraction is an example of a scientific term becoming simply a label for a process rather than interpretative tool. Sutton (1992) argued that words are a much more powerful and useful aid to our understanding when we are aware of the story behind the word.

For example, let us consider the case of *benzene*. A ubiquitous and important term introduced early in organic chemistry and for which several scientific stories may be told. Firstly, there is the well-known 'structural' scientific story about Kekulé's snake dream as science pondered benzene's chemical structure. Not the most exciting of scientific stories but useful in appreciating the development of scientific ideas and a visual representation of the ring structure. Secondly, there is the 'structural/reactivity' story with the development of an explanation of benzene's low reactivity despite appearing to contain three double bonds. Here, the teacher can lead the students in to a state of cognitive dissonance where practical observations, such as a lack of reactivity with bromine water, do not agree with predictions based on a carbon carbon double bonded structure.

But what about the "*why is benzene called benzene*" story? One can make a structural connection to the suffix "ene" and the presence of carbon carbon double bonds but why is it not called cyclohex-1-3-5-ene for example? Where does "benz" come from? Have you just made an association with an expensive German car? If so then you are, inadvertently, on the right lines because the etymology of benzene is that it is derived from the German word "benzin" (see box 6). This word, in turn, was derived from benzoic acid which was initially isolated from "gum benzoin". Gum benzoin is a resin from the Styrax genus of trees that is famed for its fragrance and is commonly used in church incense (Frankinsence). Benzoin itself is derived from the Arabic لُبَان

جاويّ (lubān jāwiyy) which translates as “incense of Java”. Exploring the origins of this word has turned benzene from having simply an arbitrary, functional chemistry meaning with little association to the actual word into a substance whose origins are grounded in human history of the past two thousand years.

Box 6. *The etymology of “benzene”*



This etymological or ‘word origin’ scientific story evokes image of traders traversing the spice route and exchanging this exotic and valuable substance until it eventually reached our shores. It provides valuable opportunities to demonstrate chemistry’s historical and cultural origins as well as connections with other significant chemistry words. For example, the term *organic* is now better contextualised as one can see how this substance originated from a plant and a bottle of benzoin essential oil can easily be passed around a class and suddenly the origins of the term *aromatic chemistry* makes more sense.

Furthermore, one can then make links to perfume manufacture and cosmetics or ideas of early chemists heating up this curious substance to find out more about it. More modern linguistic links may be found with “benzin” or “benzina” the German and Italian words respectively for petrol. This can then lead to a discussion of the

occurrence of benzene in fuel and potential opportunities to develop scientific literacy. One may also consider the confusion of phenol (surely this should be benzenol?); the only way one can logically show the link between the words phenol and benzene is by considering the alternative etymological route of the French word "phène" for benzene. This may then lead to stories of competing chemists discovering chemicals and developing alternative names. If you still have the stamina, you may then be tempted to consider carbolic acid and toluene – the connections go on and on! So, whilst previously the word benzene may have been taken for granted as a label for a particular chemical, benzene is now a much more exciting and meaningful word that locates this compound within human history. This is a worthwhile strategy in any teaching environment but may be particularly useful for teachers working in multicultural environments. These word origin stories can be used to show the connections between different languages and cultures and help engage a diverse student cohort.

The common roots of words

Another etymological tool for chemistry students is to understand the common roots of words so that they improve their reading skills and interpret new and unfamiliar vocabulary. Lactic acid, for example, is a term many students will be familiar with as a product of anaerobic respiration and the cause of cramp. There are many other words which share the common root of "lact" which may be less familiar to students; such as lactate, lactose, galactose, alactic, lactamase, lactation and many more. By exploring the meaning and origin of this common root to the words, the word gains more meaning and students are more able to "decode" new and unfamiliar vocabulary.

The "lact" root is derived from the latin for "milk" but there are very few of these words, with the exception of lactation, that one would make an obvious association with milk. So why is a substance associated with our muscles named after milk? Once again, we must delve in to the history of science which informs us that lactic acid was first isolated from sour milk by Carl Wilhelm Scheele in 1780. Hence, the origin of the word "lactic" becomes clear and it also tells us that the other related words are likely to have something to do with milk. If one is aware of other word roots as well, then new words can be translated and meaning determined without having previously been aware of the word. For example, the root "ose" refers to sugars so lactose and galactose are likely to be sugars found in milk; or "a" at the front of a word refers to "not" so "alactic" suggests "not lactic acid". As Herron (1996) stated

"*Discussion of word histories can add a human touch to the teaching of science as well as improve the student's understanding of science and help students develop word-attack skills"* (referring to developing the reading skill of recognising new words formed by adding prefixes and suffixes to root words).

So the next time you are using scientific words with students try to not simply see them as an arbitrary label for a chemical or a process or an idea. Instead, try revealing the "story behind the word" and use it as an interpretative tool to engage with and support the understanding you are seeking from your students.

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