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EDITORIAL

Communicating Science: Candles, Flames and Faraday

American university campuses in the late 1960s and early 1970s were hugely influenced by the war in Vietnam; a conflict that seemed to be perceived as a monumental misadventure. The war appeared to immediately impact campuses as young men (often little more than boys) were likely to be drafted into military service, unless deferments were obtained. As a Ph D student on an American campus at that time, the concerns and fears of my contemporaries left a lasting impression. This was also a time when technologies were evolving rapidly. The *Apollo* moon missions were events that merited near continuous coverage on television, with viewership peaking during the near disastrous *Apollo 13* mission in 1970, which provided cliff hanging suspense for several days. Colour television had arrived in America; a medium that students from India had never encountered before. In 1972, a new TV serial appeared based on happenings in an army medical unit serving on the frontlines in the Korean war; a setting that seemed particularly appropriate in a country consumed by another far-off Asian conflict. *M.A.S.H*. was a serial that was often funny, although the dark humour seemed to be a defense mechanism that enabled the characters to maintain their sanity, in a maddening environment. *M.A.S.H*. turned out to be a long running serial, and as I just discovered, using the long arm of *Google*, one that ran for over a decade. Its lead character, Hawkeye Pierce, played by Alan Alda was appealing in many ways, especially in an environment where anti-establishment sentiment was running very high. He was cynical, disrespectful of authority, casual but surprisingly competent, resourceful with a wicked sense of humour. My memory, now partly fading, of a forty-year-old TV serial was jogged when I found Alan Alda's photograph on the Editorial page of the 2 March 2012 issue of *Science*. What indeed was a TV actor of yesteryear doing on the pages of a science journal? Alda was promoting the increasingly important area of communicating science to a general audience. He begins his essay 'The flame challenge', by recalling a childhood question posed to his teacher: ' "What's a flame?" I asked her. "What's going on in there?" There was a slight pause and she said, "It's oxidation". She didn't seem to think there was much else to say. Deflated, I knew there had to be more to the mystery of a flame than just giving the mystery another name." ' (*Science*, 2012, **335**, 1019.)

Alda's question was asked and answered in dramatic fashion just over a century and a half ago by Michael Faraday. The six lectures he delivered at the Royal Institution in London, during the period December 1860 and January 1861, on 'The chemical history of a candle', later published as a book, are now a part of the folklore of science. A sesquicentenary edition has just appeared, edited by Frank James (Oxford University Press, 2011), reminding us that masterpieces endure the ravages of time. A recent review of the book notes that James points out that the continuing relevance of Faraday's lectures stems from the fact that 'they remain almost entirely scientifically valid (The only shaky sections are those that touch on the sources of light emission; these would have benefited from a quantum mechanical understanding that was still decades in the future)'. The reviewer draws attention to James' suggestion that Faraday's religious beliefs 'influenced his deep appreciation of the natural world'. He goes on to add: 'There's some irony in the fact that Faraday's most famous studies – on electromagnetism – laid the groundwork for the mass electrification that ultimately supplanted candles as practical sources of light. It seems likely he would have appreciated their sustained current role in spiritual settings, as people continue to contemplate the strange beauty of their flickering flames.' (Yeston, J., *Science*, 2011, **334**, 1644.)

The classic account of Faraday's discourse on the candle was transcribed and edited by William Crookes and is available in India as a reprint produced by Vigyan Prasar in 1995. In a letter to *Nature* (1997, **388**, 710), J. M. Thomas pointed out that 'Japanese translations of…Faraday's Christmas Lectures (1859–60) have gone through more than 70 editions and are required reading for Japanese schoolchildren'. Faraday addresses his lectures to the young: 'I claim the privilege of speaking to juveniles as a juvenile myself'. Like the young Alan Alda nearly a century later Faraday is fascinated by the flame, 'where you have such beauty and brightness as nothing but combustion or flame can produce. You have the glittering beauty of gold and silver, and the still higher lustre of jewels like ruby and diamond; but none of these rival the brilliance and beauty of flame. What diamond can shine like a flame? It owes its lustre at night-time to the very flame shining upon it. The flame shines in darkness, but the light which the diamond has is as nothing until the flame shines upon it, when it is brilliant again. The candle alone shines by itself and for itself…'. Faraday's use of a candle to illustrate a wide range of natural phenomena remains a timeless classic in communicating sci-

ence. Towards the end he draws the parallel between combustion and respiration, both of which utilize oxygen and produce carbon dioxide ('what a wonderful change of carbon must take place under these circumstances'). Faraday urges his young audience to consider the consequences of respiration: 'A man in twentyfour hours converts as much as seven ounces of carbon into carbonic acid; a milch cow will convert seventy ounces and a horse seventynine ounces solely by act of respiration… And what an extraordinary notion this gives us of the alterations going on in our atmosphere. As much as 5,000,000 pounds or 548 tonnes of carbonic acid is formed by respiration in London alone in twenty four hours. And where does all this go? Up into the air.' Faraday goes on to discuss the absorption of carbon dioxide by plants. Remarkably, Faraday wonders about the effects on the atmosphere, anticipating the many contemporary discussions of the effects of burning fossil fuel. He concludes with a wish for his young audience: '…a wish that you may, in your generation, be fit to compare to a candle; that you may like it, shine as lights to those about you; that, in all your actions, you may justify the beauty of the taper by making your deeds honourable and effectual in the discharge of your duty to your fellow-men.'

Faraday used the candle and its beautiful, flickering flame to illustrate the chemical nature of combustion, the carbon cycle, the two parts of water – hydrogen and oxygen – and the profound connections between respiration and photosynthesis. Physics and biology hovered in the background when Faraday engaged his audience on a discussion of the chemical history of a candle. Over a century later in a review titled 'From candles to chemistry', of a book by P. W. Atkins (*Atoms, Electrons and Charge*, W.H. Freeman, 1991), J. P. Simons describes 'the task that Faraday set himself'. Even with the insights of the 20th century the task is formidable: '…to see the complexity (and underlying simplicity) of chemical change through the light of a candle's flame' (*Nature*, 1991, **353**, 805). In Faraday's time atoms and molecules were ideas just beginning to form. Chemical thermodynamics was still over a decade away with Willard Gibbs producing his work only after Faraday's death. Yet much of Faraday's discourse is completely valid today. In 1991, the second centenary of Faraday's birth was an occasion for celebration and nostalgia at the Royal Institution. John Maddox in an account of the seasons main event describes the lectures of the two past Directors of the Royal Institution, George Porter and John Thomas. The former 'acting as if relieved that the constraints of being President of the Royal Society had been sloughed off…sat inside an electrically conducting cage' in a demonstration to establish 'that the electric charge of a conducting body lies on the surface – as Faraday had done at the same spot in 1836'. Thomas' discourse fittingly evoked memories of the lectures on the 'candle' reminding 'the audience that Faraday was first a chemist and only afterwards the founder of electromagnetism'. Did the public lectures, 'discourses', at the Royal Institution, founded by Count Rumford in 1799 as 'a centre for the popularization of the "mechanical arts" ' have a larger purpose in later years? According to Maddox, Humphry Davy, who succeeded Rumford and was Faraday's predecessor, realized that 'the Royal Institution was a means of making propaganda for the mechanical arts among the well-to-do of Mayfair and thus of raising money for research' (*Nature*, 1991, **353**, 599).

Writing and speaking about science in a manner that engages a large audience of the general public is a talent that few possess. In his *Science* editorial, Alda wonders 'if written and oral communication skills could be taught systematically throughout the entire length of a student's science education'. In teaching students 'to distill their message and write without jargon', Faraday's classic would undoubtedly be required reading. Faraday's great contemporary, Charles Dickens whose bicentennial is currently being celebrated believed that science 'does immense good – moral, social and intellectual – but only when it works hand in hand with imagination and reverence' (Jenkins, A., *Nature*, 2012, **482**, 32). In her essay, Alice Jenkins notes that this was a Victorian view and one shared by Faraday, who believed that 'in the pursuit of physical science, the imagination should be taught to present the subject investigated in all possible, and even in impossible views'. Dickens commissioned Percival Leigh in 1850 to 'rework Faraday's notes for his lectures on the candle' for a magazine, *Household Words*, that he edited. 'Leigh turned Faraday's notes into a narrative', involving family conversations at teatime, where a young boy enthusiastically describes Faraday's insights. Ironically, Dickens turned his back on science and Faraday when he vapourised a character in *Bleak House* by 'spontaneous combustion'. Victorian England seems to have been a stage in which science and storytelling coexisted comfortably, at times learning from the other. In her retrospective on Dickens' attitudes towards science, Jenkins concludes: '…when science conflicted with a good story – he combusted it'. I suspect Faraday (and possibly Alan Alda) would have secretly approved.

Flame chemistry continues to be a subject of research and Faraday is still cited in studies of 'hydrocarbon oxidation' (cf Taatjes, C. A. *et al.*, *Science*, 2005, **308**, 1887). Candles even appear on journal covers, most recently in the 6 January 2012 issue of *Science*, which reports a new use of candle soot 'as a template for a transparent robust superamphiphobic coating' (Deng, X. *et al.*, *Science*, 2012, **335**, 67). Not only Alda's 11-year olds, but even serious researchers may continue to ask: 'What is a flame? What's going on in there?' In introducing Faraday's Christmas lectures one hundred and fifty years ago, William Crookes concluded: 'the lamp of science must burn'. Indeed, it must.

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