Lind to Linus: Two Eras in the History of Vitamin C

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Abstract: This paper compares two scientists who are associated with investigations into Vitamin C, James Lind and Linus Pauling. The acceptance of their findings by the scientific community and the public showed distinct variations in each case. This comparative approach highlights the influence that personality and public prestige can have on the acceptance or rejection of a scientist's ideas.

This paper examines two scientists with long and successful careers, James Lind and Linus Pauling. Lind's "Essay on Preserving the Health of Seamen" in 1763 foreshadowed the rise of social medicine, at a time when preserving health was a novel concept. Centuries later Pauling, the recipient of two Nobel Prizes, popularized his views on medicine by speaking directly to the public. They are both best known today for their investigations into the effects of Vitamin C. Comparing their experiences with Vitamin C is an excellent way to explore the effect that personality and public prestige can have on the acceptance or rejection of a scientist's ideas. That effect is sometimes so powerful that it can overshadow the quality of the scientific evidence. James Lind was unknown to the public and carried little weight with his superiors in the British Navy. This lack of credibility greatly affected the acceptance of his work. Conversely, Linus Pauling had tremendous prestige within the scientific community and with the public and his erroneous promotion of Vitamin C as a cure for the common cold and cancer garnered much support.

Our scientific understanding of the medicinal benefits of Vitamin C was greatly expanded upon in the 1920s. Albert Szent-Gyorgyi, a Hungarian physiologist, first identified a compound in the adrenal gland, which he called Hexuronic Acid. The significance of his discovery became apparent when the compound was matched with studies undertaken on the cause of scurvy. At that time, infection, toxicity and deficient diet were blamed for the disease. Using a number of different animals, Szent-Gyorgyi's team found that they could induce scurvy in guinea pigs and cure it with Hexuronic Acid, extracted from lemons. Hexuronic Acid was rechristened with two names that are familiar to us today, Ascorbic Acid and Vitamin C, and scurvy was recognized as a deficiency disease. Scurvy, it was discovered, could be prevented by eating a quarter of an orange daily.[1] The use of guinea pigs for lab

[1] Kenneth J. Carpenter, *The History of Scurvy and Vitamin C* (Cambridge, 1986), 225.

testing was a lucky coincidence. Most animals manufacture their own Vitamin C with the exception of man, monkeys and guinea pigs. Scientists would have been unable to reproduce scurvy in other test animals because they would have manufactured their own Vitamin C.

Scurvy existed in ancient times. For example, the Greeks and Romans both identified a disease that is believed to be scurvy.[2] Known cases of the disease exploded in frequency after Columbus successfully crossed the Atlantic Ocean in 1492, resulting in longer sea voyages. Historians have estimated that more than two million sailors died from scurvy in the Age of Sail, from the sixteenth century to the mid-nineteenth century.[3] Scurvy victims first lose energy, becoming listless, and then suffer from pain in the muscles. As the disease progresses the gums ulcerate, teeth drop out and eventually lung and kidney dysfunction cause death.[4] We now know that Vitamin C is essential in the production of collagen, which is the glue that holds the body together. Without collagen the body literally falls apart, teeth fall out, bones unravel and blood vessels become unglued.[5] Although the concept of a nutritional disease was completely unknown, sailors had been aware of remedies against scurvy since the sixteenth century. Jacques Cartier's men were cured by Stadacona natives with the juice from cedar bark in 1535 and James Lancaster recommended the use of lemons to treat scorbutic sailors.[6] These practical treatments were never adopted by the British scientific community and theories on scurvy's cause ranged from laziness to salt air to, ironically, the addition of oranges and lemons to the diet.[7] By the eighteenth century scurvy had become the scourge of seaman everywhere.

In 1740, George Anson's four-year voyage around the world and spectacular capture of a Spanish galleon brought millions of pounds of bullion back to England. After the celebration, the awful carnage wrought by the voyage was brought to light. Only a few hundred of the two thousand who left four years before had survived, scurvy was responsible for most of the losses.[8] While this voyage was the beginning for Britain of a fifty-year period when scurvy was at its worst, an

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[2] Stephen R. Bown, *Scurvy: How a Surgeon, a Mariner, and a Gentleman solved the Greatest Medical Mystery of the Age of Sail* (Toronto, 2003), 33.
[3] Bown, *Scurvy*, 3.
[4] Linus Pauling, *Vitamin C and the Common Cold* (San Francisco, 1970), 16.
[5] Bown, *Scurvy* , 41.
[6] Bown, *Scurvy*, 4, 29.
[7] Bown, *Scurvy* 37.
[8] Bown, *Scurvy*, 68.

effective remedy for the disease was about to be re-discovered by a scientist using a new experimental method, the clinical drug trial.[9]

James Lind came from a well-established Scottish merchant family and entered the navy as a surgeon's mate in 1739. By 1747, he was a full surgeon on the H.M.S. Salisbury, stationed in the English Channel.[10] Here he carried out the first controlled clinical trial in medicine. Lind took twelve sailors who were suffering from scurvy, gave them the same quarters and diet, and divided them into six groups of two. The six groups were given, in addition to their regular diet, a different treatment for scurvy for fourteen days. The treatments tried were cider, sulphuric acid, vinegar, seawater and a medicinal paste including nutmeg, garlic and other ingredients. The lucky sixth group received two oranges and one lemon per day for six days, until the supply ran out. Not surprisingly, they also fared the best and both sailors were able to go back to work. Cider had a small positive effect but the other four treatments failed. Lind's trial achieved two goals. Firstly, it disproved the effectiveness of sulphuric acid and vinegar, which were the British Navy's official treatments. Secondly, it showed that oranges and lemons given together were an effective treatment, confirming knowledge that had been available for two hundred years. Unfortunately, for the sailors in the British Navy this knowledge would mean nothing. Lind's work would be ignored for over forty years while scurvy raged on unabated.[11]

How could the world's most powerful navy ignore a solution that was so readily at hand? To answer this question we must consider politics, influence and economics. The first roadblock was the treatise that Lind produced on Scurvy in 1753. Devoting much more space to the history, description, diagnosis, and post-mortem findings of scurvy, Lind's clinical trial is described in only two pages of a 454 page document. Derrick Baxby argues that proof of the effectiveness of lemons and oranges may well have been overlooked partly because it was buried too deeply in a much larger work.[12] Lind also continued to recommend traditional remedies that he did not test, such as onions and pickled cabbage, which contain little Vitamin C. Lind's conclusions were also challenged by others, including fellow physician Charles

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[9] Carpenter, *The History of Scurvy and Vitamin C*, 223.
[10] Carpenter, *The History of Scurvy and Vitamin C*, 51.
[11] Carpenter, *The History of Scurvy and Vitamin C*, 51-54. (All information on Lind's clinical trial derives from this source).
[12] Derrick Baxby, "Lind's clinical trial and the control of scurvy," *Journal of the Royal Society of Medicine* 90 (September 1997), 526.

Bisset, who argued that the cause was solar heat and salted food and that scurvy could be treated with wine, rum, sugar and rice.[13]

Lind's effort to find a practical method to carry supplies of citrus juice by producing a "rob" or concentrate of lemon juice was unsuccessful because the process reduced significantly the concentration of Vitamin C. Lind thought that if he boiled the rob it would retain its potency but did not test it for effectiveness.[14] The expense of making the concentrate also contributed to its failure to be adopted.

It is fair to say that the British Navy, in the eighteenth century, was not particularly concerned with the health of its sailors. The Navy was primarily concerned with its economic soundness. All things being equal they would have preferred to keep their sailors alive, but at the cheapest cost possible. In 1767, physician David MacBride recommended a new treatment for scurvy: wort or infusion of malt. MacBride had two advantages over Lind, his treatment was cheap and his brother was a Royal Navy captain who provided him with influence.[15] MacBride's treatment was supported by Sir John Pringle, physician and president of the Royal Society. Pringle was a man of great influence and admirable accomplishments, but he championed the use of an ineffective cure for scurvy. Whether his reasoning was more greatly influenced by the inconsistency of the citrus concentrate or loyalty to his good friend Charles Bisset is difficult to determine. However, what is of consequence here is that his opinion mattered to the decision-making powers within the British Navy.[16]

The British Navy sought resolution to the scurvy debate by having Captain James Cook investigate the various treatments on his voyages. Unfortunately, although Cook was able to avoid outbreaks of scurvy on his ships, he could not shed any light on which treatments were most effective because he failed to do any clinical testing. His statements on scurvy were also contradictory. At one point, he claimed that malt "is without doubt one of the best anti-scorbutic sea medicines yet discovered," but then went on to say that he was "not altogether of opinion that it will cure it at sea."[17] He also recommended sauerkraut and lemon juice but thought lemons were not cost effective.[18] Cook was highly regarded, and an endorsement by him would certainly have carried weight with the British Navy.

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[13] Carpenter, *The History of Scurvy and Vitamin C*, 63.
[14] Carpenter, *The History of Scurvy and Vitamin C*, 74.
[15] Baxby, "Lind's clinical trial and the control of scurvy," 526.
[16] Bown, *Scurvy*, 167.
[17] Bown, *Scurvy*, 155.
[18] Baxby, "Lind's clinical trial and the control of scurvy," 526.

The implementation of a solution required a man with both strong intellectual capabilities and political influence to back Lind's effective remedy. The man who broke the deadlock was Gilbert Blane, whose powerful connections allowed him to enter the navy as personal physician to Admiral Sir George Rodney. Blane collected statistics on the death of sailors under his care. He found that only 60 out of 1600 deaths were from enemy action, and the rest were caused by disease. Having sufficient social status, he wrote directly to the admiralty advocating Lind's cure of oranges and lemons. Although Blane adopted his own recommendations with great success, the Admiralty refused to change their policy.[19] It was not until Blane was appointed Commissioner of the Board of the Sick and Wounded Sailors in 1795 that lemon juice was finally adopted as an official policy.[20] At this time, Britain was back at war with France and the economics of sick and unproductive sailors had become important. Between 1795 and 1814, the British Navy used 1.6 million gallons of lemon juice and the incidence of scurvy declined accordingly. This meant that the British were able to maintain their blockade of the French fleet throughout the war with Napoleon, while the French still struggled with the loss of sailors from scurvy.[21] Blane had convinced the Admiralty to adopt a cure that had been known for two hundred years. It took a man with powerful political connections who was in a position of power to facilitate the adoption of a proven treatment. James Lind had neither of those advantages and unfortunately died in 1794 never knowing that his cure was eventually adopted by the British Navy. Blane gave him full credit for his work however and, as a result, Lind's name will forever be associated with curing scurvy. In the nineteenth century, Britain switched from lemon juice to lime juice; thereafter, British sailors became known as 'limeys.'

The second scientist examined in this paper, Linus Pauling, had a very high-profile career two centuries after James Lind. He received a PhD in chemistry and physics in 1925 from CalTech in California and was awarded the Nobel Prize for Chemistry in 1954 for his work on chemical bonds. Following his wife's lead Pauling became an advocate against nuclear weapons and received a Nobel Peace Prize in 1962. Pauling is the only person to have received two unrelated Nobel Prizes that were not shared with another recipient. These two awards greatly enhanced his reputation within the scientific community and with the

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[19] Carpenter, *The History of Scurvy and Vitamin C*, 92.
[20] Carpenter, *The History of Scurvy and Vitamin C*, 95.
[21] Carpenter, *The History of Scurvy and Vitamin C*, 96.

wider public. While contemplating retirement Pauling stumbled across a new issue that peaked his interest: Vitamin C.

In 1966, Dr. Irwin Stone told Pauling that he could live another fifty years if he started taking large doses of Vitamin C. At the time, Pauling was 66 years old. Pauling's second influence came from two psychiatrists who were using high doses of Niacin and Vitamin C to treat schizophrenia. As a result, Pauling decided not to retire and became an advocate of Vitamin C.[22]

In 1970, Pauling wrote a book, *Vitamin C and the Common Cold*, to convince "both the public and physicians" that the widespread use of Vitamin C would control respiratory infections.[23] Pauling proposed the theory that humans lost their ability to make Vitamin C millions of years ago, when their diet was primarily vegetarian. He postulated that, although we need only 10 milligrams (mg) per day to prevent scurvy, our optimal intake should be about 2300 mg.[24] He surveyed studies complete before 1970, arguing that they showed that regular doses of Vitamin C prevented colds or reduced their longevity, and that high doses could treat existing colds. He maintained that Vitamin C was an effective and safe treatment and preventative for the common cold. Pauling expressed the hope that his book would inspire large-scale studies on the benefits of Vitamin C. He was particularly critical of the pharmaceutical industry for promoting cold medications that were ineffective, expensive and dangerous, and claimed that there was a medical conspiracy against Vitamin C therapy.[25] He quoted Dr. Gildersleeve who claimed that "effective treatment for the common cold … is being ignored because of the monetary losses that would be inflicted on pharmaceutical manufacturers, professional journals, and doctors themselves."[26] The irony is that the main beneficiaries of Pauling's theories have been the pharmaceutical companies he so despised.

In the mid 1970s, Pauling teamed up with researcher Ewan Cameron to demonstrate that Vitamin C intake had an even greater medical benefit: the treatment of cancer. Pauling claimed, "that a decrease of seventy five percent [in cancer mortality] can be achieved by use of Vitamin C alone, and a further decrease by use of other nutritional measures."[27] Pauling's claims were not accepted by either the medical or research communities who saw them as outside the bounds of his

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[22] Abram Hoffer, *Adventures in Psychiatry* (Caledon, 2005), 150.
[23] Linus Pauling, *Vitamin C and Common Cold (*San Francisco, 1970), 5.
[24] Pauling, *Vitamin C and Common Cold*, 64.
[25] Pauling, *Vitamin C and Common Cold*, 51.
[26] Pauling, *Vitamin C and Common Cold*, 48.
[27] Anthony Serafine, *Linus Pauling: A Man and his Science* (New York, 1991), 281.

expertise. As a result he took his case directly to the public. Pauling began to appear on talk shows and give interviews in popular magazines. He also undertook speaking engagements, in 1990 addressing 1,500 people at The University of British Columbia and 1,200 in Victoria. His campaign was successful. Manufacturer Hoffman-LaRoche responded to his book by doubling its production of Vitamin C.[28] By 2005, the global consumption of Vitamin C was 100 million kilograms per year.[29]

The studies that Pauling called for back in 1970 have since been conducted. Fifty-five studies of 11,000 subjects found that Vitamin C is only effective in populations exposed to significant cold or physical stress such as marathon runners or soldiers.[30] The duration of colds was only marginally reduced by the consumption of Vitamin C and only one study showed its effectiveness in treating colds.[31] A study that followed Vitamin C usage by 10,000 male physicians over ten years found no evidence that it was effective prophylactically to prevent cancer.[32] Two studies conducted by the Mayo Clinic were unable to repeat the findings of Ewan Cameron, which had been used to prove that high doses of Vitamin C could treat cancer.[33] Researchers are calling for more investigation to be done to see if Vitamin C is more effective used intravenously rather than orally.[34] Linus Pauling, it turns out, was more wrong than right on Vitamin C. He remained convinced of the benefits of Vitamin C, however, right until his death. He and his wife both took large doses of Vitamin C daily. Ironically both died of cancer, but Pauling did not die until 1994 at the age of ninety-three, twenty-eight years after Dr. Stone had predicted that Pauling could live another fifty years if he took Vitamin C.

James Lind and Linus Pauling worked in very different ways. James Lind looked for a foundation of fact and did not trust unsupported

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[28] Evalleen Richards, "The Politics of Therapeutic Evaluation: The Vitamin C and Cancer Controversy," *Social Studies of Science* 18 (1988), 658.

[29] "Chemical and Engineering News," *Top Pharmaceuticals: Vitamins* 83, no. 25 (June 20, 2005), 3.

[30] Robert M. Douglas and Harri Hemila, "Vitamin C for Preventing and Treating the Common Cold," *PloS Medicine* 2, no. 6 (June 2005), 503.

[31] Douglas and Hemila, "Vitamin C," 503. The study in question used a dose of 8000 milligrams and requires further research to be proven accurate.

[32] *Times Colonist*, November 17, 2008.

[33] Serafine, *Linus Pauling: A Man and his Science*, 267.

[34] Mark Levine, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland, podcast interview, May 19, 2007, http://lpi.oregonstate.edu/podcast/index.html. Intravenous administration is the injection of medication directly into a vein.

theories.[35] Regarding scurvy, he stated that, "it is indeed not probable that a remedy for the scurvy will ever be discovered, from a praeconceived hypothesis."[36] Pauling took the opposite approach, coming up with a theoretical hypothesis to a problem and then testing it against experimental evidence. In 1953, he put forward a theory on magnetism that, although proved wrong, showed that, as biographer Anthony Serafini recognizes, he "failed ingeniously."[37] Pauling's genius was his ability to think outside the box, allowing him to develop new scientific theories that challenged recognized conventions. These theories were often proven wrong, as was his theory on magnetism, but sometimes they were proven correct, such as the work on chemical bonds that garnered him a Nobel Prize. Pauling had the confidence, courage and imagination to deviate from conventional thinking and this led to discoveries that have made him a scientific legend.

More significant to the acceptance of their work on Vitamin C was the personalities of the two men. Lind was a "man of observation" but he did not have the patience, aggressive nature or powers of persuasion to change the minds of his employers. Conversely, Pauling was always a self-promoter. As early as 1925, long before he became famous, he persuaded local newspapers to publish an article on the study he was conducting in Germany. Having honed his ability to present his case to the public in his anti-nuclear campaigns in the 1960's, Pauling never hesitated to take what the medical profession regarded as a strictly scientific issue directly to the public. As a result, Vitamin C has become one of the leading alternative treatments for cancer and is still used by many to prevent and treat colds.[38] His success was enhanced by his dynamic personality. Science writer Isaac Asimov credits Pauling with "communicating enthusiasm and exerting charisma" in his speeches.[39]

By studying these two scientists, we see how different styles, personalities and social status can affect the acceptance of scientific research. Lind used groundbreaking experimental techniques to come to the correct conclusion, but was unable to convince those in power to implement his findings. It took forty years and someone with influence and power to make lemons standard naval issue. Pauling's theories on Vitamin C were wrong, or, at best, vastly overstated. Unlike Lind,

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[35] C.P. Stewart, "The Third Edition of the Treatise," in Lind's *Treatise on Scurvy: A Bicentenary Volume containing a reprint of the First Edition of A Treatise of the Scurvy by James Lind, M.D*, eds. C.P. Stewart and Douglas Guthrie (Edinburgh, 1953), 361.
[36] Stewart, "Third Edition of the Treatise," 361.
[37] Serafine, *Linus Pauling: A Man and his Science*, 161.
[38] Richards, "The Politics of Therapeutic Evaluation: The Vitamin C and Cancer Controversy," 657.
[39] Serafine, *Linus Pauling: A Man and his Science*, xiv.

Pauling's powers of persuasion and elevated social and scientific status facilitated the acceptance and implementation of his theories by the public, without them being proven scientifically. Pauling's Vitamin C campaign was so successful that it inspired what is termed the 'Pauling Effect.' This maxim states that there are some scientists whose reputation is so great that any theory they propose receives instant credibility. The experience of these two scientists demonstrates that success or failure is not always determined by the strength of experiments, but rather by the strength and reputation of the scientist conducting the research.