7-27-2020

A Grain of Salt (text and video)

Timothy Rettich
Illinois Wesleyan University

Kemp Award Address 2020
Timothy Rettich

"A Grain of Salt"

April 8! The theme of this talk was written with this date for Honors Convocation in mind. It was intended to be not only timely, but also somewhat light-hearted. The times have changed, but I decided to keep the same talk, thinking that light-heartedness, like toilet paper, is now in short supply. But by keeping the same talk you will note some anachronisms. Those of you playing along at home can keep track of how many temporal mistakes I make.

My talk formally starts by thanking President Nugent, Provost Brodl, members of the Kemp Foundation, and the faculty and staff of IWU for the privilege of addressing our student honorees. I thank our current students and those from years past as those ultimately responsible for me being here. And a special "thank you!" to my family who bore with me the last twelve months as I wrote and revised many versions of this presentation. I finally organized this talk like my general chemistry lectures: I start with a bit of science-related history, include a chemical of the day, then on with the main topic (with a demonstration if there is time.) So, on this date in 1869:

SLIDE 1: April 8, 1869; photograph of Dr Cushing

Harvey Williams Cushing was born. In 1902 he performed the first brain surgery in the US. He was the first to use x-rays and blood pressure measurement in surgical practice, he discovered the role of the pituitary gland, and he introduced the practice of using a saline rinse for irrigation of surgery wounds. [1] We will come back to Dr Cushing's work later, but for now, just note his use of a saline rinse on surgical wounds. **SLIDE 2: Sodium Chloride (NaCl)** The term "saline"

refers to aqueous salt solutions. And our chemical of the day is sodium chloride, common, ordinary salt. But don't worry; this won't be a lecture on the chemistry of NaCl (fascinating though that is.) Instead we will look at the extraordinary role that ordinary salt has played… in our bodies and in society, from ancient times to modern, and salt's religious, economic, and political significance.

Humans and salt have a long and amazing history together. The connection may go back to the start of life on earth, which some think began in the ocean since the cells in our bodies reflect a salty, aqueous origin. The human body has roughly 250 g of salt, or about 3 to 4 salt shakers full. [2] We lose about 5-10 grams of salt from our body every day. Urine, sweat, tears all remove salt, as does loss of blood. Our bodies need salt for a variety of reasons. One example: every cell in our body has special pores that allow sodium ions to move back and forth across the cell membrane. The resulting concentration difference makes tiny batteries that do electrical signaling. Our nerves and muscle fibers are activated by those electric signals. That is how the muscles I am using to talk are triggered, that is how your perception of sound travels from your ear to your brain, and that is how the many nerve cells in your brain signal back and forth in a way that elicits meaning from those signals.[3] Our need for salt is in a real sense "hard wired" in us. But symptoms for low salt levels are vague: headaches and weakness, followed by light-headedness and nausea, followed by death. [4] Natural selection solves that problem, possibly by our surviving ancestors having developed an enhanced sense of taste for saltiness, or perhaps a psychological craving for salt.[5] Salt cravings in today's humans, however, are reported to be most often triggered by boredom.

SLIDE 3: image of potato chips, caption: "When is Lunch?"

Well, you can easily satisfy your salt cravings soon. But what about our human ancestors two million years ago? Salt is a solid mineral (a rock) and humans do not have the habit of eating rocks. At that time, our ancestors were hunter-gatherers, and the red meat they ate was rich in salt. For example, the Maasai, current nomadic cattle herders, meet all their salt needs by bleeding their cattle and drinking the blood. [6] But when some of our ancestors changed from hunting and gathering to an agricultural based food supply, a diet of grains and vegetables would likely not provide enough salt. Even supplementing their diet with occasional meat from slaughtered domestic livestock would not necessarily provide the salt needed. The free range Maasai cattle can find their own salt, but cattle confined to a farm cannot. **SLIDE 4: Cow and a commercial salt lick** Instead they have to be provided salt by their human owners in the form of a commercial salt lick.

Herbivores in the wild sometimes find natural salt licks, outcroppings of solid salt formed from the evaporation of water from salt springs. Humans entering new territories may have learned to track animals to find these sources of salt. That area would not only provide good hunting, it would be a source for humans to collect salt for their own use.

Communities historically grew up around salt resources.[7] It would be ill advised to settle far away from a critical need. As we will see, there is a large demand for salt, it is a bulky commodity, and transporting salt any distance on land is a pain without a good road system.[8]

SLIDE 5: The Roads of Ancient Rome

And if we are talking roads, that inevitably leads us to Rome. The Roman Empire built many roads, but the earliest is thought to be the *Via Salaria*, the salt road, which started at *Porta Salaria* (the salt gate in the walled city) and ran east to some salt marshes on the Adriatic.[9] This

connected Rome to a means of salt production. The Romans built their roads not only to move their armies quickly but also to establish commerce. Much of the early trade was in salt, but the Romans soon realized that it was more efficient to set up salt works along the way that could supply the salt their armies would need when on the march, and use excess salt for trade. This connection among salt, armies, and money is thought to be the origin of our words 'salary' and 'soldier'.[10]

The original technique for making salt was a bit primitive. A large clay pot was filled with salty water and heated over a fire. As water boiled off, more salt water was added. Eventually (after burning an enormous amount of wood) the clay pot would be filled with a solid lump of low-purity salt. The clay pot was then broken to get the salt block. This may partially answer the question why some excavated Roman sites have tons of broken and charred pottery. [11] Over time, they learned to use solar heating to evaporate the water. This was done in stages with a dozen or so separate large basins dug into the earth at various elevations. The first and highest was the starting solution: sea water (if necessary) or perhaps brine from a salt marsh (which would be preferable since it is already higher in salt concentration.) As the sun caused water to evaporate, the salt became more concentrated. It was then drained into the second, lower basin for additional concentration. The process was repeated. Sea water starts out at about 3.5% total salts. Of this total salt, about three-fourths is NaCl, which is the most soluble. The rest are mostly magnesium, calcium, and iron salts. Between the third and sixth basin, those other salts begin to precipitate as solids, with the remaining solution becoming more and more concentrated in NaCl.[12] In the final basin the liquid is highly concentrated in relatively pure salt.

SLIDE 6: Cargill Facility San Francisco Bay, with red ponds.

Current salt production facilities, such as pictured here, still use this procedure. The saturated salt solution is often red at this point, as it is easily contaminated by an odd microorganism, Dunaniella salina. It is odd in that can survive at this high salinity (which very few microorganisms can do) and it is odd in that it produces beta carotene, which gives tomatoes and carrots their color.[13] The salt that first starts to crystallize at the surface is called "*Fleur de sel*" a premium fine grain white salt sought by connoisseurs. The bulk of the salt collected is from the bottom of the basin. It is coarser, more contaminated, and is usually more gray than white. [14]

There are well over a hundred specialty salts of varying colors commercially available. **SLIDES 6, 7, 8: Red Salt, Black salt, pink salt** Hawaiian alaea salt is red from the volcanic clay impurities mixed with NaCl. Hawaii also produces a black lava salt, where minerals leached from lava contaminate the NaCl. Himalayan salt from Pakistan is pink due to several trace impurities including iron. But absolutely pure NaCl is….? **SLIDE 9: Colorless salt** Colorless. Sorry, no partial credit for guessing 'blue'…that is just the color of the background.

The relatively pure salt one normally sees appears white partially because the colorless crystals absorb water vapor from the air. That mars the surface and makes it appear hazy white. The white color mostly comes from diffusion, refraction, and multiple reflection of light inside the crystal.[15] In the same way, a pane of window glass is transparent and colorless, but when smashed into small bits, the shattered pieces appear white.

Solid salt can often be directly obtained by scraping the surface of dried rivers and lake beds found in some deserts. But getting a load of salt back across a desert was a real logistical problem. By the middle ages, camels were domesticated, and they were used to transport these scrapings. Later, huge deposits of solid salt near the surface were

found in the Sahara. Numerous two-hundred pound blocks of salt were carved out and two such blocks were placed on each camel.[16] Reports of caravans with camels numbering in the thousands were common at this time, arriving in Timbuktu, a key trading station in Mali. That is a lot of salt. **SLIDE 10: Musa Keita** The 14th century emperor of Mali, Mansa Musa Keita, is thought by some historians to have been the richest human ever, due mostly to the salt trade. [17]

But why so much salt and so much money? The driving force in the middle ages was the use of salt as a food preservative. That story seems to have begun much earlier, in pre-dynastic Egypt. **SLIDE 11: Ancient Egypt** The land immediately adjoining the Nile river for a couple of miles on either side was arable. Beyond that narrow belt was desert; the river tributaries and lakes that had been there evaporated long ago, concentrating salt, and letting it mix with the encroaching sand. With little land available for growing food, human burial occurred in the nearby desert. The cadavers discovered there today as the sands shift are not mummies, but are surprisingly well preserved, still with flesh and skin (and a similar sight would have greeted burial parties when they went out around 3000 BC.) Such a gruesome discovery likely was a seminal moment for those early Egyptians. Their fascination with the afterlife and religious ceremonies, the elaborate making of mummies and pyramids, all likely flowed from such observations. The dry air of the desert and the saltiness of the soil preserved the buried bodies. Eventually, the Egyptians began to deliberately mummify the dead: simple salt (NaCl) was used to preserve bodies from the lower classes; higher class individuals were mummified using "natron", a naturally formed but rarer mixture of NaCl, Na2CO3, and NaHCO3.[18] While sodium chloride salt is neutral, natron is basic and thus even better able to kill off bacteria.

As the preserving nature of salt became religiously significant to the Egyptians, the same happened to the Jews. In the Torah, the sacred

agreements between God and his chosen people were called salt covenants, indicating their eternal nature. On the Sabbath it is customary for Jews to eat bread dipped in salt. The bread may symbolize the joy of gathering and the salt may symbolize the holy nature of that gathering and the preservation of the covenants.[19] In Shintoism, salt purifies locations. **SLIDE 12: Sumo salt ritual** The salt ceremony preceding a sumo wrestling match reflects this. In the Buddhist tradition, after a funeral, salt is thrown over your left shoulder to prevent evil spirits from following you.

In the Christian tradition, Jesus instructed his followers to be "the salt of the earth" possibly meaning they should help preserve humanity from the corruption of sin. Given its holy associations, the accidental spilling of salt is seen as an evil omen.[20] **SLIDE 13: Last Supper; Slide close-up.** In "The Last Supper", da Vinci incorporates many details, including Judas spilling the small dish of salt used for dipping bread.

What the Egyptians learned by studying the mummification process was then applied to food preservation.[21] Salted meat and salted fish began to appear in food offerings left for the deceased in their burial rituals, and details of the making and use of salt in preserving food appeared in murals painted on the walls inside the pyramids.

Salt is a preservative of animal and plant tissue because it excels at tying up the water in the tissue. By depriving the bacteria of water, salt can kill off bacteria.

Let's try a demo. I could show the actual preservation of food, but then you would have to be very patient, waiting a couple of weeks, to observe the effect. Instead I am going to use a model system. I start with a fair amount of water and food color for visibility. Then I add a small amount of organic polymer to it and stir. This polymer is used in overnight super-absorbent Pampers, baby diapers. This polymer excels

at holding onto water, bending and twisting its long chain to maximize the exposure of the part of the polymer that likes water, and forming this gel. This is a model system for living tissue: large organic polymers submerged in a lot of water. This tissue would be a tasty meal for bacteria. But if we add just a bit of regular salt, the salt wrestles the water away from the polymer. Consequently, the gel disappears and the physical shape the polymers had been in when surrounded by water is altered by the presence of salt.

When food is treated with salt as a preservative, not only is spoiling avoided by killing bacteria, but the food may also become more digestible. One example is olives, which as picked from the tree are essentially inedible, even when ripe. Only after olives are cured with brine are they eaten.[22] Also note the common use of a medical term "cure" in describing the effect of salt on food, as in "curing a ham".

Salt became essential by making food available for large scale and long distance commercial trade. Lots of wealth changed hands and governments payed attention. China began a salt tax and used the profits to build the Great Wall.[23] Ancient Rome used a salt tax to fund the Punic Wars.[24] When Rome finally fell, salt production moved north to Venice, located on islands with salt marshes that made salt production highly profitable. In time the Venetians learned that there was even more money to be made by moving away from just the manufacture of salt and into monopolizing all aspects of the salt trade: buying, reselling, and transporting salt.[25] They became the Amazon of the middle ages, with a huge commercial fleet that became a powerful navy. **SLIDE 14: Venice** The Venetians built amazing architecture from the riches they drew from the sea in the form of salt. Ironically, with rising sea levels, that splendid architecture (this one looking like a ship) is now sinking back into the sea.

Salt often appears in the fall and rise of governments. The French revolution was fueled in part by the citizens' hatred of the gabelle, the royal salt tax.[26] 90 years ago this week, Mahatma Gandhi **(SLIDE 15: Gandhi collecting salt**) initiated a non-violent overthrow of British colonial rule in India with his march to the sea to make salt.[27] That violated a law that all salt in India had to be purchased from the British, but Gandhi convinced his countrymen that making salt was an undeniable human right.

There are many proverbs or common sayings about salt. One website listed 287 examples.[28] I will close by mentioning just two. But if I <u>did</u> read you <u>all 287</u> sayings, I might be said to be "rubbing salt in the wound", commonly interpreted as compounding an injury, like kicking someone when they are down, or twisting the knife.[29] But a closer look finds this interpretation problematic. Putting salt in a wound does cause pain, but is it necessarily nasty in its <u>intent</u> (like twisting a knife)? Salt is, after all, an antiseptic, one of the few that has been available throughout human history. Sailors in particular were known to use salt as an effective, albeit painful disinfectant at a time when even a small cut getting infected could prove fatal.[30] Also, remember Harvey Williams Cushing? He began the practice of rinsing surgical wounds with salt water.

Finally, I end with one last saying about salt that relates to this year's theme of "fact or fiction". We are told to consider evidence and arguments with "a grain of salt." Figuratively, that encourages us to be somewhat skeptical, not to believe everything we see or hear. (For example, maybe salt is not really white; maybe putting salt in a wound is not always bad.) Note we are advised to take a <u>grain</u> of salt, not a pound or a cupful. Too much skepticism becomes cynicism, which can lead to dismissing inconvenient facts as "fake news". And why "<u>salt</u>" in the expression? Why not a grain of <u>rice</u>? The <u>original</u> Latin expression "cum grano salis" commonly translates as "with a grain of salt". Sal,

salis is Latin for salt, but has a second meaning of wit or wisdom.[31] Those terms apply to an understanding of the human condition and of ourselves. When we are advised to take a grain of salt, we are also asked to take that skepticism, that preservative from error, and apply it to our own thinking, for our own benefit, to cure our prejudices. We should question our own opinions with the same skepticism we apply to the opinions of others. And that *little* grain of salt can have a very *big* effect. Thank you.

1. Today in Science History, https://www.todayinsci.com, accessed online 5-31-19
2. "How much salt is in a human body?" Len Fisher, BBC Science Focus Magazine, accessed online 5-31-19.
3. "In Their Element: Sodium the Key to Life" BBC Science, https://www.bbc.co.uk/sounds/play/b0bd9123, accessed online 11-5-19.
4. Kurlansky, Mark, *Salt: A World History*, Penguin Group, New York, 2002, p. 9.
5. Laszlo, Pierre, *Salt: Grain of Life*, Columbia University Press, New York, 2001, p. 96.
6. "Traditional Maasai Food: Blood and Milk" by Thomson Safaris, January 16, 2014, accessed online 5-31-19.
7. Kurlansky, p. 200.
8. Laszlo, p. 22
9. Kurlansky, p. 63.
10. Kurlansky, p. 63.
11. Kurlansky, p. 64.
12. Laszlo, p. 47.
13. Laszlo, p. 49.
14. Kurlansky, p. 80.
15. Laszlo, p. 49.
16. Kurlansky, p. 49.
17. Business Insider, Feb 14, 2018.

18. Kurlansky, p. 42
19. Laszlo, p 144.
20. https://www.leaonardodavinci.net/the-last-supper.jsp, accessed 5-31-19.
21. Kurlansky, p 44.
22. Kurlansky, p. 40.
23. Kurlanski, p 31.
24. Kurlansky, p 62.
25. Kurlansky, p 84.
26. Laszlo, p 74.
27. Laszlo, p. 89.
28. https://brainyquote.com/topics/salt, accessed online 5-31-19.
29. Wiktionary, https://en.wiktionary.org/wiki/rub-salt-in -the-wound, accessed 5-31-19.
30. Laszlo, p.4.
31. Latin Dictionary and Grammar resources, https://latin-dictionary.net/definition/33925/sal-salis, accessed online 5-31-19.