Modern Merchants of Light

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Today many of you will be giving talks and posters for the first time ever. So, in an act of *esprit de corps*, I pushed myself out of my comfort zone and put together a talk unlike any I've ever given. Normally, I assemble some slides and talk off the cuff. This time I wrote the whole thing out (something I never do), and tried to keep the slides to a Spartan minimum. As such, this talk is an experiment, and that makes me a little nervous. I mentioned this concern to my eight-year-old son Jack last night when he was kicking my butt in a Pokemon card game, and he gave me unusual advice for a science talk. It went something like this:

Jack: "Dad, who was that guy who set the slaves free? Junior Martin?"

Me: "Lincoln freed the slaves, buddy. But Martin Luther King, Jr. fought to get equal rights for everybody regardless of color."

Jack: "Oh, okay. Well, I read when he ran out of stuff to talk about he just talked from his heart. So, just talk from your heart."

Me: "Talk from the heart? To scientists?"

The truth is, it is great advice. We do science because we love science. Speaking from the heart doesn't sound so strange in that context. What I plan to do in this talk is to start by explaining what "Merchants of Light" are and then use quotes from some famous Merchants of Light to guide the talk.

Let's start with a story:

> For the several employments and offices of our fellows, we have twelve that sail into foreign countries under the names of other nations (for our own we conceal), who bring us the books and abstracts, and patterns of experiments of all other parts. These we call merchants of light.
>
> -Sir Francis Bacon, *New Atlantis* 1626

In his utopian short story "New Atlantis," Sir Francis Bacon imagined a peaceful, hidden country full of futuristic marvels like hybrid animals, telescopes, and automatic water pumps. This world pursued invention and innovation in isolation, as their emissaries wandered the world incognito, collecting the latest in scientific knowledge. These emissaries were New Atlantis's Merchants of Light because they brought scientific knowledge to the people. Many have interpreted Bacon's Merchants of Light as the modern scientists employing the scientific method Bacon himself formulated. While I think that is true, I think the first thing it is important to recognize is that the primary duty of these individuals in the story was to communicate new ideas in science to the citizenry. The second thing we should take note of is that

Bacon chose to introduce his hopes and dreams for the role of science in the future in a story. A fictional story. While this may seem like a funny place to put important ideas about science, I hope to convince you that it is an essential approach.

> *We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology.*
>
> -Carl Sagan

We live in a time when biomedical advances are rapidly expanding the ethical considerations with which citizens and policy makers must grapple, when communities battle over what qualifies as science in public schools, and when taking action on global climate change is influenced as much (and probably more) by economics and political agendas than it is by the merit of the science. In this climate, we confront the disheartening fact that only one in five Americans comprehend or appreciate the value or process of scientific inquiry.[1] Students in the United States are performing at or below the performance levels of students in other developed countries in science and mathematics, and according to the National Assessment of Education Progress (NAEP), the science proficiency of high school seniors has dropped from 21% in 1996 to 18% in 2000.[2]

That's a bummer, but here is the crazy thing: in the National Science Foundation's (NSF) "2010 Report on Science and Engineering," the majority (70%) of students in eighth grade and below reported liking science and mathematics despite the fact that they also considered them more difficult than other subjects. I can attest to this. I run a program at my sons' elementary school called "Inverte-brata-rama" in which I show and tell kids about various creepy crawlies and help them to write a comic book about their favorites. There is no shortage of enthusiastic hands that greet every question I ask. Neither is there a shortage to the questions that they ask. They are natural experimentalists. But something happens between then and when I see them again in college. It's called high school. High school students begin to diverge from their peers in other developed countries, underperforming significantly by comparison.

So, what's happening? A big part of the problem is that high school students report that they don't understand why math and science are important to their everyday lives. Obviously, something isn't quite right.

In a report from the National Science Board (NSB) on Communicating Science and Technology to the Public, the board underscored the need to communicate the fascination, joy, and utility of science.[3] Who do you suppose is going to do that?

> *He who can, does. He who cannot, teaches.*
>
> -George Bernard Shaw

Anyone who has ever tried to teach anything to anyone else knows that Shaw's quote is a big pile of horse crap. Teaching or explaining something well is hard because a good explanation requires clarity and thoughtfulness. You undoubtedly wrestled with this as you were preparing your presentations. I can

see it in my ten-year-son Max's burbling excitement when he wants to talk about quarks and gravity waves but is struggling to find a way to explain it so that his dumb dad can understand it. Once on a trip to State College, Pennsylvania, he started reading something about gravity waves from *Scientific American*. As he was reading, he slowly fell into the article and his voice trailed off. When I told him that I didn't quite catch what he had just said, his small voice from the backseat said, "Okay, Dad, I'll try to put it in simple terms." And then he did.

Enthusiasm is not necessarily required, but it can be the vital ingredient to capture someone's imagination. Frankly, you have to know something well to explain it well and you need to feel the wonder to convey the wonder. This requires expertise. That is why you are the ideal candidates to be modern Merchants of Light. And fortunately, you have great subject matter to work with.

Science is the poetry of reality.
-Richard Dawkins, *The Enemies of Reason*

Now I know what you're thinking. This is going to be easy! The natural world is a veritable treasure trove of excitement. It is a toy box full of wonder. We've got the data, the experiments, the libraries full of books and journal articles. Certainly Dawkins was right. But, as someone who has read his fair share of poetry can attest, poetry sometimes requires interpretation, clarification, and guidance from someone who knows what the heck is going on. That is the hard part.

There is no shortage of wonder in the universe about which we can wax poetic. We live in a cosmos that contains objects with such an intense gravitational pull that they bend the very fabric of space and time. We live on a planet in which the continents shift under our feet and there are bacterial species living deep in the Earth that use decaying uranium (instead of sunlight) as their source of energy. We are the product of self-assembling replicating molecules that can configure matter in such a way as to build a brain which is self-aware. There is no shortage of wonder. There is, however, a shortage of clarity and context.

All science is either physics or stamp collecting.
-Ernest Rutherford, 1962

I've always hated this quote, but I was never sure if it was because I think it is so completely unfair or because it was so disturbingly accurate. It wasn't until I started preparing this talk that I realized it was both. It is unfair, because all the natural sciences have compelling stories, just like the beautiful mathematical stories that underlie physics. Unfortunately, the beauty can get lost in the disconnected laundry lists of species names, orbital shells, and types of rocks that we have to memorize. Don't get me wrong — a certain basic working knowledge is essential. But if there is no coherent story to knit that factual information together today, then you are going to lose a lot of great thinkers.

I can remember watching several good friends migrate from biology to physics or mathematics in college because they weren't good at memorizing, and they saw that as the primary requirement for

studying biology. They saw no coherence in the ideas because little was presented to them. This notion is supported in an NSB report that indicated textbooks now present more content with less coherence.[4] In other words, they are books with lots and lots of stamps.

As I consider why I stayed in biology (given that I'm not particularly good at memorization), I've come to the conclusion that it's because I had been reading about this stuff on my own since elementary school. I can remember carrying around *The Hot Blooded Dinosaurs* by Adrian Desmond in fifth grade, *Cosmos* by Carl Sagan in ninth grade, and whatever Isaac Asimov I could find. These guys were storytellers, and for me the stories made all the difference.

The symbol and the metaphor are as necessary to science as to poetry.
-Jacob Bronowski, *Science and Human Values*

My sons Max and Jack have the astonishing ability (shared by most kids) to remember the minutest details from stories. (They also remember every single promise you ever make them, so be careful). Anyway, I read aloud to them every night for an hour or so, and they absorb the stories. It doesn't matter what the content is. We've read everything from Roald Dahl to Stephen Hawking and the ideas in all of them stick. Psychologists say that this is because the information is situated in the narrative and that humans are wired to remember stories. We internalize symbols and metaphors. We personalize them and connect with characters. Stories allow us to slide into characters and experience what they experience. If this wasn't true, we wouldn't cry at the end of *Old Yeller*. Heck, he wasn't my dog, but there I was getting all misty-eyed. The question I asked, as an aspiring professor over ten years ago was, "What if I wrote a story in which the characters experienced science? And what if the story had pictures?"

Comics are just words and pictures. You can do anything with words and pictures.
-Harvey Pekar

Harvey Pekar was the author of *American Splendor*, an alternative comic about his life and experiences as a file clerk. They were compelling, but not traditional, comics. He and several others were pioneers in using comics to do more than tell superhero stories. I grew up reading and making comics and wanted to see what happened when I mixed them with biology.

In the last ten years, I have written and drawn three graphic novels about science. My research in graduate school and as a postdoctoral researcher was with honey bees. People always thought that was strange, but only because they didn't know the honey bee's story. So, the first graphic novel I wrote was the biography of a honey bee. Evolution is the cornerstone of modern biological thought, but is often misunderstood, so my second book is a conversation about natural selection between Charles Darwin and a follicle mite living in his left eyebrow. My third book is a comic book textbook for my Sensory Biology class that was funded by a grant from NSF. It features the eye-themed adventures of Wrinkles the Wonder Brain. All of them situate information in a story and are my attempt at being a Merchant of Light.

For many students, the traditional tool used to access knowledge in college is the textbook. As a natural born nerd, I love textbooks. But many people less enamored with science can find them intimidating. Everyone loves comics, though. I have done some preliminary experiments with my last book that focused on how comics might help improve science literacy. My book *Optical Allusions* uses comics to introduce basic concepts about evolution and eye biology. I tested it in my Sensory Biology course, which is primarily populated by non-science majors. I gave students a pretest to assess what they already knew about evolution and eyes (the content test), another to asses their attitudes about biology, and a third to assess the attitudes about comics. Then, two weeks after using the book, I gave them the same three tests to see if anything had changed.

In terms of content, I am happy to report that the comic didn't make them dumber. In fact, everyone did better on the content test, suggesting they had learned something. In terms of the attitudes, the Sensory Biology students had a significantly improved attitude about biology after using the book and that was correlated to an improved opinion of comics. All in all, we take this to suggest that comics might have played a role in making science fun and in communicating some of the wonder I feel as a biologist. It is a small step, but every little bit helps.

There are a couple of things I hope that you take away from this talk. First, not everyone is going to make comics to explain their science. This is my modest contribution to the effort. If the ardent defender of evolution T.H. Huxley was "Darwin's bulldog," then I am more like Darwin's Chihuahua – a small, yipping Merchant of Light.

Second, you should give a significant amount of thought to how you explain your science. From the public's standpoint, the most beautiful experiment in the world is only as elegant as its explanation. Teaching, whether formally or informally, is no trivial pursuit. Explanations instruct, but great explanations can inspire.

Finally, you are the scientists in your dorm rooms. When you graduate, you will be the people in your neighborhoods with scientific training. And people will expect you not only to know things but to be able to explain them. A few years ago during a visit to my folks in Indiana, my dad and I were sitting outside and we were looking at this gigantic cloud in the sky. He asked me what kind it was, and in the exasperated tone sons reserve for their fathers I said, "How should I know?" He replied, "Well, you're the scientist."

To most in the public the big differences between an inorganic chemist, a behavioral biologist, and a cosmologist aren't that big. Like it or not, we are the scientists; we are the modern Merchants of Light. And in a society so deeply dependent upon science, and simultaneously uncertain of it, that is a significant responsibility. Of course, you don't have to do it. You can employ the self-serving philosophy Shaw discusses and say dismissively that you are a do-er, not a teacher. But, if you abdicate that

responsibility, it will almost certainly be taken up by someone else, and the results can be disastrous, especially if the explaining is being done by those with political and economic agendas.

Allow me to conclude as I began, with a quote from Carl Sagan (because for me any discussion begins and ends with Sagan). I believe it is the perfect sentiment to kick off our conference and the exchange of new ideas. Good luck.

Somewhere, something incredible is waiting to be known.
-Carl Sagan

P.S. I eventually looked up the name of the cloud, by the way. It was a cumulonimbus. My dad was pleased to know it.

NOTES

1. National Science Board, *Communicating Science and Technology in the Public Interest*, NSB Publication No. NSB-00-99 (Arlington, VA: National Science Foundation, 2000).
2. W.S. Grigg, M.A. Lauko, and D.M. Brockway, *The Nation's Report Card: Science 2005*, NCES 2006–466 (Washington, DC: U.S. Department of Education, National Center for Education Statistics, 2006).
3. National Science Board, *Communicating Science and Technology in the Public Interest.*
4. National Science Board, *Science and Engineering Indicators 2004*, NSB Publication No. NSB 04-01 (Arlington, VA: Division of Science Resources Statistics, National Science Foundation, 2004).