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Humpback Whales, Bacteria, and the Liberal Arts

Remarks by Anne Bernhard, Professor of Biology
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Thank you, President Bergeron, for the invitation to speak today, and thanks to all of you for being here.

I thought I would start out today by telling you a little bit about how I came to do what I do. For as long as I can remember, I wanted to be a biologist. Not just any kind of biologist. I wanted to study whales. And not just any whales, I was going to study Humpback whales, because I had read all about them in National Geographic magazines. And I was going to swim with them. So when I went to college, it was no surprise that I studied marine biology, and even took scuba lessons and got certified to dive. But when I was a senior, one of my professors told me there were no jobs and no money in marine biology, and that I should consider doing something else. Not really the words I wanted to hear after spending 4 years studying to become a marine biologist, but his words made a huge impression on me. So when I graduated, I tried a lot of different things and I studied lots of other organisms.

I spent a year in Alaksa studying seaweeds, where at least I got to see some whales in the distance. Then I spent a summer studying an endangered bird, the marbled murrelet, but most of that involved schleping around in the forest in the dark at 3 am, where there are very few whales. And after that, I worked in a research lab where I had to cut off rat heads with a guillotine. Rats are really not very similar to whales at all. None of these jobs got me closer to studying whales, but I did learn a lot about a lot of different things. And, I finally made the decision to go to graduate school to get a master's degree in Environmental Science. My thesis project was... not about whales, but instead about the tiny organisms, plankton, that whales eat. Aha! I'm finally doing something that's sort of, kind of like studying whales. But then, I quickly fell in love with the tiny creatures, and that's how I ended up at the other end of the size spectrum, studying bacteria, which are not even close to whales.

I study the bacteria that live in salt marsh mud. I slog around in stinky, gooey muck, fighting off pesky mosquitoes and ferocious greenhead flies that take a chunk of flesh out of you every time they bite you. A far cry from swimming with Humpbacks in pristine ocean waters. But there's something incredibly exciting about studying bacteria, and I can't imagine doing anything else.

Bacteria are amazing. These invisible, single-celled creatures have amazing powers. Not only can they do all the things you probably already know about, like cause disease and make yogurt, they do a whole host of other odd and crazy things. They can eat rocks, they can be used as batteries, they can make it rain, they can find land mines, they can remain alive for thousands of years buried deep in the permafrost of the Arctic. They are even involved in the production of chocolate and coffee. Bacteria are the most abundant life-forms on the planet and provide half of the oxygen that we breathe, so don't give all the credit to the plants. And yet, only a tiny fraction of these organisms has even been identified or described. Several years ago, some researchers took samples from the ocean and found over a million bacterial genes that we had never seen before — and not just slight alterations on previously known genes — these were genes that we could recognize as a gene, but we had no clue what they did, and thus, no clue what the bacteria that had these genes did. Although we know a lot about them, there is far more about bacteria that we don't know.

Because we know so little about them, much of what we learn contradicts what we thought we knew. As a postdoctoral scientist, I was lucky enough to be a part of a new discovery that challenged what I had always read about in the textbooks. At the time, I was studying bacteria that live in mud in salt marshes, with a focus on bacteria that eat nitrogen, especially those that eat ammonia. There's a process, called nitrification. It's when bacteria get energy from eating ammonia. Up until 2005, there were only a few types of bacteria that could do this. But when we measured the amount of nitrogen that was being eaten and then we counted the bacteria that were there that could eat it, the numbers didn't match. There were not enough bacteria there to eat all the ammonia being eaten. We figured there must be something else eating ammonia. So we started looking. And looking. And looking. And what we finally found surprised us all. The ammonia-eating microbe wasn't even Bacteria, but instead it belonged to an entirely different branch on the tree of life called Archaea. These are also single-celled organisms without a nucleus, much like the Bacteria, but they are really distinct in terms of their structure and their evolutionary history. The archaea that we knew about at the time all ate carbon, not nitrogen. But after several more experiments, and checking, double-checking, and triple-checking our data, we were certain that these Archaea were definitely eating nitrogen. Now the textbooks had to be rewritten. (Perhaps this is why new editions of textbooks come out every year and make the prices so high.)

Lucky for us, our new discovery was accepted with excitement by the scientific community, even though it challenged what we thought we knew. But this has not always been the case when people propose new ideas. In the late 1970's , Carl Woese, a molecular biologist, proposed a new branch on the tree of life that was based on an organism's DNA rather than what the organism looked like. Up until then, there were basically two types of life — cells without a nucleus (bacteria) and cells with a nucleus (everything else). Woese was studying a specific type of bacteria (or what he thought was bacteria) that produced methane and noticed that it was different from any other bacteria we knew. Even though it was a cell with no nucleus, just like bacteria, it was different in many other ways. By studying its genetic code, and comparing it to the genetic codes of other organisms, he showed that this unusual methane-producing organism was as different from Bacteria as Bacteria were from everything else. Based on this evidence he proposed a new branch on the tree of life, the Archaea. His proposal was not just dismissed by scientists, but was met with hostility. He was even called names, including a crazy crackpot, and was no longer accepted in the scientific community. It took many years to convince other scientists to abandon their dogmatic views about the tree of life and consider a new tree of life based on new evidence. (On a side note: Carl Woese was later vindicated, and was given the Crafoord Prize for his work [the Crafoord prize is an annual science award given in categories not covered by the Nobel Prize], and once again he was embraced by the scientific community as one of the brilliant biologists of our time.)

So where am I going with all this? In my 30+ years of being a scientist, there are two things I have learned. The first is that much of what we know now will probably be wrong 100 years from now. Not a very comforting thought for those of you about to spend the next 4 years learning new things!

During your next four years, your ideas and what you think you know will be challenged (or at least I hope they will). You will be asked by your professors to consider new ideas, even when they conflict with your own. Your professors will ask you to turn your ideas sideways and upside down. They will ask you to throw out old ideas and embrace new ones. They might even ask you to come up with your own new ideas. My advice to you is don't be like the scientists who called Carl Woese a crazy crackpot, and held on to their theories even in the face of contradictory evidence. Be more like Carl Woese, who, when faced with new information that challenged his current knowledge, kept an open and objective mind, so that he could make revolutionary discoveries, and change the way we think about things.

I told you there were two things I've learned. The second thing that I have learned is that much of what we study in science is often connected in unexpected ways to ideas and theories in other disciplines. The most obvious one for me is that all organisms are given a Latin name, a genus name and a species name. The names are often long and hard to pronounce, but if you know a little Latin, you realize that the names are actually very informative. For example, the nitrogen-eating Archaea I just told you about is named *Nitrosopumilus maritimus*, which means nitrogen-eating dwarf of the sea (it's an extremely small microbe, even by microbe standards).

But there are plenty of other examples of how science is related to or influenced by other fields of study. Thomas Malthus, a political economist, is famous for his work on human population growth and the world's food supply, arguing that human populations will always outpace the supply of food. His work, however, forms the basis for the entire field of population ecology, the study of how populations grow and interact with the environment.

Another example, Game Theory, which was developed by a mathematician, and driven, in part by the idea of bluffing in a poker game. Game theory is mainly used in economics, but John Maynard Smith, a biologist, argued that Game Theory could be used to help explain certain behaviors in evolutionary biology. Maynard Smith was later awarded the Crafoord Prize for his work in this area, and Game Theory now forms a major branch of study in evolutionary biology.

And then there's The Red Queen hypothesis, which states that organisms must constantly adapt, not only to reproduce successfully, but also just to survive, and was inspired by a statement made by the Red Queen to Alice in Lewis Carroll's Through the Looking Glass, where in Looking Glass Land, "it takes all the running you can do to keep in the same place." These are but a few of the many examples of how ideas from other disciplines shape scientific thinking.

Many of you are thinking, I'm not going to be a scientist, so why does this matter? Because this is at the heart of a liberal arts education at Connecticut College. As you navigate your way through the curriculum, you will have opportunities to take classes in fields seemingly far distant from your major, yet if you are paying attention, you will see that they are not so far distant, and they might even help you to understand some of the concepts in your own major. If you're a Dance major, you might want to take a biology class so you can learn more about how the body works; if you're an English major, you might want to take a computer science class so you can learn how to mine text for word usage; if you're a Biology major, you might want to take a class in government so you can have a better understanding of how policies affect the way science is done. My advice to you is to keep your mind open as you choose your classes. Look for the unexpected connections you may encounter, and be alert to ways these encounters may reshape your thinking.

This brings me back to whales. Although I don't directly study whales, I study bacteria that live in oceans and some of those bacteria make it possible for whales to survive. So in a bacterial version of "6-degrees of Kevin Bacon", I do study whales.

Thank you very much for listening, and have a great year!

(Remarks as prepared by Anne Bernhard.)