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EDITOR'S CORNER

Why I Teach Evolution

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I am a secondary special education science teacher currently working for Port Jervis Middle School in Orange County, New York. Port Jervis is a small historical town located near the border of New Jersey and Pennsylvania in a beautifully forested valley on the banks of the Delaware River. Nature abounds. Hunting, fishing, rafting, and quad bike riding are favorite activities of the student body. Many students live on working farms where they raise crops and animals. The night sky is brilliant with stars. The contrast to my last job is stark.

I started my career six years ago with the New York City Teaching Fellows, a program that entices new teachers to work in underserved and struggling schools in New York City, mostly in the outer boroughs of Brooklyn, Queens, and the Bronx. I was given a full teaching position with no classroom experience while I worked on a Master's degree in teaching students with disabilities. The school where I worked for four years, John F. Kennedy High School in the Bronx, is an eight-story building with many thousands of students. Metal detectors operated by New York City police officers block all usable entrances. Additional officers patrol the hallways, some carrying service weapons, all carrying handcuffs and pepper spray. On my very first visit to the school, I saw this graffiti scratched into a desk: "JFK—Jail for Kids." I found it clever and amusing, however inappropriate it may be to deface school property, but it was also an indication of the challenges I would face there as a new special education teacher.

In August 2003, before I began teaching, I was working at a law firm near ground zero in New York City when the power went out. Office workers poured into the streets, anxiously seeking news. We eventually learned that a blackout had cut electricity to much of the northeastern United States. Having no way to get home with the subways stopped, I walked to my friend's apartment in Brooklyn where we sat on his roof playing chess to pass the time and escape the heat. The city was almost entirely dark, and the night sky revealed itself to Brooklyn for the first time in a generation or more. As I sat there marveling at the unexpected reversal of dark sky, bright city to dark city, bright sky, it occurred to me that there must be millions of people in the city below who had never really seen the stars, and I wondered how that disconnection from the natural world affected their sense of who they were and how they fit in.

I would often think about this question as I got to know my first students at Kennedy. Looking out of a sixth-floor window from a science lab, we could see the waters of a canal connecting the East River to the Hudson. This canal, I later learned, was dredged and blasted to create a navigable passage out of the treacherous and wonderfully named Spuyten Duyvil Creek that once separated northern Manhattan from the mainland. Here, as bored students peered south into Manhattan, could be seen a thick growth of plants covering the cliffs over the canal and an occasional passing boat manned by the Columbia University crew team rowing in unison. I had the distinct feeling that this was the most nature many of my students were likely to see anywhere near their neighborhoods, and it seemed so distant and inaccessible.

I was astonished at first by how little my ninth- and tenth-grade students at Kennedy knew about the natural world. In the beginning of the year, I handed out a list of objects and asked the students to identify each as living or non-living as a warm up activity. Many thought the sun was alive, that water was alive, that mold was not. When we moved past characteristics of living things and on to the six

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kingdom classification system, I was less surprised to note that few of my students knew we were animals. Although some students flatly refused to believe it, many were simply surprised to have it explained to them. Part of my explanation to doubters went something like this:

Student: "Mister, I ain't no animal." Me: "What are you then, a plant?" Student: "No." Me: "Fungus? No? Let me ask you this, are people living things?" Student: "Yes." Me: "All living things can be classified in one of six kingdoms. Are we more like dogs or are we more like mushrooms? Are we more like rats or trees?"

It was such a new concept for some of the students that they had trouble accepting it, but for many, I could see a sense of wonder and delight that came from learning something new about themselves and how they fit in to the world. This new perspective on the world led to a long stream of questions from the kids. Are spiders animals? Are fish? Or cockroaches? How are species related? How did this all come to be? It was a favorite moment of my first year, and covering these basics has become a favorite part of every year. Inspiring students to ask questions about the world around them is a fundamental goal of teaching, and one of the most rewarding parts of the job when it is achieved.

But sadly, and perhaps inevitably in a 180-day school year, not all of my lessons are always as successful. One of the greatest challenges of the special education teacher is motivating students to engage with the subject matter, whatever the discipline. Disinterest often runs high among students who have had little sense of academic success, and it can be difficult to convince students why they should care about minutia like mitochondria or xylem and phloem, particularly when the material is presented simply as a list of facts to be memorized. All too often, it seems we teach what we teach only because it will be on the state exams, and student performance on those exams is seen to reflect the quality of the school and of individual teachers. From this reasoning comes a tendency, or at least an urge, to "teach to the test," a practice that emphasizes specific concepts that are heavily represented on exams and de-emphasizes material that is less heavily represented. Although this is sometimes necessary to prepare students for success on external assessments—an important part of the job, for better or worse—it can come at the expense of exploring the bigger picture or the finer details that make science so fascinating.

Preparation for state exams tends to focus more on rote memorization of facts and vocabulary and less on a deep or nuanced understanding of processes or relationships. The sheer volume of material covered on the tests, at least on New York State secondary level science exams, necessitates a speedy and all too often superficial examination of concepts that ultimately boils down to teaching the vocabulary of a scientific discipline and then rapidly moving on. Hence, a unit on ecology essentially requires students to memorize the vocabulary of various aspects of ecology such as levels of organization, ecological succession, feeding relationships, basic biomes, and the material cycles, with perhaps a bit of human impact thrown in, and then move on after a week or possibly two, at the most. Ecology, to me, is nothing less than the study of every living thing on Earth and how they interact with each other and with the non-living parts of the planet. It is the story of how our planet lives and how human activity is changing and disrupting life on Earth. To me, ecology is beautiful and majestic, both staggeringly complex and endlessly and amazingly evident and accessible. It is one of my favorite topics to teach, but it loses its most compelling features, the reality and beauty of it, all too easily in the confines of the classroom.

Evolution often suffers a similar fate. The small number of questions about evolution on state exams creates a need to summarize it quickly as a self-contained concept that is largely limited to fossils, adaptations, Charles Darwin and the voyage of the *Beagle*, peppered moths, finch beaks, and why the doctor tells you to take all of your antibiotics. Teach these concepts through memorization of key vocabulary words and move on within five days, or risk running out of time before covering all of the human body systems by the end of the year. When the unit is complete, evolution then too often disappears from classroom conversation as quickly as it appeared, without connecting back to any other aspect of life science. This approach to biology curriculum is all that is needed to prepare students for success on state exams, and, even worse, seems almost necessary in order to make it through all of the material students will be expected to have learned by the end of the year. But there is a price to be paid for this compartmentalization and segregation of units. Evolution, like ecology, permeates nearly every aspect of life on Earth and can be connected to almost any lesson in a secondary school life science curriculum. To deny students access to that unifying quality of evolutionary theory is to purposefully paint a narrower, less coherent, and ultimately less believable and less compelling story of life on Earth.

If time is limited and there are more questions about Punnett squares and pedigree charts than evolution on the test, it can be argued that spending too much time on evolution is detrimental to student achievement. Student disinterest in science and nature when studied in a prep-for-the-test, lecture, and textbook format can also be a hindrance. Evolution can seem vast and nebulous when presented this way and can therefore create confusion or anxiety, particularly for students who struggle academically. This, in turn, can lead to student disengagement with the material. Or, alternately, it can become just another unit to digest, another chapter to read, and another test to take before the weekend sets you free. Added to all this is the peculiar distinction evolution has earned as being the one

fundamental piece of human knowledge in any discipline that society encourages students to reject. Given these challenges, it is not surprising that evolution is difficult to teach and learn and therefore often marginalized in our schools. Under increasing strain to prepare students for yearly improvements on state exam scores, teachers must cover the material that will be tested and spend little, if any, time on what is not. Absent that external pressure of test-worthiness, teachers have little incentive to make evolution the cornerstone of life science curricula that it deserves to be.

So why is it important to teach evolution? It can seem difficult and almost unnecessary to do more than simply touch on the basic vocabulary of evolution in a middle school or high school level biology class, so why go beyond the bare essentials? There are many excellent arguments for why we should improve science education in the United States and why evolution should play an important part in sweeping reform to the education system. Our status as a premier economic power in the world has always relied on our innovation and invention. Breakthroughs in medical research, biotechnology, agriculture, and wildlife management will be made by scientists who command a deep understanding of evolution. New jobs created in these fields will require an educated workforce that understands how science works and how we know what we know. Evolution is good science: a theory that can be used to make testable predictions to solve problems in the natural world. In order to properly educate the youth of our nation, we must tell them not just what we know, but why we think we know it, how we came to the conclusions we have, and how to probe deeper into the mysteries of the universe. Human actions and decisions are influenced by information, good and bad. The more we learn about the history of life on Earth and how paleoecology has affected that history, the more seriously people will examine their behaviors that are contributing to global climate change and the current mass extinction. This will help to create a better educated, deeper thinking, problem-solving, forward-looking, and powerful workforce for the twenty-first century.

I am a special education teacher in a middle school, though, and not an education policy expert or cabinet level economic advisor. Although I care deeply about the future of our planet and our nation's economy, my most immediate concerns are about the students in my class and how to get them interested in science. The big reasons for incorporating evolution more coherently into science curricula outlined above, however true, carry little weight for a bored seventh grader with minimal interest in science and no desire to pursue biology as a career. There are other reasons why evolution should be taught as the unifying theory of biology that it is: it is a truthful representation of what we have learned through investigation, it is intuitive and evident all around us, it ties otherwise disparate units of study together, and, most importantly, it is a great story.

Kids do not like being lied to. When a student asks a question in class—my favorite part of the job—I always try to answer them honestly. If I know the answer, I tell them what I think I know and how I know it. If I do not know, I am never embarrassed to say "That is a great question, Sam, I really don't know the answer. We should look it up and find out." Or I will tell them what I do know and what I do not, or what my thoughts are and why. Students appreciate this more than hearing some pseudo-authoritative answer that evades the question, an answer designed to make it seem as if the teacher is all-knowing. Why make something up when you do not know? There is no shame in not knowing the answer; after all, not knowing the answer to important questions is the foundation of science, and has led to the great discoveries of human history. Students can detect inconsistencies and falsehoods. Even if they do not have better information to challenge a teacher's possible inaccuracies, they can sense when they are being fed half-truths or flimsy reasoning. This can be very damaging to student achievement. In order to motivate students and capture their interest, there must be a level of trust established in the classroom. If a teacher violates that trust, they can have no legitimate expectation that students will believe another word they say.

And evolutionary theory is the truth, at least the truth as we currently know and understand it. It is the best information we have available to explain the diversity of life on Earth and the relationships between and origins of living things. To segregate and marginalize evolution in biology class is to present a disjointed, incomplete, and ultimately dishonest picture of the study of life science. Although students may not know it, I believe that subtle inconsistencies and omissions, or grand ones in the case of some science classes, compromise the trust that should be established between teacher and pupil. When students have reason to doubt the veracity of your claims, it is very difficult to get them on your side.

But how do people know that evolution has occurred if they have never been taught evolution in a classroom? How do kids know you are lying to them when you ignore the importance of evolution to the story of life on Earth? It is all around us to see, in the interdependence of species—ourselves included, of course—in the stability of climax communities and the disruptions to those communities caused by human activity, in the similarities and differences between species. Students often imagine themselves as vastly different from their pet dogs, until you ask them to make a Venn diagram (a graphic organizer consisting of two or more overlapping circles that are used to list similarities and differences.) Noting the characteristics of tetrapods and mammals shared between dogs and people, students can see there are more similarities than differences. Compare dogs to spiders and it is clear that dogs are much closer to people.

Compare spiders to trees and we can see spiders are more closely related to us. These conclusions are obvious and easy to reach. They surround us; they are in us. Evolution is simply an explanation of why that is and how it works.

There is no better way to learn than by experience. If a teacher can use real-life experience to connect students to a lesson, those students will be far likelier to engage with the material at a deeper level and will be more likely to retain it. Ideally, field trips, labs, and projects should be incorporated into a class to give students firsthand knowledge and practical experience. For the majority of the days of a school year, spent in a classroom, lessons should connect to students' lives. Evolution is ideal for this, because it is endlessly present and evident.

In the fall of 2005, The American Museum of Natural History in New York opened the exhibit Darwin, curated by my father and co-Editor-in-Chief of this journal, Dr. Niles Eldredge. I was teaching at Kennedy at the time and was eager to take my students to see the exhibit. I prepared them for the trip by telling Darwin's story and the basics of his idea. As with my first batch of students the previous year, there was a mixed reaction to the introduction of evolution. Some students already knew a little about evolution and were interested in learning more. Some students were hesitant to commit to the idea because of their upbringing but were curious and inquisitive. And inevitably, there were a few committed creationists who flatly refused to believe any explanation for human origins other than the story of Adam and Eve, so could not abide any discussion of evolution at all. Nonetheless, everyone was interested in going to the museum for the day.

When we arrived, we went straight to the Darwin exhibit. After watching the live Galapagos tortoises stand around majestically doing nothing for five or ten minutes, we entered the hall. The kids were excited to see the exhibit. The very first thing we saw when we walked in was a large glass Victorian-era case that had been refitted to hang vertebrate skeletons. It was reminiscent of the "cabinet of curiosities" style of displaying collections popular in Darwin's time, stuffed full of many different species in no particular arrangement. With a dolphin skeleton hanging next to a chimpanzee and a fruit bat, among many others, the case was meant to show the Victorian-era, creationist-based, scientific thinking that species are demonstrably different types that do not change. I walked up to the case with some of my students and pointed to the chimpanzee. "See how similar a chimpanzee skeleton is to a human skeleton?" I said. "Look at the similarities in the hands alone." Carlos, one of my tenth graders who had expressed some skepticism about evolution, says, "That is a chimpanzee skeleton?" And then, excitedly, shouts (I will never forget this for the rest of my life) "That's it, right there, I believe the whole thing!" Carlos knew well enough what the bones of a human hand look like, and he could see with his own eyes the overwhelming similarities to the chimpanzee. This personal experience of seeing evidence firsthand was strong enough to overpower any reservations he may have had and any misinformation he had received over the previous fifteen years. It was also a two-minute lesson that was far more persuasive than any of the PowerPoint slides, lecture notes, readings, cladograms, or illustrations I had used as evidence of evolution in the classroom. Nothing compares to personal experience for teaching, and the products and processes of evolution are evident all around us.

My father has been an evolutionist and a curator of paleontology at the American Museum of Natural History since before I was born. When my older brother and I were growing up, we spent a lot of time running through the halls of the museum during summer vacations while Dad worked in his office upstairs. We loved the dinosaurs, of course, but there were wonders to be discovered on every floor, and we would be fascinated by dioramas of African and North American animals, the models of Native American villages and the great South and Central American cultures, the films about gold, meteors, or hunting with poison arrows and blow guns in the Amazon. When on vacation, we would often go to the Adirondack Mountains in upstate New York, where we would walk through the forest and swim in the lakes, enjoying the natural splendor. Back at home, I would always be full of questions about what I had seen in the woods or at the museum. Dad always had an explanation for what we were seeing, about how it came to be through biological, geological, historical, or social processes. The education I received from my parents, in fact, is not only the basis for my understanding of the world, but it is the reason why I became a teacher and why I love to teach science. I loved seeing all of the amazing things the world had to offer as I grew up, and the interactions and connections between everything just seemed so cool.

And this, to me, is the best reason of all to teach evolution: it is such a great story. As Darwin himself famously said, "There is grandeur in this view of life." Students need their teachers to help them get excited about the material they are learning. Rote memorization and chapter-by-chapter examinations of what is happening outside the window may work for advanced placement students, but they are rarely effective for special needs or at-risk kids. Students with a limited interest in science and a diminishing dedication to their education need more than to be told what they must learn to pass some state exam. They need to have their interest captured, to have their imaginations sparked. What better way to do this than by

tying all aspects of the curriculum together with a unifying theme? Evolution is a story, after all. It is the story of what we have learned so far through scientific investigation about who we are, where we came from, and how we fit in to the world. It explains so much. It is so evident. It is so testable and provable. It is quickly becoming the greatest story ever told, and we should tap into its power to help our students learn.