reports

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Why Nature of Science? p. 3

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Dear NCSE Members,

By the time you read this, we as a nation will have passed many milestones—many of them grim. A full year of working and learning from home for the lucky among us; a full year of unemployment and sporadic access to school for too many others. Saddest of all, if death rates from COVID-19 continue to hold steady at around 1,700 per day, we will be nearing 575,000 deaths in the U.S. by the end of March 2021. It has certainly been a year unlike anything in my lifetime, and I'm no spring chicken.

Facing challenges of such an immense scale can make you feel helpless and overwhelmed. What can a small organization like NCSE do in the face of multiple, interlocking, international crises? Yet, while I willingly acknowledge that we certainly can't fix everything, looking back on the past year, I think NCSE has made distinctive and valuable contributions.

We've produced a series of articles for teachers that gives them the resources they need to answer their students' questions about the pandemic and help their students learn how to evaluate scientific news for themselves. You can find all the "Teachable Moments" at our website (https://ncse.ngo/coronavirus-resources). And you can sign up (https://www.cognitoforms.com/NCSE/SignUpForEmail UpdatesOnCoronavirus InformationYouCanUseInYourClassroom) to get notified when a new article in the series is published. You don't have to be a teacher!

We've begun developing model lesson plans on the nature of science, having recognized that the ability to distinguish science from hype and misinformation has become critically important. (You can read more about that effort on p. 10.) Our teacher ambassadors have continued to help us while dealing with the challenge of teaching in inconsistent and unpredictable formats from in-person to all-virtual to hybrid classrooms. They are our inspiration.

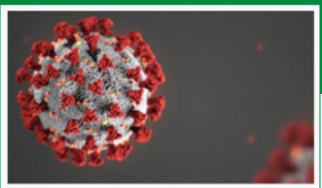
Our graduate student outreach fellows went completely virtual—quite a feat when the goal of the program is to improve their science outreach skills. They created museum exhibits, re-engineered in-person activities to suit virtual formats, and surveyed their universities' outreach activities and their communities' outreach needs. They've dug into the literature on climate change communication and applied what they learned to everything from evaluating how climate change has been covered in local newspapers to how it's been portrayed in television comedies.

Finally, we've continued to keep our eyes on state legislatures and boards of education, especially when state science standards are under review. As we reported in the last issue of *RNCSE* 42[1], we teamed up with the Texas Freedom Network Education Fund to evaluate climate change standards in every state and the District of Columbia. That work will continue to serve us well as additional states take up the task of incorporating this vital topic into their science standards—and even, as with New Jersey, into their standards for other academic topics (see Updates, p. 8).

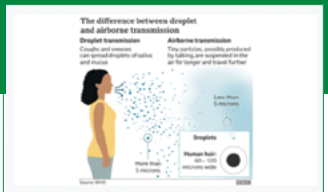
We would not have been able to react so swiftly and flexibly to this crazy, devastating year without your support. We are so grateful for the many encouraging messages that you've sent in along with your donations. Without a doubt, we have the most committed and supportive members in the world. Please accept all of our best wishes for your safe passage through the end of this pandemic and the return to whatever normal looks like.

Ann Reid is the executive director of NCSE. reid@ncse.ngo

WHY NATURE OF SCIENCE?



March 10, 2020
How deadly is COVID-19?



October 9, 2020
It's the Great Debate, Charlie Brown: Aerosols vs. Droplets

December 11, 2020
A few small grains of truth

January 15, 2021
Turning Vaccine Dreams into Vaccine Realities

If you're a supporter of NCSE, I already know that you care about science. You probably believe that everything from our personal life choices to our national policy decisions should be informed by carefully considered scientific evidence. Indeed, you probably believe that choosing to ignore science, or to be guided by anecdotes instead of data, is a recipe for a bad outcome. And so I'm going to go ahead and assume that in the last year you have repeatedly slapped your forehead and thought "How can anyone believe that?!"

The term "anti-science" gets thrown around a lot in attempts to explain neglect and denial of evidence. But I prefer to diagnose the problem as due to an inadequate ability to think critically about scientific claims. And what's great about that diagnosis is that a lack of ability, no matter how widespread, is something that we know how to fix. Indeed, at NCSE, we know that science teachers can be a huge part of the solution. After all, we already know how important science teachers are in helping students overcome misconceptions about evolution and climate change.

The coronavirus pandemic has put science on the front pages and in our news feeds day after day for months. On the one hand, this has been great for science: nothing drives curiosity more than urgent, personal relevance, so people are hungry for science news. And the scientific community has come through with amazing results, beginning with publishing the sequence of the new virus within weeks of its emergence and following through by developing vaccines in record time. On the other hand, the glut of science news has resulted in an uneven news landscape, with solid reporting mixed in with hype, premature conclusions, and outright misinformation.

Here at NCSE, we wanted to help. What could we do to support the tens of thousands of science teachers—most of them suddenly teaching from home—as they became, for their students, perhaps the one person in their lives trusted to help decipher the often-conflicting news about the science underlying the pandemic?

Lin Andrews, NCSE's Director of Teacher Support, had a great idea, which we got rolling even before most schools closed. We began sending out a weekly article to help teachers answer questions we thought students would be asking. The first of these "Teachable Moment" articles was published on March 10, 2020, tackling the question: "How Deadly Is COVID-19?" If you can cast your mind back that far, there was considerable uncertainty about that question at the time. Preliminary evidence from China indicated a mortality rate of 1–3%, but some commentators were arguing that the mortality rate was drastically lower because so many cases were not even being diagnosed. Which estimate was correct?

That first Teachable Moment set the pattern for those to come. Our goal was not just to give students the answers; we wanted them to learn how to think about these science stories for themselves. What evidence were these two different opinions based on? Did either group have more expertise? Was the disagreement based on data or speculation? Did anyone have mixed motives underpinning their conclusion? We tried to model how scientists evaluate evidence and reach conclusions. We included an easy activity or exercise that teachers could have their students do, even at home.

These Teachable Moments proved quite popular, and not just among teachers. It turns out that lots and lots of people have been feeling overwhelmed by the sheer volume of scientific information and were grateful for some guidance on how to winnow it down to something they could act on.

As we wrote the articles, we quickly realized that the universal theme was helping people understand how science works. For example, those early mortality estimates of 1–3% turned out to be pretty accurate. But if they hadn't, that would have provided a teachable moment about how scientific conclusions can change over time, but only if there is credible new evidence. Scientists don't change their minds because they're fickle, or watching the poll numbers; they change their minds when evidence conflicts with their previous conclusions.

Taking a deep dive into pandemic news each week made us realize that misconceptions about how science works were pervasive. Over and over again we saw headlines that exaggerated scientific findings, news stories that quoted conspiracy theorists alongside legitimate scientific experts, and opinion pieces that cherry-picked evidence, cited fake experts, or rejected public health guidelines because science could not provide absolute certainty. Some of these stories were actively misleading, but many of them simply represented standard practices of journalism (highlight the most newsworthy finding; represent all sides of an issue) that conflict with standard practices of science (don't speculate beyond the evidence; give greater weight to conclusions backed by multiple lines of credible evidence).

The problem was much bigger than casual neglect or outright rejection of scientific evidence (although those were definitely problems). Even journalists and commentators who just wanted to understand what was going on with the pandemic and to convey that to their audiences often harbored fundamental misconceptions about how science works. And thus was born our second big reaction to the pandemic—the development of a set of lessons designed to help students understand how science works, all using themes in epidemiology as "anchoring phenomena" (as they say in the science education world), and centered on the most common misconceptions about the nature of science

What are some of these common misconceptions? Perhaps the one that has been most obvious during the pandemic is the idea that science uncovers The Truth and that scientific findings are therefore either Right or Wrong. For example, early in the pandemic, most experts thought that coronavirus was likely to spread by large droplets (because that was how other coronaviruses were thought to spread), which would mean that surface contamination would be a big problem and frequent handwashing and sanitizing the best response. They didn't think masks would be as important, and since masks were in short supply for health care workers, their use was de-emphasized. As evidence built up, the importance of respiratory transmission became clear, and public health experts began emphasizing the importance of masks.

The damage, however, was done. For those who wanted to politicize the pandemic, the faulty early advice on masks was a convenient pretext to reject all public health guidance. And even for those who just wanted to know how to protect themselves and their families, the change in message was confusing.

It's easy (and probably fair) to criticize public health messaging, and equally easy (and even more fair) to blame those who misrepresented science in bad faith, but at NCSE we wonder whether much confusion could have been avoided if everyone had learned in science class that science is not a box full of facts, representing immutable eternal truths, but an ongoing process that reconsiders its conclusions based on new evidence.

Astute observers of people or groups that reject the science of evolution and climate change (or tobacco safety, or vaccine safety, or any other well-supported scientific conclusion that some people hope to discredit) will notice that this important aspect of the nature of science—that it is always open to considering new evidence—is often cynically exploited to claim that any old line of argument might be true because, after all, science is provisional, they laughed at Galileo, etc., etc. Yes, science is provisional—but some scientific claims have been supported by such a vast amount of evidence, often from numerous lines of inquiry, that it no longer makes sense to consider them open to debate in any meaningful way.

As expressed by the incomparable Stephen Jay Gould: "In science, 'fact' can only mean 'confirmed to such a degree that it would be perverse to withhold provisional assent.' I suppose that apples might start to rise tomorrow, but the possibility does not merit equal time in physics classrooms." (from"Evolution as Fact and Theory" in *Discover* 1981, reprinted in *Hen's Teeth and Horse's Toes*.)

Helping students understand the nature of science is the goal of NCSE's new set of lessons, each giving students lots of practice at recognizing particular misconceptions about the nature of science and all organized around public health, epidemiology, and the coronavirus pandemic. We hope these topics will soon no longer be quite so timely, but the same misconceptions can be illustrated by just about any area of science that teachers want to emphasize.

By the summer of 2021, we will have recruited a group of teachers to field-test these lessons in the fall so that we can measure whether they are successful at reducing students' misconceptions about science. Like any good scientist, we'll use the results of that experiment to improve the lessons. Ultimately, our goal is to have our teacher ambassadors train their peers in the use of these lessons, in addition to our evolution and climate change lessons, which are also designed to help students recognize and correct their misconceptions.

The pandemic has had a terrible cost—in lost lives and lost livelihoods, in exhausted health care providers, teachers, and parents, in loneliness, frustration, and missed milestones. I would never say that it had an upside. But in NCSE's case, it did highlight a need that we hope to meet—the need for educators to develop their students' understanding of the nature of science as an essential skill for the next generation.

Ann Reid is the executive director of NCSE. reid@ncse.ngo

Welcome to DeeDee Wright

NCSE is pleased to welcome **DeeDee Wright,** NCSE's new Postdoctoral Fellow in Science Education Research and Evaluation. Wright comes to NCSE from Colorado State University, from which she will soon earn her Ph.D. in ecology, with a human-environment interactions specialization. Her experience also includes a 25-year career teaching K–12 science and supporting teachers as a curriculum coordinator. At NCSE, she will be working with the Breaking Down Barriers and Supporting Teachers programs by developing and conducting research and evaluation related to climate change and evolution education. "To truly understand the effectiveness of the NCSE lesson plans in developing scientific literacy in students, it is important to also understand the teacher experience in delivering the curriculum," she commented. "Conducting evaluation and research simultaneously helps us to see the myriad of ways teaching and learning are intertwined."

Random Samples with Briana Pobiner

Briana Pobiner is a paleoanthropologist with the Smithsonian National Museum of Natural History whose research centers on the evolution of human diet, with a focus on meat-eating, but ranges as far afield as human cannibalism and chimpanzee carnivory. She joined the Smithsonian in 2005 to help put together the Hall of Human Origins. In addition to continuing her active field, laboratory, and experimental research programs, she leads the Human Origins Program's education and outreach efforts, which includes managing the Human Origins Program's public programs, website content, social media, and exhibition volunteer training. Pobiner has also more recently developed a research program in evolution education and science communication. NCSE's Director of Community Science Education Kate Carter spoke with Pobiner recently about her work as a science communicator. *The interview has been edited for length and clarity.*

Kate Carter: What has living through a pandemic taught you about what needs to improve in science communication?

Briana Pobiner: I think what has been unsettling this year is that there has been so much less agreement on what facts are, and that is particularly unnerving for the scientific community. When there is not an agreement on what the facts are, it is really difficult to have a conversation about the meaning of those facts. One of the problems for science communication during a pandemic is the way we talk about science. Communicating uncertainty in science is important, but I think communicating certainty is important too, and sometimes that gets lost in translation.

KC: Sometimes we make the uncertainty the hook of the story, when really it is a minor consideration.

BP: And even if it is not the hook, if we lead with the uncertainty, it sounds like the hook. The academy teaches scientists to put the take-home message from their research at the end of the story, but when you communicate suspicion of science with public audiences it has to be the first sentence, the headline.

KC: Has the pandemic amplified these issues?

BP: I'm not sure if it has been worse. But COVID-19 has highlighted the polarization of people thinking along the lines of their worldviews. There is still the sort of anti-intellectual, anti-elite sentiment that has always been associated with suspicion of science, but it has been heightened to a frightening extreme.

KC: So I want to ask what we as science communicators can do better. But I want to acknowledge that this burden isn't just on us.

BP: I think that we each need to figure out who the audiences are that we can reach, based on our own group membership. Ultimately our message will resonate best with people who see us as part of the same group. But we also want to make sure that our tent is big enough to be welcoming to everyone. I also think we need to find trusted non-science allies. For example, I read an article recently that talks about how powerful celebrities can be in communicating a pro-science message.

KC: You're advocating a radical departure for science communication strategies.

BP: Exactly. Misinformation is spread via specialized communities, and I think we need to fight fire with fire. We as science communicators have to realize that not all scientists are good at science communication. If the most important thing to us is the message being sent, then we have to prioritize effective messengers.

KC: How can we model that effective science communication in museums?

BP: In the Hall of Human Origins at the Natural History Museum, we have a thread that goes throughout our exhibit. We have displays with images of scientists with speech bubbles that talk about the process of science and they all start with the question: How do we know? How do we know that these fossils are that old? How do we know this? How do we know that? This approach demystifies how we get to this news headline or that conclusion. We build those questions into lessons and museum exhibits as often as we can.

One of the things that I try to do when I am on the floor of the museum is to validate visitors' questions by saying, "That's a question scientists would ask, and here's the process a scientist might go through to answer it. What evidence would we need to answer that question? Let's figure it out." I think that highlights the discovery involved in the process of science. The discovery is what got me hooked into science and suggests that science is relatable and doable.

KC: Building inclusion in science is key for building trust.

BP: Absolutely. I joined Twitter about three months ago and I found that being on Twitter as a scientist really levels the playing field. Anybody can reach out to you and ask you a question. There are tons of scientists on Twitter and we all are there as people. Ultimately, I think we have to emphasize that science is done by humans. And those humans may occasionally make mistakes, but they are there to work for the public good.

Kate Carter is NCSE's Director of Community Science Education.
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Vostok Station: Climate Change Is Real

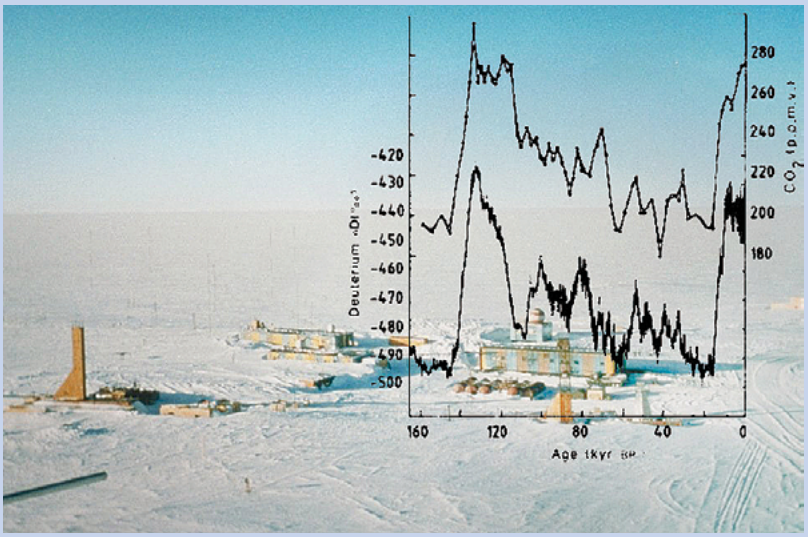


Photo by NOAA

The Vostok Station. Upper curve: CO_2; lower: temperature from 160,000 years ago to recent (today the level is much higher). Figure adapted from figure 1 of J. M. Barnola, D. Raynaud, Y. S. Korotkevich, and C. Lorius, "Vostok ice core provides 160,000-year record of atmospheric CO_2," Nature 329 (1987): 408–414.

How warm would Earth get? By the mid-1980s computer models had converged on a rough answer: when the amount of carbon dioxide (CO_2) in the atmosphere doubled, as expected sometime in the 21st century if we kept burning fossil fuels, the average rise would be three degrees Celsius plus or minus 50 percent. (Today's models confirm this, giving a lower limit of 2 degrees and an upper limit of 5.) That would be dangerous even at the lower limit and catastrophic at the upper. But how reliable were the computer models? The scientific community pegged the studies as "bleeding edge" research, uncorroborated, nowhere near what could persuade people to make radical changes in the global economy. It was theoretical, abstract. Was there any real evidence that changes in CO_2 could change a planet's temperature?

The answer came from the coldest place on Earth—and the sunniest.

In 1957 the Soviet Union had established the Vostok research station near Antarctica's "Pole of Inaccessibility." Vostok holds the record for the lowest temperature ever reported (-89.2 °C), and it is always well below zero there. Yet on a windless summer day you can almost feel warm as the sun circles the horizon unceasingly across the blinding-white snow. The air is thin, for the Vostok station stands on top of more than three kilometers of ice. In 1970 they began to drill a hole.

This was a heroic feat of technology, wrestling with drill heads stuck a kilometer down at temperatures so low that a puff of breath falls to the ground in glittering crystals. Supplies were brought once a year by a tractor convoy that clawed for weeks across 1400 kilometers of ice. Underfunded and threadbare, the station was fueled by the typically Russian combination of cabbage, cigarettes, vodka, and stubborn persistence. (In 2000, a journalist for *Science News* asked, "What do you do for recreation?" and was told, "Wash ... you have a bath once every ten days.") In April 1982 the generator shed caught fire; the chief mechanic, Aleksei Karpenko, died in a futile attempt to save it. The main generators were wrecked and no resupply was possible until November. The crew survived the winter by crowding into a little hut warmed by wicks dipped in diesel fuel.

Nothing would stop them. Layer by layer they drilled down into the past. By 1985 they had pulled up fat cylinders of ice as clear as glass stretching through the last Ice Age and into the preceding warm period, a complete glacial cycle of 160,000 years. Short on funds as the Soviet Union collapsed, they shared the ice cores with a team of French scientists for analysis. Trapped in the ice were microscopic bubbles of fossil air, unchanged for tens of millennia. You could measure the ancient CO_2 level directly. And you could analyze isotopes of oxygen in the ice to find the temperature of the snow crystals when they fell long ago.

The results were plain as day. During the coldest parts of the glacial cycle, the CO_2 level had been much lower than during the warm periods before and now. Indeed, the curves of gas level and temperature tracked one another remarkably closely. It was like putting Earth on a laboratory bench, switching conditions back and forth and observing the consequences. Yes, CO_2 and global temperature change were tightly linked. Better still, you could get numbers. A doubling of the CO_2 level accompanied a rise in temperature of 3 °C, give or take 50 percent — just what the computer models calculated.

Many in the scientific community saw the Vostok results as the first solid proof that global warning was truly a threat. Nothing in science is more convincing than getting the same number by two totally different methods. That is when you feel you have touched reality.

Spencer Weart was Director of the Center for History of Physics at the American Institute of Physics from 1974 to 2009; he is the author of *The Discovery of Global Warming* (second edition, 2008) and maintains a website of the same name: https://history.aip.org/climate/index.htm. sweart1@gmail.com

news from the **membership**

Judith Weis of Rutgers University was interviewed for the "In Their Own Words" column of the June 2020 issue of *BioScience*, published by the American Institute of Biological Sciences. As president of AIBS in 2001, she related, "I had been also very concerned with efforts to try to get creationism into teaching in the public schools and decided we need to have evolution as the theme of the meeting. And I got all the big shots to come. Ernst Mayr came. E. O. Wilson came. Stephen Jay Gould came … I was very, very pleased to have put together this conference with lots of the bigwigs in the field of evolution, which is not my field, but I appreciate its [importance]."

Jason Wiles of Syracuse University was a member of the team that was awarded the Society for the Study of Evolution's T. H. Huxley award, which recognizes outreach and education achievement by early and mid-career scientists, for 2020. The award was conferred in recognition of the team's work on "Exploratory activities for understanding evolutionary relationships depicted by phylogenetic trees: United but diverse," in which students use complementary phenotypic and molecular data to explore how to build phylogenetic trees and interpret the evolutionary relationships they represent. The activities are described in detail in Erin L. McCullough, Lauren Verdeflor, Alaina Weinsztok, Jason Wiles, and Steve Dorus's article of the same name, published in the May 2020 issue of *The American Biology Teacher.*

Michael Wysession of Washington University in St. Louis was awarded a 2019 Spilhaus Ambassador Award Grant from the American Geophysical Union to support his continuing work with Washington University's Institute for School Partnership bringing modern high-quality science to St. Louis regional elementary and middle schools. Wysession writes, "I will be contributing to the program in a variety of pro bono advisory roles, particularly in the way of scientific professional development for St. Louis region K–12 science teachers, helping them to increase their understandings of the fundamental big ideas of science, new cutting-edge scientific discoveries, best practices in science education … , and the goals of the Next Generation Science Standards."

THANKS TO LONG-TIME MEMBER CATHY CALLAGHAN

One of NCSE's most loyal members, Cathy Callaghan, sadly passed away at the age of 87. She cared deeply about science education, which led her to make a planned gift to NCSE to ensure future generations learn accurate and uncompromised science in their classrooms.

Callaghan had been a professor in the Department of Linguistics at the Ohio State University. Her area of expertise and life's work centered on the indigenous languages of the San Francisco Bay Area. Specifically, she focused on the Pentutian languages, especially the connections between Yokuts and Miwok.

She wrote five books, including four dictionaries of Miwok languages. As a professor, she taught courses on field methods, anthropological linguistics, and Native American languages. Her papers, including her research materials, were donated to the University of California, Berkeley, from which she received her Ph.D.

Outside her academic career, she had many interests, including earning a black belt in judo and writing and publishing poetry and science fiction.

Her generous bequest will have an enduring impact on thousands of K–12 students by helping them overcome their misconceptions about evolution, climate change, and the very nature of science. To learn more about NCSE's Legacy Society and planned giving that benefits NCSE's work, contact Director of Development Deb Janes at janes@ncse.ngo.

UPDATES

Are there threats to effective science education near you? Do you have a story of success or cause for celebration to share? E-mail any member of staff or info@ncse.ngo.

IDAHO

After a legislative attempt to block the adoption of new science standards because of their scientifically accurate treatment of climate change failed in February 2020, the Idaho legislature demanded a revision of the standards, partly in order to "provide balance in standards that have been politicized," including by discussing "positive and negative aspects" of energy sources. The revised standards are expected to be evaluated by the state board of education in October 2021 and then by the legislature in 2022.

MINNESOTA, BRAINERD

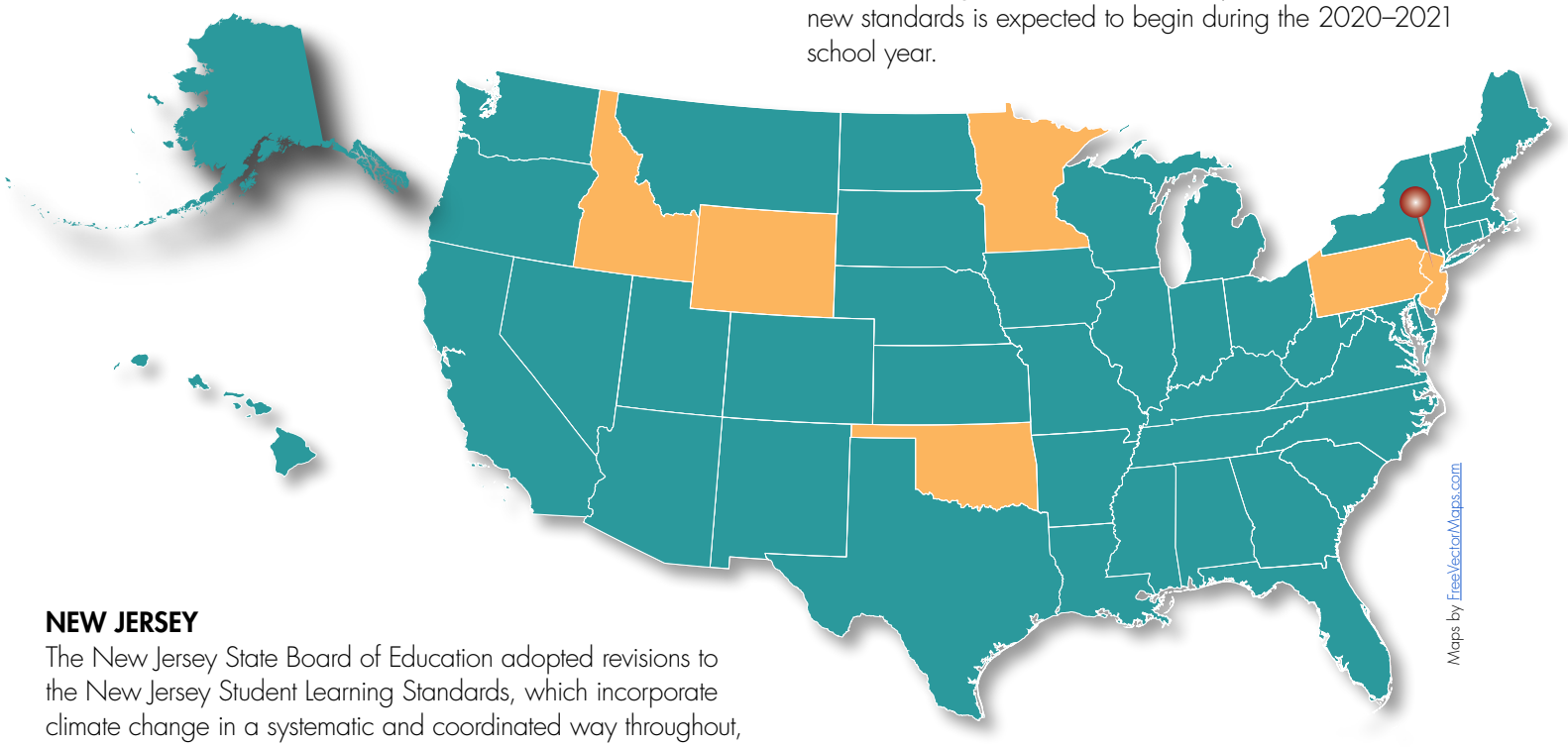
A member of the Brainerd School Board revived her advocacy for the inclusion of creationism in the science curriculum in May 2020 as the board was considering a new science curriculum for seventh and eighth grades. Sue Kern reportedly called for "the science part of creationism" to be added; previously, in September 2019, she questioned the point of teaching evolution in the high school biology classroom. The curriculum was adopted, without any additions, on a 5–1 vote.

NEW JERSEY, SOUTH ORANGE AND MAPLEWOOD

Bryn Healy, a recent graduate of Columbia High School, is protesting the use of a social studies textbook, *American Government*, in part because it misrepresents anthropogenic climate change as scientifically controversial, even citing the self-styled Nongovernmental International Panel on Climate Change. The edition used in the district was reportedly published in 2011; a later edition acknowledges "climate scientists almost all agree that human activity contributes to global warming." The district is reviewing the complaint.

OKLAHOMA

When the Oklahoma legislature adjourned on May 15, 2020, a new set of state science standards, which the Oklahoma state board of education previously approved on February 27, 2020, was approved by default. The treatment of evolution and climate change was improved and expanded in the new standards owing to the input of "hundreds of Oklahoma science teachers from public schools and universities," according to *The Oklahoman*. Implementation of the new standards is expected to begin during the 2020–2021 school year.



Maps by FreeVectorMaps.com

NEW JERSEY

The New Jersey State Board of Education adopted revisions to the New Jersey Student Learning Standards, which incorporate climate change in a systematic and coordinated way throughout, in June 2020. Climate change is now included not only in science and social studies standards but also in the standards for career readiness, life literacies, and key skills; comprehensive health and physical education; computer science and design thinking; visual and performing arts; world languages; and (in appendices) English language arts and mathematics.

PENNSYLVANIA

House Bill 2795, introduced in August 2020, would have required the state's public schools to provide instruction on climate change aligned with the Next Generation Science Standards. The department of education would also have been required to develop a model climate change science curriculum to be freely available to public and non-profit private

schools. The nineteenth measure aiming to support climate change education introduced in 2020, HB 2795 died in the House Education committee when the legislature adjourned in November 2020.

PENNSYLVANIA, WEST YORK

The West York Area School Board voted 5–4 in May 2020 to reject a standard geography textbook proposed for use in a new high school geography course, with objectors complaining that its treatment of climate change constituted indoctrination. Douglas Hoover, who voted to adopt the textbook, warned the board about the disastrous consequences of the nearby Dover Area School Board's textbook controversies in 2004, leading to *Kitzmiller v. Dover*. But the board then voted 8–0 to adopt it after all in June 2020.

WYOMING, CODY

A proposal from a local resident "to add textbooks comparing intelligent design and evolution to the middle school curriculum" was rejected in May 2020 by the Park County School District 6 school board, which supervises schools in Cody, according to the *Cody Enterprise*. It was not clear whether the proposal identified specific textbooks. In any case, teachers explained that "intelligent design" was not in the curriculum. Evaluating the proposal delayed the purchase of mainstream middle and high school textbooks.

INDIA

The Indian Society of Evolutionary Biologists deplored the omission of evolution and ecology from high school biology curricula for the 2020–2021 academic year, a step taken by the Central Board of Secondary Education to streamline the curricula in response to the COVID-19 pandemic. "Understanding practically every aspect of a zoonotic pandemic requires a thorough grounding in diverse areas of ecology and evolution," the society commented. "A direct consequence of our neglect of ecology and evolution is the relative paucity of epidemiologists in India."

INDIA

A group of teachers complained about mistakes in the biology section of the National Eligibility Cum Entrance Test 2020, including a question asking "Embryological support for evolution was disapproved [*sic*] by?" to which the answer was supposed to be Karl Ernst von Baer. In fact, embryology supports common ancestry: "community of embryonic structure reveals community of descent," as Darwin wrote. Although the mistake may have originated in long-ago-debunked creationist allegations, the remainder of the mistakes appear not to involve evolution.

Congratulations to NCSE's Glenn Branch!

NCSE's Deputy Director Glenn Branch received the annual National Association of Biology Teachers' Evolution Education Award for 2020. The acknowledgment of Branch's significant contributions to evolution education should come as no surprise to those familiar with his work at NCSE. Branch's prodigious efforts and information retrieval skills keep NCSE connected to teachers, legislators, journalists, activists, and anyone working to support and promote evolution education.

What is even more impressive is his ability to identify, track, and organize information about anti-evolution activism, legislation, and organizations. His research and communications skills seem boundless; he is at home intellectually in a variety of disciplines where scholarship is important to the goal of promoting and defending evolution education; and his ability to synthesize the relevant aspects of this information helps us all apply his insights to improving our advocacy.

All of the things that Branch does at NCSE serve to prepare those on the front lines to reach out in their communities to keep evolutionary science at the heart of biology education. So it is not surprising that an organization of professional educators with a commitment to evolution education should recognize Branch's contribution to their mission.

What is remarkable is that Branch is the first awardee whose primary responsibilities are not instructional. This shows a recognition within NABT that his role in tracking trends, contacting and coordinating with local supporters of evolution education, interacting with the media, informing us all about legislation, and so much more are vital in the promotion and success of evolution education. All of these provide the context in which classroom instruction must operate to teach evolution well.

Recognizing Branch's contribution to evolutionary education also recognizes NCSE's important role in promoting evolution education for nearly 40 years. Through its dedicated staff and network of contacts, NCSE both provides support for educators, parents, and students, and attracts members committed to promoting evolution education. The synergy between the organization and its members on the front line is reflected in the number of award winners who were affiliated in some way with NCSE: 12 of the 19 Evolution Education awardees to date have connections to NCSE.

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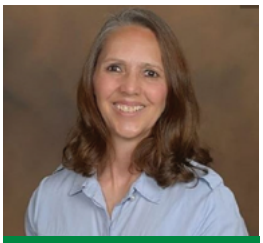
SUPPORTING TEACHERS

ALLOWING STUDENTS TO OWN THE DATA AND SEE THE PROCESS



Bonnie Bourgeous

Ericca Thornhill

When it comes to curriculum, teachers trust teachers. After all, who better to develop lesson plans than someone who knows what it's like to implement those activities in the crucible that is a classroom full of students? Of course, the content and the pedagogy have to be sound and carefully thought out, and meet local requirements and state standards. And the activities should be inquiry-based to give students the experience of examining evidence as any scientist would. With all that in mind, NCSE tapped its cadre of teacher ambassadors—master science teachers from around the country—to co-develop lessons with NCSE Director of Teacher Support Lin Andrews that help students overcome misconceptions about the nature of science (see "Why Nature of Science?" p. 3), climate change, and evolution.

"If one creative teacher is able to put together a solid lesson plan, imagine what a dozen can do working together—that is a work of art," says Andrews. "And I could not have asked for a better team to help build these lessons for NCSE."

> "If one creative teacher is able to put together a solid lesson plan, imagine what a dozen can do working together—that is a work of art."

We expect all three sets of lessons to be available—free to download—by the start of the 2021–2022 school year. Most recently, the new nature of science lessons have begun to come online. They are complex, involving multiple strands and an emphasis on inquiry and analysis, with the cumulative effect of overcoming common misconceptions. NCSE teacher ambassadors are beginning to field-test the nature of science lessons in their classrooms, so we decided to reach out to two who have been intimately involved in their creation to find out how the lessons are being received—by students and colleagues.

Bonnie Bourgeous, a biology and chemistry teacher in Utah, helped develop Science is a Never-Ending Process, the second lesson in the five-lesson nature of science series. The lesson uses historical case studies focused on germ theory and plate tectonics to help students understand how these theories have changed over time while still maintaining their scientific rigor and relevance. Bourgeous taught the lesson earlier in the year, used parts of it for an online course she leads for teachers who are working towards becoming certified to teach science, and led a professional development session walking teachers through a portion of the lesson as part of the Utah Science Teachers Association conference. Both students and teachers were engaged and, for many of the teachers, the lessons provided an eye-opening perspective.

"The nature of science is dynamic, it's interactive. It's not just a cookbook—it's an ongoing process," Bourgeous says. "When you approach teaching through the NCSE nature of science lessons, you're allowing the students to own the data and see the process, rather than simply feeding them information."

For **Ericca Thornhill**, a biology, physics, and engineering teacher in Missouri, teaching students about the nature of science helps inoculate them against the pseudoscience they encounter in their daily lives. And so she was thrilled to work alongside fellow NCSE Teacher Ambassador Blake Touchet on the fifth lesson in the nature of science sequence, which calls on students to examine data to distinguish between sound science and unintentional misinformation or even blatant pseudoscience. The fifth lesson provides a capstone to the previous four lessons and focuses primarily on the science behind masks as protection against viral infection—a timely and relevant topic that is all too familiar today to students around the country.

"If our students can think like a scientist and use evidence to make decisions, they will be able to make decisions that benefit not just themselves, but all of us in the long run," Thornhill says. "Science is a human tool. And if we can understand it, we can accurately answer lots of critical questions like

Is vaccination safe? and Is climate change real?" (Spoiler: yes and yes.)

Bourgeous and Thornhill know first-hand how busy teachers are, and how much they are bombarded by resources and activities—some of which are questionable in quality. So they're trying to do their part to help their peers by creating the nature of science lessons they themselves would want to teach.

… they are trying to do their part to help their peers by creating the nature of science lessons they themselves would want to teach.

"Good, reliable, concise resources are just a huge benefit," Bourgeous explains.

Adds Thornhill, "It's really useful how modular these lessons are. There's a lot of flexibility built in and there are a lot of different ideas that you can pick and choose from. I think any science teacher is going to find something that will fit with their objectives."

That same concern for what works for teachers—and what helps students engage with science as a scientist might—will be reflected in all three sets of lessons. NCSE's teacher ambassadors will make sure of that.

Paul Oh is NCSE's Director of Communications. oh@ncse.ngo

Breaking Down Barriers

PIVOTING FROM OUTREACH TO RESEARCH

On March 9, 2020, the newest cohort of NCSE Graduate Student Outreach Fellows was presenting pitches to me for a first-semester project, Climate Change in My Community. This type of project encourages participants to evaluate local data for themselves, and is therefore great for outreach in communities where climate change might be socially controversial. Developing Climate Change in My Community activities represent a great way for fellows to get to know their community and experience one of the core tenets of the NCSE Fellowship program: the best way to get better at science outreach is by getting up close and personal with the community. Of course with the impending national shutdown, we realized that the project was unlikely to happen that spring, but were hopeful that it could go forward early in the summer.

Needless to say, the 2020 Climate Change in My Community project never happened. For a fellowship predicated on the importance of doing outreach, the pandemic created a hurdle that at first seemed insurmountable. We discussed the possibility of cancelling the 2020 cohort or of pushing it back until 2021. Ultimately, we developed a model that, despite its origin in necessity, ended up being stronger and more innovative than anything the Breaking Down Barriers program had done before: we focused on science communication and outreach research projects.

The success of the model had a lot to do with the 2020 cohort's pre-existing skills. Many of the fellows already had significant experience in outreach and were interested in using the fellowship to gain experience in other areas of informal science, such as research, evaluation, and grant writing. Knowing this, we divided the fellows into three groups. Each group would work with NCSE staff to conduct a research project within the realm of science communication or informal science learning. In addition, the fellows were placed in two other groups to develop final projects about climate change in rural newspapers and build a climate change board game for adults. As for publication, papers based on many of the research projects are in review at peer-reviewed journals. Before they are published, we wanted to give *RNCSE* readers an inside look into the research process the fellows have undertaken.

continued on p.12

Genetics and Evolution in Museums Team


Keighlley Reisenauer


Abigail Howell


Michelle Valkanas

Making evolution relevant can be difficult, but one effective way is to focus on genetics. With this in mind, the Genetics and Evolution in Museum Team of Keighley Reisenauer, Abigail Howell, and Michelle Valkanas created a traveling exhibit that helps personalize genetics and evolution. Before they began building the exhibit, however, they conducted a meta-analysis and systematic review to identify so-called genetics deserts: areas in the U.S. in which someone would have to drive more than 150 miles to reach a museum or other informal science learning center that has genetics content. The team identified many locations in the South and Midwest where this was the case and worked with local libraries to create agreements for hosting the exhibit.

In addition, the team interviewed a dozen curators from different genetics exhibits across the country, finding that genetics exhibits fall into one of three categories:

- "Genetics is Fun" exhibits focus on interactivity and volunteer facilitation, and emphasize specific inherited traits and genetics tools and technology.
- "Genetics is Relevant" exhibits highlight DNA basics and health testing.
- "Genetics is Discovery" exhibits feature heavy use of fishbowl-style genetics labs, highly visible museum collections, and an emphasis on visitor participation in science research.

While each type of exhibit leads to high engagement with genetics topics, they also all lead to construction of different personal identities around these topics. The team's resulting paper, which grapples with the ramifications of these narratives, is in review at an education journal.

Rural Museums Team

NCSE's Emma Doctors, along with fellows Catherine Henry and Zach Compton, analyzed how to improve climate change and evolution education at rural museums. Henry was interested in understanding the barriers for climate change education in rural museums in her state of Michigan. She found two interesting results. First, the major reason museums don't discuss climate change has nothing to do with fear of pushback, but a worry that they cannot make climate change interactive. Second, many museums are doing climate change

Corporate Cancer: Recontextualizing Disease through Board Games by Kate Carter

The 1999 film *Office Space* is a cult classic that deals with the minute frustrations of office environments. From bloated hierarchies to labyrinthine procedures, the film manages to showcase just how ineffective corporate life can be. Yet, for breast cancer biologist and 2020 NCSE Graduate Student Outreach Fellow Keighley Reisenauer, the humor surrounding the trappings of corporate life may help the public better understand how the body battles cancer.

Reisenauer is a PhD candidate in Biology at Baylor University, studying breast cancer in a lab analyzing why cancer cells behave in certain ways during metastasis. She is also a prolific science communicator, working to make complex topics such as cancer biology accessible. Reisenauer's science outreach work is uniquely focused on adults, particularly through the "Present your PhD" training program that she founded.

Through her work communicating her research, she noticed a consistent pattern of misunderstanding around cancer. "People think that there is one cure for cancer and don't understand why we haven't found it yet." While the pandemic has made people more interested in understanding immunology and disease, it has also led to increased expressions of frustration from outreach participants. "People saw how fast a COVID-19 vaccine was developed and don't understand why we cannot do the same for cancer."

In Reisenauer's opinion, one of the problems is the metaphors we use to describe cancer. "Everyone talks about the battle against cancer, but that suggests there are two sides. In reality, cancer isn't a foreign invader—it is you." Treating cancer involves being able to differentiate not between a host and a foreign invader, but among individual cells in a body. Though part of many cancer treatments involves identifying and eliminating these cells, many treatments now focus on containment and management. Military metaphors not only fail to encompass this nuance, but also suggest that people who die from cancer could have survived if they had only fought harder, an idea that can be frustrating for patients and their families.

To overcome these issues, Reisenauer built a board game called *Corporate*

Catherine Henry

Zach Compton

education through local conservation efforts and other related activities, but don't categorize these efforts as such. Based on this knowledge, the rural museums team was able to intervene directly by providing hands-on climate change activities and connections with climate scientists.

Doctors wanted to understand rural museum partnerships with academic and other larger institutions. Small museums have a high degree of public trust and can effectively convey potentially controversial science within their communities, but can lack infrastructure to fully implement their goals. Based on her research, Doctors found that the following "best practices" are beneficial in crafting effective partnerships between small, non-academic, informal learning environments and other organizations: seeking out like-minded organizations, pursuing flexibility in funding arrangements, having access to infrastructure, and employing memoranda of understanding or other written contractual agreements. Papers based on both research projects from this team are currently in review at the *Journal of Museum Education.*

Annie Stoeth

Climate Change Summit Team

Climate Change Summit is an extended activity that encourages engagement with a local climate issue through a guided role-playing experience. Based on the success of our 2019 topic about dam management, Annie Stoeth along with NCSE intern Emma Herdmann developed a second topic for Climate Change Summit called 100K Challenge. This latest version challenges participants to consider the intersection between evidence and social values as they analyze the merits of five different proposals to mitigate or adapt to climate change. In addition, this activity enables participants to contend with uncertainty in climate change decision making, without feeling overwhelmed and stifled.

Creating each Climate Change Summit is a major undertaking. Each version requires generating up to 50 unique pieces of data that are easily accessible to broad audiences, as well as creating 30 different characters for participants to inhabit during the activity. Stoeth is taking this project one step further by analyzing the impact of character choice on willingness to accept new viewpoints throughout the game. Stoeth is implementing this project in introductory environmental science classes at the City University of New York, with hopes of publishing the project in the *Journal of Research in Science Teaching* later in 2021.

Kate Carter is NCSE's Director of Community Science Education. carter@ncse.ngo

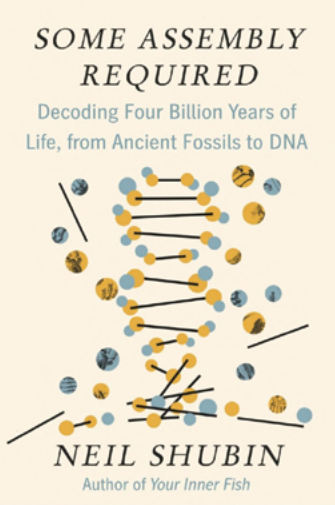
Cancer. "I wanted people to look beyond the war and the woe that often comes from discussing cancer, and see the biology in a new light." She and the other graduate student outreach fellows spent July 2020 designing a board game for teens and adults that incorporates systems thinking. In the past, Fellows have built games focused on wildlife management, carbon balancing, and predator-prey dynamics, all of which similarly reject that idea that there are simple answers to these complicated problems.

Corporate Cancer is a tongue-in-cheek game that challenges players to work as different immune system cells, each with specific duties, to manage a tumor before it metastasizes. Players explore the nuances of cancer mitigation through a game that simulates tumor growth and immune reactions. After each turn, a player draws a card that produces a random event that may require a different strategy.

Intense cooperation between the different immune cells is key. But as is so often the case, players may find that the perfect is the enemy of the good. "The solution isn't always to get rid of the tumor entirely. You have to be more strategic and creative to find the right way of managing the tumor given the constraints you have." Mirroring real life, players who act too aggressively to remove the tumor may also end up damaging the host, whereas containment-only strategies will work only if the tumor is in certain organs. For each game, as for each patient in real life, the winning strategy may be different.

The serious nature of breast cancer is counteracted by the witty design of the game, which hearkens back to turn-of-the-millenium office culture. From design aesthetics that recall clipart to the primary pastel color palette, the entire game feels like it is lifted from Windows 95.

Initial play tests of the game have resulted in rave reviews. Still, Reisenauer is hoping to continue improving her game. "One of the things I want to incorporate is the bench-to-bedside pipeline, or helping players understand how basic science research can eventually become widely used treatments. So many people are generating basic science research around cancer, and I want the players to know just how much work goes into understanding and improving treatment."



Some Assembly Required: Decoding Four Billion Years of Life, from Ancient Fossils to DNA

editors: **Neil Shubin**

publisher: **Pantheon**

reviewed by: **Roberta Batorsky**

In *Some Assembly Required,* Neil Shubin dons his molecular biologist hat. In *Your Inner Fish* (2008), written with his paleontologist hat on, Shubin described the discovery and significance of *Tiktaalik roseae,* a fossil fish with features like those of early tetrapods, unearthed in 2004 in Canada's High Arctic. This discovery marked a seismic shift in our understanding of how changes in animal bodies were organized as they moved to new modes of life and habitat.

Now, in his third book, Shubin explains how paleontology and molecular biology are working together to illuminate the history of life. "Rocks and fossils, when coupled with DNA technology, have the power to probe some of the classic questions that Darwin and his contemporaries struggled with," he explains. "New experiments reveal a multibillion-year history filled with cooperation, repurposing, competition, theft, and war" (p. xi).

Shubin enthusiastically describes the new vistas on the history of life that the collaboration of paleontology and molecular biology are beginning to provide. But he is no less enthusiastic about telling the stories of the scientific and even personal struggles of the researchers, which go beyond the usual textbook narratives of scientific innovations.

One of my favorite vignettes was Shubin's discussion of Walter Garstang, a 20th-century zoologist who wrote amusing poetry, studied tadpoles, and combined his interests in a book of jingles, *Larval Forms and Other Zoological Verses* (1951). From "The Axolotl and the Ammocoete":

> Amblystoma's a giant newt who
> rears in swampy waters,
>
> As other newts are wont to do,
> a lot of fishy daughters:
>
> These axolotls, having gills,
> pursue a life aquatic,
>
> But, when they should transform
> to newts, are naughty and erratic.

As Garstang's poem whimsically explains, in metamorphosis, the larvae of animals such as axolotls and salamanders lose their gills, changing from an aquatic life-style to a terrestrial life-style. "The shift from water to land, something that happened over millions of years in our own fishy past, happens over a few days of metamorphosis in these creatures," Shubin observes (p. 43).

Garstang was also fascinated by sea squirts, which as free-swimming larvae have a nerve cord, a connective tissue rod from head to tail, and gill slits: three hallmarks of our own vertebrate lineage. These features are lost or drastically modified when sea squirts become sessile adults. Garstang regarded these facts about development as evolutionarily significant: "rich with artifacts of the history of life and potential for its future," as Shubin puts it (p. 42). The ancestor of all vertebrates might have been a sea-squirt-like animal that retained its nerve cord, connective tissue rod, and gill slits into adulthood thanks to changes in its developmental timing.

Since Garstang's day, biologists have increasingly devoted attention to exploring whether alterations to the timing of embryonic development could have resulted in new kinds of creatures with different bodies, poised to enter new habitats. But now they are doing so with molecules as well as with morphology. As Shubin observes, the recipe for building animal bodies in each new generation is inscribed in the language of nucleic acids. Discovering the physical structure of DNA allowed biochemists to map the amino acid sequences of different proteins to understand how they work in the body.

Twentieth-century biochemist Emile Zuckerkandl extracted and separated crab hemoglobin proteins, using differences in molecular size and electric charge. Moving to larger game, he found that human and ape hemoglobin molecules shared more amino acids with each other than those of frogs and fish did, indicating that humans and apes are more closely related than fish and frogs are. Zuckerkandl and Linus Pauling realized that proteins are a kind of molecular clock for understanding evolution. Assuming that amino acid substitutions occur at constant rates over long periods of time, the more the proteins of two species differ, the longer they have been evolving independently from a common ancestor.

So fossils are no longer the *sine qua non* for deciphering the history of life; the molecular clock is now also used to determine the ages of various species. After Zuckerkandl and Pauling, evolutionary history would not be the sole province of paleontologists: biochemists now had a dog, or at least a molecule, in the hunt.

After Zuckerkandl and Pauling, evolutionary history would not be the sole province of paleontologists: biochemists now had a dog, or at least a molecule, in the hunt.

Shubin explains more recent research and discoveries in gene regulation as pioneered by 20th-century biologists François Jacob and Jacques Monod, the investigation of jumping genes by Barbara McClintock, the mapping of the human genome, and most recently, the gene-editing technology of CRISPR-Cas9.

Having begun with a fish swimming onto land, he ends by marveling at an even greater leap: "through eons of jury-rigging, duplicating, and co-opting, single-celled microbes have evolved in to the point where their descendants thrive in every habitat on the planet and have even walked on the moon" (p. 217). As Some *Assembly Required* demonstrates, our endeavor to understand life and nature's diversity is intimately connected to the research, effort, and thought of our predecessors.

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WHAT WE'RE UP AGAINST

Facebook Censoring Climate Change Education

"Changing Climate: Our Future, Our Choice" is a new permanent exhibit at the Museum of the Earth in Ithaca, New York. But you wouldn't have learned about it from Facebook. When a marketer working with the museum tried to publicize the exhibit on Facebook in October 2020, she found that she was unable to do so, owing to a temporary election-time ban on advertisements about "social issues" on the social media platform. Ingrid Zabel, the climate change education manager for the Paleontological Research Institution, which operates the museum, told the *Ithaca Voice*, "It's very disappointing that climate change and the education about it and a museum exhibit about climate change is considered social-political content that needs to be screened," adding, "I never would have guessed that." The Paleontological Research Institution received NCSE's Friend of the Planet award in 2019 in recognition of its efforts to advance climate change education, including *The Teacher-Friendly Guide to Climate Change* (2017).

—*GLENN BRANCH*

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