Is Man an Intruder on Nature?

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Animal Movement and Survival

Bees fly to their homes and monarch butterflies migrate thousands of miles to the same winter refuge in Mexico. These are among the wonders of animal movement that scientists are exploring. Modern technology is assisting tracking movement on land, in the air and under the seas with the use of satellites and ever-smaller and lighter high-tech tracking devices.

Animals face natural predators in their pathways. Climate change and humans destroying their habitats and food sources on their migratory journeys make survival more perilous. Articles in this resource guide encourage students to consider the natural GPS of sweat bees, monarch butterflies’ adaptations to survive, and ecologists sharing designs for less expensive tracking devices.

The article “Is Medicine a threat to horseshoe crabs?” introduces the reader to the harmless and primitive sea creature who not only plays a key role in nature, but also occupies a crucial place in the human world. Their eyes have been extensively studied and have provided insight into how our own visual system works. Chitin from its exoskeleton has been used as an absorbable suture material and for wound dressings for burn victims. But it is a special protein discovered in horseshoe crab blood that the article, as well as the medical and pharmaceutical industry, is focused on. Able to rapidly detect bacterial endotoxins, this protein is used in a test that must be done on every manufactured drug. So if you and your students have taken medicine or received a COVID vaccine or even a flu shot since the 1960’s you have the horseshoe crab to thank.

Lisa Wu, former oceanography lab director at Thomas Jefferson High School for Science and Technology, wrote the “From Crabs to Labs” activity and the case study “Covid, Crabs and Compromise” as well as compiled resources in “Learn More About Horseshoe Crabs.” In her more than 30 years of teaching, she worked with many STEM students on their projects in, on and under the sea including the Potomac River and Chesapeake and Delaware bays.
Go to a park on a hot summer day, and you will not be surprised to see bees buzzing in and out of flowers. They drink flower nectar and collect flower pollen. Then, depending on what kind of bees they are — we know of 20,000 species around the world — they fly back to their hives or nests.

In the tropical forest of Barro Colorado Island in Panama, you will encounter native sweat bees (Megalopta genalis) only during the night. They collect nectar and pollen just after sunset and about an hour before sunrise. It is so dark at these times that “if you extend a hand out as far as you can, you wouldn’t be able to see your thumb,” says William Wcislo (pronounced wice-lo). He’s a senior scientist at the Smithsonian Tropical Research Institute at Barro Colorado.

How are these green-and-gold bees able to find their way around in such dim light? That was the question Wcislo and collaborators from Sweden wanted to ask.

The trick to studying animal behavior, says Wcislo, is “knowing what thing [the animals are] trying to do so you can ask questions in a way that they’re able to tell the answer.”

For bees and wasps, we know that after they get food, “they’re trying to get home, and they have the ability to navigate through really complex environments,” Wcislo says.

How do they see the nest in the dark? The researchers thought maybe they look up at the forest canopy, where blobby patterns of the night sky look slightly brighter against the super-dark tree leaves. Do the bees recognize these patterns to get home?

The researchers built nests that had different patterns of black-and-white stripes over their entrances. The bees could find the nest that matched the pattern they memorized when they left home, even if the researchers moved its location.

This ability to navigate using forest canopy patterns, says Wcislo, “is fairly remarkable. It shows that this is a sensory world and what these bees pay attention to is richer than we thought before.”

It also shows that light pollution (too much artificial light) could confuse bees and other animals that are active at night: They need the pitch dark to navigate their own special way. Wcislo says the good news is that we can prevent light pollution. For example, people can program highway lights to turn off when there are no cars on the road, and we can use different wavelengths of light that do not disturb animals.

“If we want plants and fruits, we need pollinators” such as sweat bees, Wcislo says. And by figuring out what they need to navigate, we can do better work to help conserve them.

—September 28, 2021

Panamanian sweat bees look for food just before dawn and just after dusk, times with little light. This species can find their way by memorizing patterns in the forest canopy above their nests, scientists have found.
How the amazing monarch butterfly migrants became refugees — from us

BY DAN FAGIN

• Originally Published May 30, 2021

On a damp January afternoon 46 years ago in rural Mexico, a wayfaring American retiree, his adventurous young Mexican wife, and a local villager, along with a skinny pack horse and a dog named Kola, trudged up a muddy mountainside in search of a waking dream. At 11,000 feet, improbably, they found it.

Ken and Catalina Brugger, searching on behalf of Canadian butterfly scientist Fred Urquhart, had heard hard-to-believe stories about patches of a high-altitude forest teeming with millions of butterflies.

Now, suddenly, they knew those stories were true. They had found the hidden winter refuge of the eastern monarch butterfly, an iconic species whose epic annual migration had preoccupied Urquhart and other butterfly chasers for decades.

Today, the overwintering colonies in Mexico are still visually stunning, and the story of monarch migration retains much of its alluring mystery. But both the colonies and the 3,000-mile journey that sustains them are far more fragile than they seem — especially right now, as the social disruption and chaos of the global coronavirus pandemic reaches even to the isolated mountaintops where the Bruggers made their historic find. The potential losses — to monarchs, to science, and to all of us — are beyond calculation.

There is nothing else in the world like the migration of North America’s best-known butterfly. Despite the intensive efforts of Urquhart’s successors, who have made the monarch the world’s most studied butterfly, the experts still haven’t worked out precisely why and how an insect that spreads out widely enough during the summertime to occupy most of eastern North America — including your neighborhood, probably — consolidates every winter on the same half-dozen or so Mexican mountaintops. Why would tens of millions of finger-length creatures propelled by gossamer wings — imagine orange stained-glass panels made of tissue paper — undertake such a perilous journey? How could they possibly find their way?

It turns out that migration has been so vital to the monarch’s survival as a species that the best science now suggests it has evolved two extremely sophisticated navigation systems: a light-sensitive “sun compass” that compensates as the sun moves across the sky, and an “inclination compass” that can detect Earth’s magnetic field. (The second compass is especially important on days when clouds block the sun.) Both compasses are essential for the “Methuselah” generation of monarchs that does most of the round-trip migrating and lives about eight times longer than the summer generations that gambol in backyard gardens in the United States and Canada.

There’s a lot more mystery still left to solve, though, because the Methuselahs have an uncanny ability to find the very same mountaintop redoubts their great-great-grandparents occupied 12 months earlier. How they do that, no one knows — yet.

The overwintering sites are not only a compelling puzzle of evolutionary biology, they are also a phantasmagoric spectacle. I have visited twice, most recently in January 2020, as part of my research for a book on monarchs and the future of life on a changing planet, and can affirm that it is impossible to adequately describe in words, photographs or even video what it feels like to be surrounded by millions of butterflies.
This is especially true in midmorning, when the warmth of the rising sun filters through the oyamel fir trees and the resting monarchs blanketing almost every inch of every branch begin to stir and take flight, swooping and whirling overhead. (The collective noun for a group of butterflies is “kaleidoscope,” which is perfect.)

On both of my visits, I spent time on Cerro Pelón, the imposing mountain where the greatest secret of animal migration was first revealed to the world (though local villagers almost certainly knew about it already).

You might think there would be a plaque to mark the spot, or maybe even a statue, but there isn’t. In fact, no one is sure exactly where the Bruggers made their discovery, because while monarchs come to Cerro Pelón each November, they have several preferred roosting spots there, not just one. Lincoln Brower, the preeminent monarch scientist, who died in 2018, believed the historic spot was probably a grove on the mountain’s northwestern slope known as “La Lagunita,” or “the Pond” (monarchs like to be near water).

If Brower was right — and on the subject of monarchs, he almost always was — then you and I will never again see La Lagunita as the Bruggers saw it. More consequentially, neither will the monarchs, because during these past 15 months of pandemic-induced deprivation and desperation, La Lagunita has been trashed. Last year, someone — likely impoverished young men from a nearby community — illegally cut down several dozen oyamel firs, hauling them away for lumber. In December, the arriving monarchs tried to form a colony at La Lagunita but failed, according to Ellen Sharp, who runs a monarch-centric hotel at the foot of the mountain.

“It was chilly and cloudy, the kind of weather conditions that make them cling to the trees, but instead of clustering they were flying everywhere, restless when they should have been resting,” she told me. More than the usual number of dead monarchs littered the forest floor, probably because the surviving trees were now spread too thin to offer much protection from orioles and other predators, as well as from winter storms. “Usually, I like to linger at the colony,” Sharp said, “but that day, I hurried home, trying to escape the panicked feeling that I’d just witnessed the beginning of the end of the eastern monarch migration.”

A few weeks later, the monarchs gave up and abandoned La Lagunita altogether, shifting to a different location on the mountain. These migrants had become refugees.

Sharp and her husband, Joel Moreno Rojas, have gone to great lengths to try to protect Cerro Pelón from loggers, even forming a nonprofit organization that has hired local “forest guardians” to patrol the mountain and report what they see to the Mexican authorities. But their reports are usually ignored, Sharp says.

Last month, the guardians found another six trees felled at La Lagunita. Eight more were cut down a few days later. These latest wounds make it even less likely that La Lagunita will ever again successfully host roosting monarchs.

The motivation behind these destructive incursions is sadly obvious. The pandemic has had a devastating effect on the struggling, tourist-dependent communities bordering the 52-square-mile core zone of the Monarch Butterfly Biosphere Reserve, where logging is nominally banned but is now on the rise, reversing years of progress. Reserve officials recently acknowledged that 33 acres in the core zone had been illegally logged last year, up from just one acre the year before. The toll this year will surely be worse.

Violence is on the upswing, too, including the unsolved killings of two men who worked at the most heavily visited monarch colony, El Rosario. Now that the pandemic has driven away international tourists, gangs are filling the vacuum.

A scientist who has worked in the area for many years told me that, for the first time, their research group was recently forced to turn back after being halted on the road by a makeshift barricade manned by a gang of young men openly identifying themselves as members of a drug cartel.

It will take years to identify all of the ways this global pandemic has frayed the social fabric that binds us together,
and many more years to repair it. But the monarch migration may not have years. Monarchs are not close to extinction, thanks to robust nonmigratory populations established over the past 200 years in warm climates around the world (wherever humans wittingly or unwittingly plant milkweed, monarchs are likely to follow — even if they have to cross oceans). But in the place where the species likely first evolved, the mountains of central Mexico, the monarch’s long-term future is very much in doubt, as is the record-breaking migration that is its most distinctive feature (no butterfly flies farther).

Deforestation at the overwintering sites is the most immediate threat but is hardly the only one. In the U.S. corn belt, the widespread use of pesticide-tolerant, genetically modified crops has drastically reduced the supply of milkweed available to summering monarchs. That’s a huge problem because monarchs won’t lay their eggs on anything else.

Over the longer term, climate change is an even bigger threat. Drought along the monarch flyway is now commonplace, and the resulting lack of nectar sources worsens the odds that monarchs will survive the trip. Meanwhile, warmer winters are gradually pushing monarchs to higher elevations at Cerro Pelón, El Rosario and the other sites because the butterflies can roost successfully only if temperatures are, like Goldilocks’s porridge, neither too hot nor too cold. But the colonies are already near the mountaintops; in another couple of decades, there will be nowhere for them to move up to, and it’s unclear whether they can be induced to go elsewhere.

Don’t be fooled by their good looks and delicate features; monarchs are tough little bugs. They have dealt with global change before during their roughly 1.5 million years on this planet. Today, though, the barrage of extreme challenges we humans are throwing at them is overwhelming the much slower pace of adaptive evolution.

Fortunately, monarchs still have a crucial advantage: The same all-powerful species that poses the greatest threat to their future has also fallen hard for them, beguiled by their flashy coloring and evocative backstory of metamorphosis and migration. Hundreds of thousands of people in North America have resolved to help monarchs and other beneficial insects (monarchs are woefully inefficient pollinators, but they do pollinate) by planting native milkweeds and nectar plants in gardens and parks. Can you imagine a similarly broad social movement to protect, say, kangaroo rats, even though several species in that subfamily are much closer to extinction than monarchs? I can’t either.

With enough positive intervention by humans, the monarch migration may yet survive, though it’s very much an open question. The proliferation of butterfly gardens hasn’t halted the terrifyingly steep decline of the much smaller western monarch population; fewer than 2,000 were counted this year at their California overwintering sites, down from 1.2 million in 1997. For the eastern monarchs, this year’s population estimate from Cerro Pelón, El Rosario and the rest of the colonies in Central Mexico was roughly 45 million, down from 250 million 25 years earlier. Next year’s count is anyone’s guess, but the signs are not encouraging.

The monarchs have given up on La Lagunita. The increasingly urgent question is, are we giving up on the monarchs? ■

Dan Fagin is a professor of science journalism at New York University and the author of “Toms River: A Story of Science and Salvation,” winner of the 2014 Pulitzer Prize for general nonfiction.

Additional Reading

“Butterflies are vanishing out West. Scientists say climate change is to blame.” Dino Grandoni, March 4, 2021.
https://www.washingtonpost.com/climate-environment/2021/03/04/climate-change-butterflies/

“For more than a decade, butterflies have repeatedly landed on me. I think I’m blessed by the red admiral.” Washington Post Magazine, Dan Southerland, March 24, 2020.
https://www.washingtonpost.com/lifestyle/magazine/for-more-than-a-decade-butterflies-have-repeatedly-landed-on-me-i-think-im-blessed-by-the-red-admiral/2020/03/20/566468da-fa67-11e9-8190-6be4deb56e01_story.html

https://www.fws.gov/savethemonarch/

https://www.worldwildlife.org/species/monarch-butterfly
Fantastic and Fragile Monarch Butterflies

Fossils found in Germany provide evidence that butterflies have been on the planet for millions of years. In 1758 Swedish naturalist Carl Linnaeus, when he created a system for defining genera and species and naming animals, described the monarch butterfly in his *Systema Naturae*.

The butterfly’s color is believed to have influenced its common name. Early American settlers associated the beautiful orange and black wings with the Dutch Prince of Orange, the monarch who would eventually become king of England.

As you read “How the monarch butterfly migrants became refugees — from us,” consider the generations of these butterflies that have survived — their habitats, nutrition, adaptability and beauty.

1. Know the definitions of the following terms before reading the article:

   | Barrage | Impoverished | Preeminent |
   | Epic | Migration | Redoubt |
   | Gambol | Overwinter | Refugee |
   | Gossamer | Perilous | Refugee |
   | Habitat | Phantasmagoric | Roost |

**THE LEAD**

*The first four paragraphs of the article are the lead (also spelled lede). This sets up the article and grabs the reader’s attention. It ends with the nut graph — the paragraph that summarizes the rest of the article, what you will learn in more detail when you read the article.*

2. What is described in the first paragraph?

3. For what are Ken and Catalina Brugger searching?

4. What is the significance of their discovery?

5. What is the state of the overwintering colonies today?

6. In addition to their refuge, what does Dan Fagin indicate is in peril?

**THE JOURNEY**

*Monarch butterflies live from two to six weeks except for the last generation of the year, which can live up to nine months. Although primarily solitary, they migrate in large numbers. Together they are less likely to be killed by predators.*

7. To whom is “Methuselah” a reference? What qualities do both have?

8. From where do the monarch butterflies migrate? What distances are covered?

9. What important role do the Methuselahs play in the life cycle of the monarch butterflies?
THE WINTER REFUGE
Finding milkweed, nectar and sustaining weather conditions are challenges to migrating butterflies. This year many found an additional threat at La Lagunita, a favored refuge.

10. What conditions do they usually find at La Lagunita and other winter refuges?

11. Who and why has this destination been pillaged?

12. Attempts have been made to support survival.
   a. What have locals tried to do to stop the destruction of these decades-old refuges?
   b. What have the butterflies done to survive in Mexico?

ADDITIONAL THREATS
The Methuselahs lead the next generation to their winter roosts. In addition to the immediate destruction of their nourishing habitat, other challenges are threatening monarch butterflies.

13. What is the “bigger threat” according to Dan Fagin faced by monarch butterfly survival?
   List three specific examples.
   a.
   b.
   c.

14. What are some humans doing to intervene?

15. Why should we care about the survival of monarch butterflies?

WHAT CAN YOU DO TO HELP MONARCH BUTTERFLIES?

Learn more about butterflies. See them to get to know them. Begin with the video “My Animal Friends — Monarch Butterfly” produced by WIZZ TV for kids.

U.S. Forest Service | Habitat Needs
https://www.fs.fed.us/wildflowers/pollinators/Monarch_Butterfly/habitat/index.shtml

UNESCO | Monarch Butterfly Biosphere Reserve
https://whc.unesco.org/en/list/1290/

SCA | How to Start a Butterfly Garden in Your Backyard
https://www.thesca.org/butterflygarden/

National Wildlife Federation | Monarch Butterfly

The Washington Post | Want to create a butterfly garden?
Here’s what to plant based on your space.

World Wildlife Fund | Monarch Butterfly
https://www.worldwildlife.org/species/monarch-butterfly

WIZZ TV for Kids | My Animal Friends — Monarch Butterfly
https://www.youtube.com/watch?v=gy1oew4IqXM

National Geographic Kids | Monarch Butterfly | Amazing Animals
https://www.youtube.com/watch?v=1b87rwtXGzA
Paul Clerkin makes his living roaming the oceans in search of obscure shark species. At 36, he’s already discovered more than a dozen.

He has a somewhat different goal with his current target, a mysterious, deep-sea recluse called a megamouth. Clerkin wants to tag one with a tracker and tiny camera to record its every move and shed light on key unknowns about the species.

A custom gadget like this would run around $10,000. So the Virginia Institute of Marine Science researcher is building his own, on the cheap. Every week, he meets with John Garst, a whiz-kid programmer who just graduated from the College of William & Mary in nearby Williamsburg. When they finish their work, they’ll share their designs online.

Around the globe, a growing community of scientists and technology experts is doing the same. Like Clerkin and Garst, they aim to accelerate the development of trackers, slash their prices and enable far more animals to be followed in the wild.

With climate change adding to the intense pressures on many species — according to a 2019 United Nations report, a million animal and plant species face imminent extinction — these efforts have a sense of urgency. Negotiators from around the world will start virtual talks this week on the latest response plan, with an eye to increasing the amount of land and water that each country sets aside as nature refuges. Greater tracking will help reveal what animals need to survive as migration patterns, food chains and breeding cycles are disrupted.

“We really have to rethink conservation,” Paul Leadley, a professor of ecology at the University of Paris-Saclay, noted recently following an international scientific report on the interplay between climate
change and biodiversity. “Species and ecosystems are going to move around a lot as the climate warms.”

Animals have been tracked from air and space for decades, with ever-greater success as the number of satellites circling the planet multiplied. The cell towers that now cover the globe have added precision to measurements.

At the same time, the actual tracking devices have benefited from technological spillovers from other areas. Demand for higher-performance smartphones has brought about smaller, energy-efficient chips. Solar panels have shrunk, giving trackers longer life.

Ten years ago, those under 20 grams were deemed state-of-the-art. Now trackers weighing four grams, a touch lighter than a nickel, are common. Scientists project them to shrink further, enabling use with creatures as small as beetles and dragonflies.

With these advances have come important revelations: how 15 falcons anticipated prevailing winds to fly from India to Africa; where 20 black rhinos roamed in a park in Tanzania; and how two leatherback turtles successfully traveled through a key fishing ground in Trinidad — all clues that could help reverse their falling populations.

Ruth Oliver, an associate research scientist at Yale University, affixed 3½-gram GPS trackers to 55 American robins with nylon “backpacks.” She found that they seem to be migrating through Canada about five days earlier every decade, a likely response to a warming climate.

Oliver thinks there is huge potential to learn how migratory animals are adjusting, even optimizing, their movements to respond to various ecological pressures.

“Every time a new study comes out with tracking data, it’s upending preconceived notions of how animals use space,” she said. “The door is just wide open. We can’t fully appreciate what types of impacts this will have.”

Yet the cost of trackers — typically thousands of dollars — has limited their use and what can be learned about species in peril. It’s now fueling a search for alternatives.

In Germany, the Max Planck Society has joined with German and Russian space authorities on ICARUS, a project to follow millions of animals from the International Space Station. ICARUS engineers have teamed with companies that make retail electronics, hoping to fashion a tracker that can be mass-produced and customized across species.

Others are taking the open-source approach, sharing their tracker blueprints and all the hard-won lessons that went into them with anyone who’s interested.
“It really does open up a whole new world to us in the nonprofit sphere when we can access open-source technology,” said Mae Lacey, a data specialist at the D.C.-based Defenders of Wildlife.

In the Netherlands, a group called Smart Parks has created a range of tracking collars to monitor species such as elephants and rhinos in African wildlife preserves. The specifications of its OpenCollar designs are public on GitHub, a website for sharing code.

And in the United Kingdom, an organization called the Arribada Initiative develops “open, affordable and accessible” technologies to aid conservation. It was founded by Alasdair Davies, a British technologist who’d grown frustrated with the cost of animal trackers.

A few years ago, Davies responded to a query from Thomas Gray, an affable West Virginia native with a ponytail and mutton chops. After almost a decade as an animal-tracker salesman, Gray had concluded the business was broken. Companies spent millions devising custom machines and so kept their work proprietary and their prices high, he groused.

Gray switched to the CLS Group, a French environmental company that operates the Argos satellite system following about 8,000 animals worldwide. In 2017 he emailed all Argos users: Did anyone want to build a tracker that was the opposite of bespoke — one that would be available to everyone?

Davies took on the challenge and came up with a chip that’s about the size of a nicotine patch and can communicate with Argos satellites practically out of the box. And in August 2020, CLS announced a sweepstakes that would award 20 do-it-yourself “kits” to whoever wanted to tackle an important tracking problem. Each would include two of those tiny chips, a free year of satellite service and free tech support from Arribada.

The catch: Winners will give away their designs.

Paul Clerkin, a researcher at the Virginia Institute of Marine Science, is building a satellite tracker for tagging and following one of the world’s rarest of sharks.

So far the $1,500 kits have gone to nine awardees. Among them: a company trying to build an inexpensive polar bear ear tag for the U.S. Fish & Wildlife Service, a pair of California high-schoolers who think they have a low-priced tracker to use when whales get tangled in fishing gear, and, in Virginia, Clerkin for his pursuit of the megamouth.

The shark has only been seen about 200 times since 1976, usually dead in fishing nets.

“We know almost nothing about megamouths,” he said. “Because of that, we can’t protect the species. We don’t know what they need for protection.”

The marine ecologist encountered his first in 2015 off the coast of Taiwan, during a trip funded by Discovery’s Shark Week. Equipped with two $4,000 trackers — which he’d wheedled a company into donating — Clerkin went out with a fishing captain who said he’d seen megamouths roaming.

Sure enough, around 3 a.m. they snagged a 20-foot female in a net dropped for just that purpose. Clerkin, an otherwise mellow Californian revved up on adrenaline and nerves, plunged into the water. He swam beneath the surface and affixed one of the trackers to the shark’s dorsal fin. It was the first satellite tag placed on a megamouth.

He has since tagged three more of the species. His research suggests megamouths are vagabonds, exploring temperate waters around the world but seemingly always returning to the Taiwanese coast. Clerkin suspects they’re there for the shrimp but wants his next tracker to prove it.

Taiwan now bans fishing for megamouths. Environmental authorities say the country is willing to go further and declare them a protected species if data supports the designation. Clerkin hopes to provide some of the findings.

Until now, his work with Garst has been slow going. A recent victory: They managed to connect to the tracker from a regular program on his computer.

The pair plan to finish building their tracker this year, test it in shallow waters near Virginia and ultimately hitch it onto a megamouth next year. The device would record the shark’s every turn, twist and acceleration for two full days.

“There’s always things you want to study in sharks, there’s all these unknowns,” Clerkin noted recently. “You think, I bet I could figure it out if I could get a tag that did X, Y and Z.”

“And if it doesn’t exist, it’d be really cool to make it.”

Paul Clerkin, a researcher at the Virginia Institute of Marine Science, is building a satellite tracker for tagging and following one of the world’s rarest of sharks.

JULIA RENDLEMAN FOR THE WASHINGTON POST
Sharing High-tech Tracking

Footprints in mud, markings on trees and broken branches reveal the presence, past or present, of a variety of animals. Read “A high-tech, low-cost push to track species” to learn about current tracking with technology.

1. “With climate change adding to the intense pressures on many species — according to a 2019 United Nations report, a million animal and plant species face imminent extinction — these efforts have a sense of urgency.” What are the efforts to which Saqib Rahim refers?

2. Name three kinds of information that increased tracking will reveal.
   a.
   b.
   c.

3. What is the role of satellites in modern tracking?

4. What is the cost of manufactured trackers? How does this impact the kind of work that can be done?

5. What is project ICARUS? Include in your response its long-term goal.

6. What is the open-source approach? What information do these examples provide?
   a. Smart Parks
   b. Arribada Initiative

7. Paul Clerkin, 36, is working with a College of William & Mary graduate to build a tracker.
   a. How does the CLS sweepstake help them?
   b. What is the goal of their project?

8. Take the point of view of companies that manufacture tracking devices. Explain what is involved in getting your product ready for the buyer to use. Defend the price you charge.

9. Paul Clerkin serves as a bookend to the science article. Read again the first three paragraphs and the last six paragraphs. Explain how Clerkin helps you to understand the main ideas of the article.

10. If you were to apply for one of the 20 do-it-yourself kits awarded by CLS, what would be the tracking problem and your goal for your tracker?
Is Medicine a threat to horseshoe crabs?

BY CAREN CHESLER

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Few organisms are as odd, or as old, as the horseshoe crab. That they predate the dinosaurs, a time when everything was large, might explain their oversize, helmet-shaped shells, which can grow as large as 20 inches. They limp along the tidal flats as if a smaller creature was hiding inside that shell, using it to move about incognito. Anatomically, they’re more like spiders than crustaceans, and they fluoresce under ultraviolet light.

But perhaps their unique feature is how their blood, which is bright blue, coagulates when exposed to harmful bacterial endotoxins, a feature that has kept them alive for about 450 million years.

Bacterial endotoxins induce inflammation and fever, and can cause anaphylactic shock and death. They are responsible for venereal disease, bacterial meningitis as well as cholera, bubonic plague and other diseases. Immune cells in the crabs’ blood trap and immobilize these type of endotoxins, rendering them inert.

It’s a blessing and a curse because once scientists discovered this amazing defense system back in the 1960s, we began using it for ourselves, bleeding horseshoe crabs and separating out that clotting feature to test medications, needles and biomedical devices to make sure they are contaminant free.

Their blood has been so useful — enabling scientists to create vaccines that help humans fend off everything from migraines to melanomas and most recently the coronavirus — that we’ve made a dent in their population.

But while science created a problem, it may be able to fix it.

A new technology is available that uses a man-made version of crab blood to detect endotoxins, but it has stirred a debate over whether it is as good. The debate has pitted conservation-minded scientists against a board that sets scientific standards for the pharmaceutical industry, which believes more study needs to be done before a synthetic version of crab blood can be used.

Last summer, as coronavirus infection rates continued to rise, a group of researchers from Eli Lilly, Bristol Myers Squibb, Pfizer and Roche-Genentech published a research report that compared the two products — limulus amebocyte lysate, or LAL, which is made from horseshoe crab blood, and the synthetic product, called recombinant Factor C assay, or rFC.

But the findings did little to quell a debate.
Pharmaceutical companies need to make sure their injectable drugs and medical devices such as hip and knee replacements are free of bacterial endotoxins. But conservationists say rFC can detect bacterial endotoxins equally well, and they have pushed the scientific standards board, known as the U.S. Pharmacopeia (USP), to adopt rFC as an alternative test for endotoxins, alongside LAL.

If drug companies continue to rely solely on LAL, they say, horseshoe crab populations will be put at risk.

It wouldn’t be the first time this species has faced potential extinction. In the 1990s, the population of horseshoe crabs along the East Coast was decimated by fishermen who used them as bait to catch eel and corner the lucrative market for whelk or conch. Before that, scientists along the Delaware Bay could find an average of 45,000 horseshoe crab eggs per approximately 11 square feet in about the top two inches of sand. Since 1995, that figure has fluctuated between 5,000 and 10,000, according to the New Jersey Division of Fish and Wildlife. And the population struggles to rebound as companies that manufacture LAL now harvest crabs, some conservationists say. About 500,000 crabs are plucked from waters and beaches along the Atlantic coast each year to make LAL.

“I could show you a movie from 1986 that was filmed right over there, at Reeds Beach, and the eggs were this deep on the beach,” said Larry Niles, a biologist formerly with the New Jersey’s Fish and Wildlife division, holding his hand about eight inches above the sand.

The eggs aren’t just a proxy for measuring crab populations. They are food for migratory shore birds such as the Rufa red knot, which flies 9,300 miles each year from Argentina’s Tierra del Fuego to the Canadian Arctic to breed, stopping in the Delaware Bay to eat crab eggs. But its population fell 75 percent from the 1980s to the 2000s, in large part because the supply of horseshoe crab eggs dropped.

The hunt for coronavirus vaccines has only fired up concerns about the sustainability of horseshoe crabs. In March 2020, there were 241 therapies, including vaccines, in development. Today, there are about 838, according to Bio, a trade association representing biotechnology companies.

“Every drug or vaccine candidate or clinical trial or finished solution injected into the body has to have LAL testing. The water and raw materials going into such solutions also have to be tested,” said Kevin Williams, a scientist who spent 30 years at Eli Lilly and now works for bioMérieux, a French multinational biotechnology firm that manufactures rFC. “So this is an immense additive effect given how many companies are now working on vaccines and drugs for covid.”

Even before the coronavirus, the demand for horseshoe crab blood was already rising.

Bleeding labs, which bleed horseshoe crabs of about 30 percent of their blood and turn that blood into LAL, collected 637,029 horseshoe crabs in 2019, 30 percent more than they took the year before. While the crabs are returned to the water, fishing authorities take it for granted that at least 15 percent — or 95,554 — of them die. Some research puts that mortality figure as high as 30 percent.

“As it is now, the entire supply chain for endotoxin testing of drugs rests upon the harvest of a vulnerable or near extinct sea creature,” Williams said. “As prudent as the pharmaceutical industry is, this seems to be a current blind spot.”

The Food and Drug Administration, which reviews new drug applications, does accept medicines tested with rFC, but companies must do more work for their application than if they had used LAL, which is costly and time consuming, making it less likely they will use the product.

To date, Eli Lilly is the only company that uses rFC when submitting its new drug applications to the FDA — although last summer, French drugmaker Sanofi said it, too, planned on using rFC. But the momentum isn’t likely to pick up until the USP says in its guidelines that drugmakers can use the alternative. The European Pharmacopeia approved rFC for endotoxin testing last year.

“While rFC is an alternative to LAL, the data available today is not enough to put them at the same level so they can be used interchangeably,” said Fouad Atouf, vice president of global biologics at USP.
Atouf said USP isn’t the only organization that says this. When it considered putting rFC and LAL on equal footing in its compendium of standards, it asked industry stakeholders for comment, and there was not a broad consensus that there was enough data. Even the FDA expressed concerns, he said.

Jay Bolden, of Eli Lilly, says his study from September provides the USP with that data.

“We looked at all the available scientific literature on rFC, and we found a dozen studies that say exactly what we think the [USP] would need to make those kind of judgments,” Bolden said.

He said there is only one study, from a company that manufactures LAL, in which rFC appears to be inferior, and it is because it used pre-filtered water, which he said can skew the results.

Charles River Laboratories International, which did that study, notes it was peer-reviewed, and used samples from various points in the pharmaceutical water purification processes.

“While these water samples are not routinely tested for bacterial endotoxins, they do exist within manufacturing facilities and thus present risks to manufacturing operations,” said Samantha Jorgensen, associate director of public relations and social media for Charles River.

Jack Levin, professor at the University of California School of Medicine at San Francisco, and the scientist who helped discover the LAL test, disputes the notion that the LAL manufacturers are killing off the crabs.

While he acknowledges the crab population in the United States crashed about 15 years ago on account of the bait fishermen, the federal government intervened and instituted quotas, and the population has rebounded, he said.

“People have often approached this with a certain religious fervor and want to ignore that,” he said. “I certainly don’t believe in killing animals unnecessarily. And you can argue, if you want to, against animal research, until it impacts your own health, of course. But the argument that the lysate industry is depopulating the crab population is just not correct.”

The American horseshoe crab is not considered endangered, although it is classified as vulnerable on the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN). But conservationists fear if it continues to be overfished, the species could go the way of the Asian horseshoe crab, which is already extinct in Taiwan, disappearing in Hong Kong and dwindling in China. The IUCN lists the Asian crab as endangered because of biomedical bleeding as well as coastal development destroying its habitat.

The USP says it is committed to finding ways to transition from animal-derived materials to synthetic ones, but it needs more proof that the two products are on par. The USP is conducting a large study of its own this summer comparing the two products — though much to the dismay of those pushing for rFC, the study will also use some water samples that are unfiltered, not unlike the water used in the Charles River study.

Jessica Ponder, a regulatory testing analyst for the Physicians Committee for Responsible Medicine, says the American crab population may not be on the brink right now, but we don’t want to be reliant on an animal, particularly one that can be found in only one country now. Her organization, which promotes in vitro assays to replace animal testing where they’re not necessary, said she has looked at the test and believes the data to use rFC is there.

There’s a reason Eli Lilly has switched over to rFC, and it’s not just good stewardship but foresight, she said.

“They see this coming a mile away, that eventually we’re not going to have this horseshoe crab blood available,” she said. “Is that going to be today? Is it going to be 20 years from now? That’s not something that’s easy to predict when you have a natural resource, but at the same time, what are we waiting for?”

As our reliance on these crabs grows, they continue to do their job, emerging from the sea each May when the tide is high and the moon is full, and climbing up onto the beaches to spawn. For now, they are saving us. One day, it may be the other way around. □
From Crabs to Labs

“Caren Chesler in her article ‘Is Medicine a threat to horseshoe crabs?’ introduces readers to the surprising relationship between horseshoe crabs and human health. It is hard to believe that almost everyone of us has in some way been touched by the existence of this amazing creature. I am of course referring to the limulus amebocyte lysate, or LAL, which is made from horseshoe crab blood. A major player in the biomedical industry since the 1960s, this amazing copper-based blue blood has helped develop vaccines and ensured that needles and instrumentation implanted in the body are free of contamination.

“I was introduced to the living creature as a resident along our mid-Atlantic beaches. In June, emerging like a D-Day invasion on the beach, these ancient mariners gather to mate. Awe struck, I found myself camping behind the dunes to watch the mating ritual during a full moon and a high tide. On field excursions to the Delaware Bay, my students were always fascinated by the strange anatomy and the myriad of organisms hitch-hiking on their helmet shaped carapace. More recently, on a vacation, my family cringed as I strode over to explain to a group that it was not in their best interest to clear the beach of horseshoe crabs by picking them up by their telson (tail) and heaving them into the trash bins. Of course, I couldn’t help but go on to explain some of the ways we and nature benefit from their existence; soon I had a following of believers carefully righting the stranded crabs and returning them safely to the surf.

“Let’s dissect Chesler’s article and discover more about connections to the *Lymulus polyphemus.*”

— Lisa Wu, oceanography/marine biology educator

1. Believed to predate dinosaurs, the horseshoe crab has unique qualities.
   a. Describe their physical appearance.
   b. What feature may have most influenced their survival for 450 million years?
2. How do the following affect the horseshoe crab population?
   a. Bleeding labs
   b. Coastal development
   c. Fishing industry
3. In addition to their copper-based blue blood, what other special adaptations does the crab possess?
4. Explain why LAL testing is so critical to the pharmaceutical industry.
5. What is the ecological connection between horseshoe crabs, the Rufa red knot, whelks and eels?
6. What are endotoxins and why must the biomedical industry be concerned about them?
7. How is the horseshoe crab’s immune system different from our own immune system?
8. What is recombinant Factor C assay, or rFC? Its use?
9. Explain the role that the U.S. Pharmacopeia (USP) plays in the debate.
10. What is the point of view of the Physicians Committee for Responsible Medicine concerning use of synthetic medicines and animal testing?
Covid, Crabs and Compromise

Debates, decisions, policy and practice take shape

As concerns have risen over the spread of diseases and a coronavirus pandemic, we have heard much reference to “follow the science.” Sometimes references refer to what we might consider established “laws” of science or theories that have so much supporting evidence that we accept them as truths. But as a student, we learn in school that science is a process. It is about questioning, hypothesizing, testing, collecting data, analyzing results and forming conclusions. This process can be used in the test kitchen, at the lab bench, on a research ship or in a business conference room. We trust this method because it is believed to be ethical and unbiased. We use it to determine protocols for procedures and policy in government and rely on the process to continuously guide us as we move through history and find ourselves in contentious debates.

From Congress to community centers, people in the position of deciding policy rely on experts in areas where they themselves may be lacking information. Federal, state, and local governments; non-profit organizations; lobbyists for a particular cause; or even a single private citizen will find that research, data and communication of this information are key in moving ahead or even countering a proposal that is being made.

In this case study, you will form a panel of experts that will provide reliable, impartial expertise, that will help decision makers develop a policy to find a balance between man and nature. Whoa! Sound impossible? Ok, let’s take a smaller slice and narrow it down to the debate concerning horseshoe crabs and the pharmaceutical industry.

Although the horseshoe crab has survived for more than 450 million years, *Limulus polyphemus* is found only along western Atlantic shores from Maine to the Yucatan Peninsula. They are at the center of a worldwide debate: Should industry detect endotoxins by using manmade recombinant Factor C assay, or rFC, instead of using limulus amebocyte lysate, or LAL, which is made from horseshoe crab blood?

To do this your panel must look historically at the horseshoe crab populations, their importance to the watermen, the fishing industry, the pharmaceutical industry and the ecosystem.
Covid, Crabs and Compromise | continued

Your team will create a written compilation of five different stakeholders’ views. Each team member will assume the role of an “expert stakeholder.” These stakeholders include:
1. Government: Federal agency, state agency for environmental issues
2. Nongovernmental Organizations (NGOs)
3. Academia or academic research
4. Pharmaceutical industry
5. Local interests: Fishermen, businesses, residents

Each student must explore the background of its stakeholder to understand its concerns and interest in the topic. Based on this research, you must determine what specific issues must be addressed in your individual testimony and you will craft outside witness testimony with two to five specific recommendations relevant to the stakeholder’s role. This written testimony will include scientific research and science-policy related recommendations. Each “expert” is required to cite three to five sources, minimally, which must come from primary and secondary scientific sources on the subject. As you form recommendations consider economic impacts, environmental impacts, community impacts, health impacts, resources, research and development, and capacity building.

As a team, you will discuss the recommendations of each member and develop four to six well-supported final recommendations concerning the question. The final team recommendations should address the “big picture” with a comprehensive approach that takes into consideration all stakeholders’ perspectives.

Written Testimony Rubric
• A written outside witness testimony from each stakeholder “expert” containing two to five individual recommendations

• Written testimony from each stakeholder should be no more than 600 words. In this written testimony, team members should respond critically to the science needs surrounding the topic, citing literature to defend their argument.

• Three to five works are cited for each stakeholder including both primary and secondary sources

• An 80- to 100-word summary of the 600-word statement, efficiently summarizing the stakeholder expert’s testimony

• The team’s final recommendations should be 400-800 words and should highlight and explain the four to six consensus recommendations of the team. The final recommendations will be the team of expert’s consensus viewpoint and recommendations to address the scientific requirements and needs regarding a comprehensive policy on the chosen topic. These consensus recommendations are well thought out, specific and highlight appropriate and realistic compromise. This should NOT be a summary of individual expert testimonies, but instead a collaborative set of recommendations that take into account each stakeholder’s interests and abilities to compromise.
Learn More About the Horseshoe Crab

Caren Chesler in her Washington Post article “Is Medicine a threat to horseshoe crabs?” provides the foundation for understanding the debate over the use of horseshoe crab blood.

There is more to their complex interactions. Although they spend most of the year several miles offshore, horseshoe crabs head to shallow, quiet coves along the coast in the spring, with the largest populations emerging around the Delaware Bay. Guided by the moon and the tides, the females crawl onto the beach, often dragging several smaller males attached to them by special pinchers. The female digs a shallow depression and deposits thousands of eggs that are then quickly fertilized by the males. The eggs will hatch within two to four weeks and the young crabs will return to the sea on the next high tide. But it is what happens between the high tides in that month after the eggs are laid that has so woven them into ecology.

In the weeks following fertilization, sometimes millions will wash out of the sand before they hatch. To fuel one of the longest migrations, numerous species of migratory shorebirds stop along the Bay and mid-Atlantic beaches each year to build up their body fat and feast on thousands of these horseshoe crab eggs, before continuing their northern journey to the Arctic. Eggs from the horseshoe crabs are also an important food for finfish and junior loggerhead turtles, a threatened species that uses the Bay as a nursery. Adult crabs are also harvested to use as bait for the lucrative whelk and eel industry as well as fertilizer and animal feed in agriculture.

Below are some suggested projects for additional understanding of this amazing creature and issues surrounding it.
1. Research the anatomy and physiology of the horseshoe crab.
2. Create a visual that illustrates the difference between horseshoe crab and human immune systems. Research is ongoing. Remember that immune systems include cells, tissues and organs.
3. Discover why the development of the synthetic recombinant Factor C (rFC) has not been fully embraced by pharmaceutical companies.
4. Explore studies done on the eyes of the horseshoe crab. How do they relate to humans?
5. Understand more about chitin from the horseshoe crab’s exoskeleton. Include how it is used as an absorbable suture material and for wound dressings for burn victims.

Read to Explore and Learn More

The Washington Post
“This creature has 10 eyes, legs that chew and blood that saved your life”

“Millions of horseshoe crabs spawn on the shores of Delaware Bay each year. Here’s how to see them.”

“New Demands Spur Focus on Ancient Crab”
https://www.washingtonpost.com/archive/politics/2003/03/17/new-demands-spur-focus-on-ancient-crab/7f0d163e-26c9-4a59-8a26-8b7708631d62/?itid=Irk_interstitial_manual_64

Are horseshoe crabs really crabs?
https://oceanservice.noaa.gov/facts/horseshoe-crab.html

A tale of two species
The many ways horseshoe crab blood will amaze you
https://www.americanoceango.org/blog/horseshoe-crab-blood/

From horseshoe crabs to the depths of space
https://www.criver.com/eureka/from-horseshoe-crabs-to-the-depths-of-space?_ga=2.15796977.652678426.1641320473-1215072164.1641320473

Horseshoe crabs and the pharmaceutical industry
https://www.researchgate.net/publication/343282844_Horseshoe_Crabs_and_the_Pharmaceutical_Industry_Challenges_and_Alterspectives_-_Project_Report?channel=doi&linkId=5f2168e7458515b729f06d8f&showFullText=true

Horseshoe Crabs: Managing a Resource for Birds, Bait, and Blood

Charles River Laboratory
https://hsc.criver.com/#conservation
Fantastic resources on all aspects of horseshoe crabs, including slideshow and a wonderful 3-minute and 53-sec introductory video

Ecological Research & Development Group (ERDG)
https://horseshoecrab.org/tag/horseshoe-crab-research-institute
Non-profit wildlife conservation organization whose focus is horseshoe crabs

Delaware Bay Horseshoe Crab Survey
https://www.delawarebayhscsurvey.org/join
Find out how to join the Delaware Bay survey of horseshoe crabs

The Maritime Aquarium at Norwalk
https://www.maritimeaquarium.org/citizen-science
Learn about an opportunity to tag horseshoe crabs in Long Island Sound

Horseshoe Crab Research Center
https://www.youtube.com/watch?v=whnayAue7pq4
Eric Hallerman, Director of Virginia Tech’s Horseshoe Crab Research Center, conducts on-going research on this important species to promote its sustainability. Here he takes a look under the full moon during their spawning period in May off Chincoteague Island in the Atlantic.

Hooray for horseshoe crabs
https://coast.noaa.gov/estuaries/curriculum/hooray-for-horseshoe-crabs.html
A 15-page curriculum (grades 6-12) on horseshoe crabs with excellent illustrations and activities was developed and produced for The National Oceanic and Atmospheric Administration (NOAA) and The National Estuarine Research Reserve System. Even includes an assessment!

How do horseshoe crabs keep you healthy?
https://oceantoday.noaa.gov/fullmoon-bluebloodsbattlebacteria/welcome.html
A great 2-minute video shows you how

High school students in college-level lab take on Bay-size studies