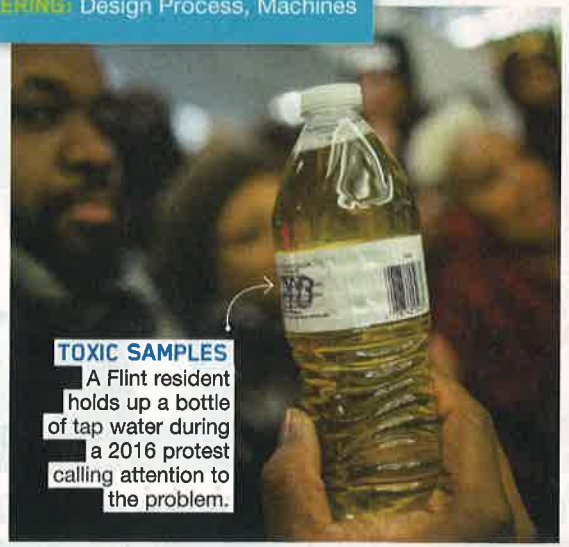
DANGEROUS WATER After Flint changed water sources, tap water became visibly discolored and contained high levels of lead.



TOXIC SAMPLES A Flint resident holds up a bottle of tap water during a 2016 protest calling attention to the problem.

TESTING THE WATERS

After taps in Flint, Michigan, turned toxic, a student invented a device to ensure water is safe for all

SAFETY PRECAUTION To reduce lead exposure, a Flint resident heats bottled water for her children's baths.

JAKE MAY/THE FLINT JOURNAL/AP
E PRESS/ZUMAPRESS.COM (BOTTOM)

ESSENTIAL QUESTION: Why is access to clean, safe drinking water important?

Four years ago, the city of Flint, Michigan, switched water sources for its 100,000 residents in an effort to save money. But local officials did not have the new water treated correctly. When scientists later performed lab tests on Flint's water in response to concerns expressed by residents, they found dangerous levels of *lead* (Pb). This toxic element can cause serious health problems. The crisis in Flint motivated 12-year-old Gitanjali Rao to design a device that can detect lead in water.

"Seeing how many people were affected by lead in their drinking water was appalling," says Gitanjali, who lives in Lone Tree, Colorado. "It was scary to think about being in their shoes. I wanted to find a way to help."

Gitanjali's device tests for lead much faster than sending samples to a lab for analysis. It also gives more detailed results than current home-testing methods. For her innovative idea, Gitanjali won the top prize in the 2017 Discovery Education 3M Young Scientist Challenge, a contest open to students in grades 5 to 8.

TOXIC WATERS

Like many people across the U.S., Gitanjali's family watched with concern as the crisis in Flint unfolded. Soon after Flint switched water supplies, discolored water started flowing from taps. For months, local officials told residents that the water was safe—but it wasn't.

Water from the new source, the Flint River, had a different chemistry than the old water supply. The river water was more *acidic*, or corrosive. It ate away at Flint's old lead pipes, releasing the toxic metal into the water. After much public outcry, the federal government declared a state of emergency for Flint, and the state began supplying residents with bottled water (*see Ongoing Crisis, p. 16*).

Lead exposure is dangerous, particularly for children. It can affect brain development, leading to learning and behavior problems. It can also damage internal organs and weaken muscles and bones, slowing growth.

Gitanjali's family wondered about their water. Her parents, both engineers, bought

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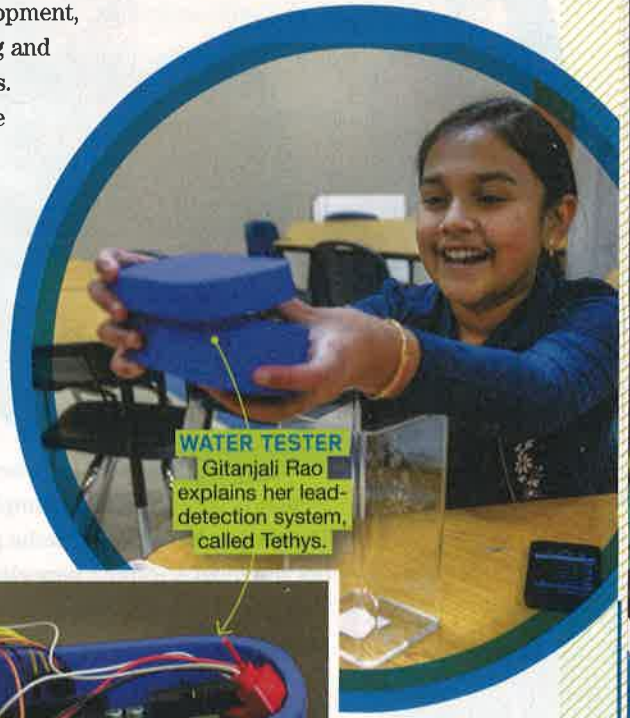
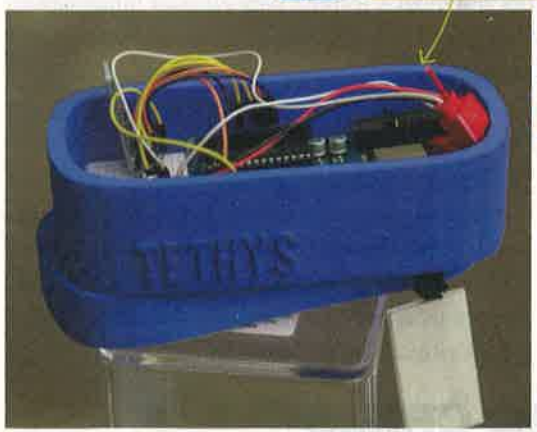
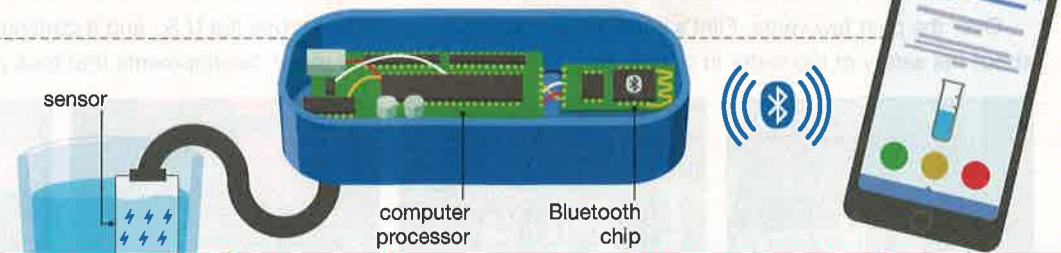


WATER TESTER Gitanjali Rao explains her lead-detection system, called Tethys.



LEAD DETECTOR

Tethys can provide information about lead levels in any



HELPING HAND: Gitanjali (*left*) with project mentor Kathleen Shafer

test strips to check samples from their tap. The strips change color in the presence of lead, but the results weren't very clear or informative. That got Gitanjali thinking about whether there might be a better way to test for lead.

INVENTOR AT WORK

One day, Gitanjali came across a news story from the Massachusetts Institute of Technology. Researchers there had developed sensors that could detect toxic gases in air. They created the sensors using *carbon nanotubes*—microscopic cylinders made of the element carbon (C). Gitanjali wondered if a similar sensor could detect lead in water (*see Lead Detector, p. 15*).

Gitanjali developed a plan for a device based on nanotube sensors, built a cardboard model of it, and entered her proposed invention in the Young Scientist Challenge. Finalists are partnered with a scientist who helps them develop their idea further. After being selected, Gitanjali was assigned Kathleen Shafer, a chemist at 3M, as her project mentor. "Gitanjali's passion and desire to make a difference stood out from the start," says Shafer.

Gitanjali spent three months turning her concept, named Tethys after the Greek goddess

DISCOVERY EDUCATION/ANDY KING (TOP); BOTTOM L-R: SARAH RICE/GETTY IMAGES; BRETT CARLSEN/GETTY IMAGES; SARAH RICE/GETTY IMAGES; GEOFF ROBINS/AFP/GETTY IMAGES

L-R: RYAN GARZA/DETROIT FREE PRESS/TNS VIA GETTY

ONGOING CRISIS

Over the past few years, Flint's water crisis has made headlines across the U.S., and it continues to spark debate about the safety of tap water in our country. Here are some of the major developments that took place.




HIGH STAKES: Gitanjali presents her invention to contest judges in October 2017.

of water, into a working model. She used a *3-D printer*, which builds up layers of material, to create a plastic frame for her device. She wired the internal electronics and discussed with a manufacturer how to produce the specialized nanotubes for the lead sensors. Finally, she programmed a smartphone app that would interface with Tethys to display its test results.

PERSEVERANCE PAYS OFF

One roadblock Gitanjali ran up against was finding a way to test her device. Lead can be dangerous, so she needed to work at a facility where it could be handled and disposed of properly. She contacted university labs asking to conduct tests. "But most places don't want a 12-year-old to do that," she says.

Even so, the competition judges were so impressed with Gitanjali's progress that they named her America's Top Young Scientist last October. Soon after, Gitanjali got in touch with technicians at the Denver Water Department, who invited her to conduct lead testing at their facility. She's been visiting the lab once a week ever since to continue improving Tethys.

"I'm comparing results from my device with the results from expensive lead-testing machines in the lab," says Gitanjali. "And I'm looking at how different concentrations of lead affect the sensor, so the results can be as detailed and accurate as possible."

FLINT AND BEYOND?

Once she's finished testing Tethys, Gitanjali hopes to make the device widely available. That way anyone worried about water quality can test for lead. Sadly, Flint isn't the only place in the U.S. at risk from lead-contaminated water because of aging lead pipes and fixtures.

In 2016, the Natural Resources Defense Council found that more than 5,300 municipal water systems, which supply water to 18 million Americans, violated federal rules for lead testing of drinking water. Those violations included high lead levels, improper monitoring, failure to report test results, and failure to address pipe corrosion. An investigation by the news organization Reuters the following year found more than 3,800 U.S. communities whose rates of childhood lead poisoning were double that of Flint at the peak of its crisis.

A device like Tethys could help people check the safety of their water. And pooling results from many home tests could help identify the places in most urgent need of help, says Gitanjali. Shafer, her project mentor, couldn't be more proud: "Gitanjali's work is a powerful example of the role of science in developing solutions that can improve our world."

—Jennifer Barone

CORE QUESTION

Why is it important for people to have access to accurate lead testing?

MAPPING MANGROVES

A teen draws attention to the threats facing one of nature's most important forest ecosystems

ESSENTIAL QUESTION: How do scientists monitor the health of ecosystems?

Not many teenagers can say they work at NASA. But then again, not many teens are quite like 16-year-old Liza Goldberg. For the past two years, she has helped researchers at NASA's Goddard Space Flight Center in Maryland develop new ways of protecting one of Earth's most important *ecosystems*: mangrove forests.

The shrubs and trees that make up mangrove forests grow only in the area between high and low tides along tropical coasts. These *intertidal zones* are hot, waterlogged, and salty. Mangroves have developed specialized *adaptations* that help them survive these conditions, which would kill most plants. Their most distinctive feature is their tall, stilt-like roots. They help anchor the plants in the mud and provide

changes to global weather patterns—have taken a heavy toll on these ecosystems. Liza, now a junior in high school, is working with NASA to use satellite images to track the health of these priceless forests.

TEEN SCIENTIST

Growing up in Maryland, Liza wasn't thinking much about tropical mangroves. But she was worried about how a warming climate might affect plant life.

For a middle school science project, Liza researched how temperature changes affect the ability of maple trees to absorb carbon dioxide (CO_2) from the air. Plants use sunlight and water to convert this gas into food—a process known as *photosynthesis*.

Liza's work caught the attention of a science-fair judge, who recommended her for an internship at NASA. Two Goddard scientists—

CORAL PROTECTOR
Mangroves protect coastal coral reefs by purifying water, stabilizing shorelines, and providing nursery habitats for fish.

Earth's physical characteristics using technology like imaging satellites.

Liza studied the topic by reading every scientific paper on remote sensing and mangroves she could find. What she discovered surprised her. "Mangroves have a higher rate of deforestation than rainforests,"

CARBON SINK
Mangrove forests absorb 2 to 3 times more carbon dioxide per acre from the air than other forest ecosystems.

FISH HAVEN
Many tropical fish, like this *Paracanthurus hepatus*, raise their offspring in mangrove forests.

TEEN SCIENTIST: Liza keeps a busy schedule. In addition to presenting at conferences and working at the lab, she's a competitive swimmer.

ability to capture carbon dioxide from the air. CO_2 is a *greenhouse gas* that absorbs heat in Earth's atmosphere, warming the planet. "Mangroves store a lot of carbon in the trees and in the soil underneath their roots—two to three times more per acre than other ecosystems,"

ECOMAP IN ACTION

Liza presents EcoMap at a conference in Ireland. The program shows where mangroves are at risk (red) and where they are healthy (green).

COURTESY OF DAVID LAGOMASINO (PRESENTATION)

branches shelter many bird species. And all sorts of creatures—from insects to tigers—spawn, nest, find shelter, or hunt around mangroves. Together, these animals create a vast and intricate *food web*—an interconnected system where organisms eat other organisms to obtain energy (*see Mangrove Food Web, below*).

People also need mangroves. Large mangrove forests collect *sediment*, like sand and silt, which builds up shorelines. That helps prevent *coastal erosion*—the wearing away of coastlines by flooding and waves. In addition, deep-rooted mangroves serve as a buffer against big storms and enormous waves called *tsunamis*, protecting coastal communities further inland.

ECOMAP

While interning at NASA, Liza began using satellite data and software called Google Earth Engine to make a new research tool. "I wanted to create a program that predicts mangrove loss and identifies its causes," says Liza. "And I wanted it to function on a global scale."

SOURCE: FLORIDA MUSEUM

Working after school, on weekends, and over holidays, Liza has come close to her goal. She recently presented a *prototype*, or working model, of her Electronic Coastal Monitoring and Assessment Program, or EcoMap, at a conference hosted by Google in Ireland.

EcoMap assesses the health of mangrove forests based on factors like land use and sea level change. The risk level is color-coded and put on satellite images so people can see how and why particular mangrove forests are threatened (*see EcoMap in Action, p. 21*).

CORE QUESTION

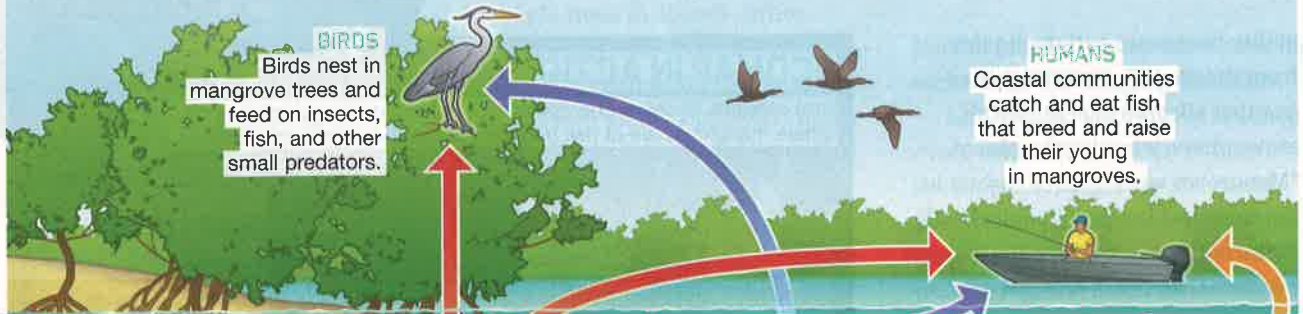
Would remote sensing be a useful way to monitor other ecosystems on Earth? Provide evidence to support your answer.

Liza hopes to provide this information freely to anyone who wants to use it to protect mangroves. "My dream is to use EcoMap and other satellite-based tools to help inform international policy and mangrove restoration," says Liza. "I want this program to give coastal communities the ability to track how their environments are changing, in order to benefit both their local region and the wider world."

—Jacob Batchelor

MANGROVE FOOD WEB

Many species live in and around mangroves. Together, these organisms make up a complex food web in which organisms feed on plants and predators seek out prey.



(DIAGRAM)

TOO MANY LEGS
A poison dart frog with an extra back leg in French Guiana, a territory in South America

EXTRA FROG LEGS

BEFORE YOU READ: Brainstorm why this frog might have an extra leg. Explain the reasoning behind your answer.

People around the world began documenting unusual frogs in the 1700s. Like the frog pictured, they had extra or missing legs. The phenomenon is due to an infection by a *parasite* called *Ribeiroia ondatrae*.

R. ondatrae is a flatworm.

of the snail's body mass becomes a "parasite factory," explains Pieter Johnson, an ecologist at the University of Colorado Boulder.

The snail releases thousands of flatworm larvae from its reproductive tract into the water. These larvae burrow into a tadpole's *limb buds*—the areas where legs will eventually grow. If the parasite attacks a tadpole before its buds fully develop, the frog is likely to have missing legs. Older tadpoles with more mature buds can grow up to six extra legs—that's 10 total.

This makes it hard for a frog to hop. That helps the parasite invade its next host—birds. "What better way to slow a frog down than to disable the back legs?" says Johnson. A bird can easily catch and

PARASITE LARVA