

Spring/Summer 2019

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Headline Discoveries



A Laboratory Balance Becomes a Surgical Monitor

Scientists are rational thinkers, but they can also be very creative when trying to find answers to real-life questions.

A recent example of this was a study initiated by bioengineer Aaron Chang, CEO of Renalert, which incorporated an Ohaus balance into a new device to more closely monitor patients during heart surgery.

At regular intervals during surgery, the operating room (OR) nurses or anesthesiologists manually record the amount of urine that a patient produces. The volume markings on the bags are not exact, so the amount is an approximation. The actual urine volume may vary from the visual estimate by as much as 26 percent and also does not indicate the rate of urine flow.

Acute Kidney Injury

Up to 30 percent of patients who undergo cardiac bypass surgery experience kidney damage or Acute Kidney Injury (AKI). The procedure is long and can affect blood circulation. Patients who develop AKI may have longer hospital stays, develop other illnesses and may even die.

A New Design

Some devices already exist for measuring urine flow rate, but they do not necessarily connect to the typical urinary catheter systems.

As biomedical engineering students at Johns Hopkins University, Chang's team created a new device that uses a digital balance to constantly measure urine flow. They created a platform with a 3D printer, attached it to an aluminum stand, and placed it on an Ohaus STX Touch-screen digital balance.

Testing the Process

In an initial feasibility study, 30 patients gave their permission to use the device during their surgeries. Their urine bags were put on top of the new weighing device, which was placed under the operating room table.

The portable balance measured and transmitted the weights to a computer where software calculated the urinary flow rates. The OR staff continued to also record their urine estimates in the patients' medical records.

"AKI is associated with more deaths than heart failure, prostate cancer, breast cancer, diabetes combined every year," said Chang.

Earlier studies showed that patients who developed AKI after heart surgery had lower than expected rates of urine production and flow rates. Monitoring urine flow rates during surgery helps to check the patients' kidney condition and lets the medical team optimize the amount of fluid being given to the patient.

Monitoring Urine Output

Before surgery, a catheter is inserted into the patient's urethra. The catheter is then attached to other tubing that directs the patient's urine to a collection bag.



Results

The new device was used successfully with all patients. Since the device and urine bag measured a little over a square foot, it did not interfere with the OR workflow.

The median percent error between the automated and manual urine measurements was just under 20 percent. Data from the new device was more accurate than visual readings and having the real-time urine flow numbers can improve patient management.

The success of this study allowed Chang and several clinicians to launch the startup Renalert, where they plan to further their work by shifting the treatment of AKI towards active prevention.



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New Technologies May Increase Our Understanding of the Brain

By Kylie Wolfe



Recent advances in microscopy have provided researchers with more detailed images of individual nerve cells in both fruit flies and mice. These techniques have also let scientists stimulate specific cells in mice, taking control of their eating behavior.

Innovative Imaging Opportunities

At the Howard Hughes Medical Institute's Janelia Research Campus, researchers have developed a microscope that can see into deep layers of brain tissue. Known as a lattice light sheet microscope, it uses a thin laser to look at the brain's cellular structures. There is a drawback to this method, however: it limits the ability to see the fine details of these cells.

Another method, developed at MIT, solves this problem. Researchers infused their samples with a gel that expands cells up to four times their normal size while still preserving the tissue's structure. This method, called expansion microscopy, makes it easier to view small samples in greater detail.

Revealing the Results

Using these methods in combination, scientists were able to uncover features of individual nerve cells, or neurons, including those that produce the important chemical messenger dopamine. They managed to count synapses, the communication connections between neurons, and were able to see the formation of myelin, a fatty substance that helps signals travel quickly. These tools also provide information about neuron anatomy and the roles of different cells.

Building on this progress, researchers at Stanford University have found a way to use laser light to control genetically engineered neurons in mice. They targeted cells in the brain's orbitofrontal cortex, the source of both eating and social behaviors. These actions are

controlled by different neurons, making them difficult to study separately. But this method allowed researchers to identify the individual cells that control these behaviors.

After determining which neurons were linked to each action, they managed to control the mice's eating behavior. When the cells were stimulated, the mice consumed more calorie-dense reward than when stimulation was focused on nerve cells associated with social behavior.

Looking Ahead

Technological advances like these allow for experiments and studies that give us better insight into cells and their functions. In particular, scientists can study synapse differences across various diseases and how myelin develops and forms. The ability to control genetically engineered cells also allows for learning opportunities related to cell function.

Previously, neurons could only be viewed in large groups. Because they can now be studied individually, researchers hope to better understand diversity among neurons and unravel some unknowns about the brain.

DISCUSSION QUESTIONS

Discuss the two techniques described, including how they're different and how they can complement each other in future studies.

Why is it beneficial to be able to look at individual neurons instead of larger groups of them?

Design your own experiment using these technologies. Research neuron structure and brain function to help determine what you'd like to learn.

VOCABULARY

MICROSCOPY NEURON

SYNAPSE MYELIN

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Robots Can Be Programmed to Follow Visual Instructions

By Ralph Birch

The days of assembling your own patio furniture or entertainment center could be over — if you have the right kind of robot, that is.

A California company has designed an operating system that allows robots to follow visual instructions and build things.

Humans — most of them, anyway — have the natural ability to look at diagrams for construction of many different items and infer what's needed to get from one step to the next without accompanying written instructions. Robots, on the other hand, need to be programmed with the exact instructions on how to move.

Until Dileep George and his colleagues at Vicarious AI in San Francisco developed their new operating system, that is. Their artificial intelligence-based system programs robots to understand the basic ideas that are conveyed in schematic instructions and translate those ideas into actions.

“Even when you try to teach robots by demonstration, they're just repeating the exact same motions you show them, not the concept underlying them,” said George, an artificial intelligence and neuroscience researcher.

These so-called “common-sense robots” have shown the ability to work on a wider variety of tasks under varying conditions when compared to machines that were given explicitly coded instructions or physical demonstrations of the steps needed for completion.

With the programming from George and his team, the new robotic system was able to learn more than 500 different general concepts by studying before-and-after images. When given a new set of instructions and the accompanying diagrams, the system considers all of the concepts it has learned and chooses the actions that will best help it achieve its goal.

George and his team tested the new operating system on two gripper-arm robots. The arms

were tasked with moving objects across a tabletop. They examined the instructions and carried out the tasks, which included separating lemons from limes and arranging cans in rows based on color.

The arms were able to carry out the instructions under a variety of conditions, responding well when researchers switched the types of objects being moved or the color of the table where the items were placed.

For George and his team, the basis of their research was being able to create a hierarchy of abstractions — from the very basic to the most elaborate — for the robots to draw upon. The programming lets the robots use the abstractions to interpret the concepts being presented via the visual instructions and correctly apply the concepts in various situations.

All of this could lead to a future where there are a couple of robots on your deck putting together the family's new barbecue grill instead of mom or dad.

DISCUSSION QUESTIONS

If this type of technology continues to develop, what other day-to-day functions could these robots perform?

What are the advantages of having robots construct things? What are the disadvantages?

VOCABULARY

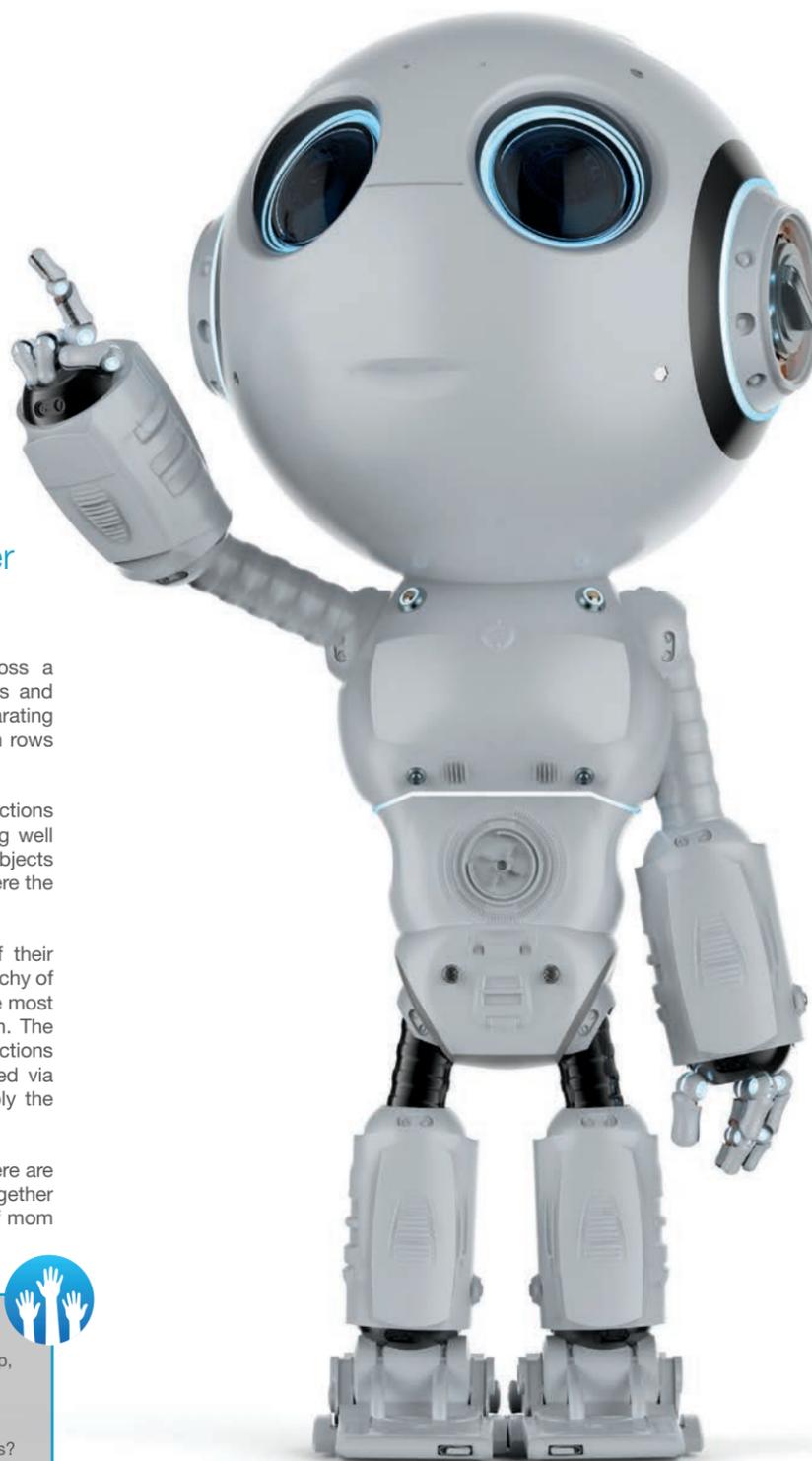
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SCHEMATIC ABSTRACTION

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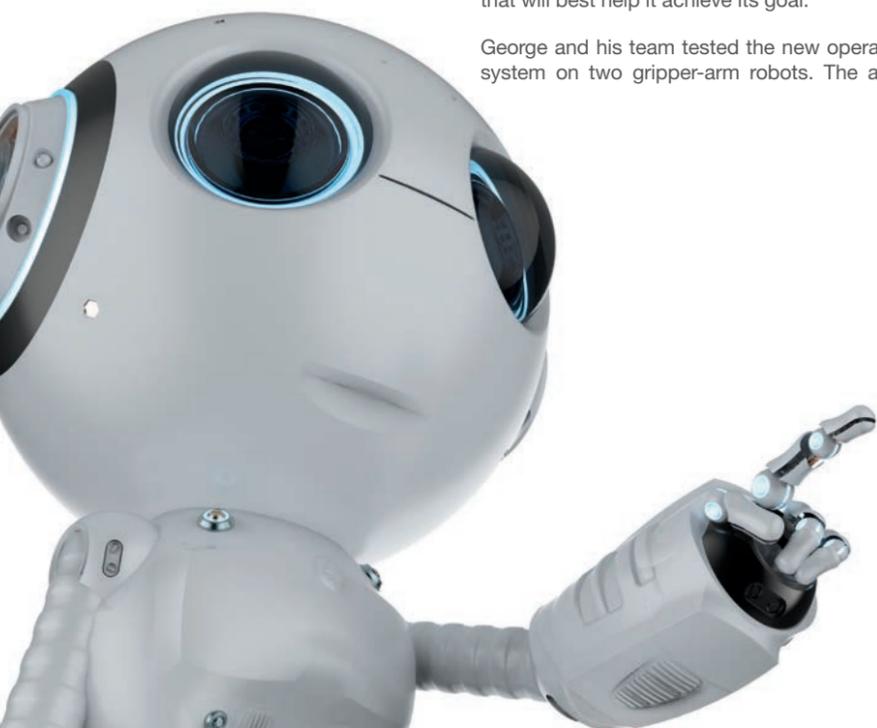


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Immune System Reboot More Effective for MS

By Christina Phillis

Multiple sclerosis (MS) is a complicated disease. Outwardly, patients exhibit vision loss, pain, fatigue, and impaired coordination. Internally, the body's immune system is attacking its own nervous system. Existing treatments seek to contain the immune response or divert it from the central nervous system, but a new treatment seeks to restart and rebuild the patient's immune system.

“A side-by-side comparison of this magnitude had never been done.”

Hematopoietic stem cell transplantation (HSCT) has been used successfully for more than 30 years to treat certain kinds of cancers. The treatment uses chemotherapy to suppress the immune system. Patients are then given an infusion of their own or donor stem cells. Although it has been a successful treatment, it's still considered unconventional and can pose serious risks. Fortunately, a new randomized clinical trial has shown that its effectiveness might rival that of approved MS drugs.

“A side-by-side comparison of this magnitude had never been done,” said Paolo Muraro, MD, neurologist, Imperial College London. “It illustrates really the power of this treatment — the level of efficacy — in a way that's very eloquent.”

Rebuilding the Immune System

To date, only one study evaluated patients to compare HSCT to standard MS treatments. Richard Burt, MD, of Northwestern University's Feinberg School of Medicine in Evanston, Illinois, worked with colleagues on the new trial involving 110 patients with the relapsing-remitting form of MS. These patients can go long periods without symptoms, but most of the participants had relapsed twice during the year before the study, despite receiving medication.

Half of the patients received HSCT and the other half received a new medication to replace

a drug that was not working well for them. Blood was collected from the patients receiving HSCT, and they were then treated with a drug cocktail that killed most of their immune cells. Afterward, they received an infusion of their own blood (including their own stem cells) to rebuild their immune systems.

Disease progression was assessed based on patient strength, coordination and speech. After a year, 34 of the patients in the drug treatment group showed disease progression (worsening), compared to just three patients from the transplant group.

Dr. Burt recognizes that HSCT may not be the best treatment option for most MS patients. Ideal candidates would be those with relapsing-remitting MS and frequent relapses, which is roughly 15 to 20 percent of MS patients.

Although skepticism about HSCT-related infections and complications still exists among U.S. physicians, HSCT adoption in Europe is increasing, suggesting that its popularity may grow over time.

DISCUSSION QUESTIONS

What are some treatments that were discovered while trying to cure other diseases? What did it take for these treatments to become widely accepted?

How can preventing relapses improve the lives of MS patients?

VOCABULARY

IMMUNE SYSTEM NERVOUS SYSTEM
MULTIPLE SCLEROSIS STEM CELLS
RELAPSE

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As opioid-related overdoses rise, researchers caution the over-prescribing and misuse of benzodiazepines, another category of anti-anxiety medication.

Visit fishersci.com/overdosededeaths to read the full article.

Pest Control

The Adverse Effects of Mosquito Repellents ...

By Iva Fedorka

Controlling mosquito bites is part of the public health goal to reduce the parasitic and viral diseases carried by these insects. Scientists recently studied the effects of common mosquito repellents on both mosquito larvae and on their aquatic predators to further assess the risks and benefits.

Need for Mosquito Repellents

Mosquito-borne viruses like Zika, dengue and chikungunya in the Americas have increased the use of chemical repellents. The active ingredients DEET (*N,N*-diethyl-m-toluamide) and picaridin (also known by other trade names) have been the most effective repellents for humans.

Unintended Effects?

Neither DEET nor picaridin is water soluble, but commercial preparations that make the repellents easier to apply can enter water systems and natural environments via sewage and graywater.

Both compounds typically biodegrade rapidly and are barely detectable in wastewater. Both DEET and picaridin have some antimicrobial properties, but the risks here are also low. Picaridin toxicity to rainbow trout, zebrafish, green algae and water fleas has been tested before, and the endpoints were found to be very low (measured in milligrams per liter).

Test Protocol

Rafael Almeida, an ecologist at Cornell University in Ithaca, NY, wanted to know whether repellents containing DEET or picaridin affect aquatic wildlife. He set up a study to measure the effects on mosquito larvae and the salamander larvae that eat them.

Mosquito larvae from several species were collected and transported to the laboratory.

The experiment was timed to last for 25 days, ending just as the mosquito larvae started to pupate.

Spotted salamander larvae were also collected, and were tested when they were mature enough to swim and forage, and external gills and forelimb buds were visible.

Groups of 30 mosquito and 9 salamander larvae were added to a series of containers, and a different dilution of one of the mosquito repellents was added to each container.

Unexpected Findings

Almeida and his colleagues found that the larval mosquitos were not affected by exposure to DEET- or picaridin-containing repellents.

The salamanders in the control group and those exposed to DEET all survived the experiment. However, the picaridin-treated amphibians died at a rate of 45 to 65 percent after 25 days of exposure. Salamander larvae exposed to picaridin also began to exhibit tail deformities and impaired development after only four days of exposure. (Kinked or bent tails are a common indicator of developmental abnormality in amphibians.)

A Serious Situation

Salamanders are important known predators of mosquito larvae, and increased picaridin in surface waters may also reduce the number of salamanders, leading to more adult mosquitos. Salamanders have a much shorter breeding

season than mosquitoes. Furthermore, their populations have already been declining globally in response to pollution, habitat loss, climate change, and other stressors.

Future studies could focus on the verification of the mortality rates under more-natural conditions, tests using later developmental stages of the salamander larvae, and examination of the sub-lethal effects of exposure on the salamander larvae.

To Repel or Not To Repel

Given the efficacy of picaridin as a mosquito repellent and its low risk to humans (when applied topically), there are clear benefits to its continued use. More investigation is needed to show whether those benefits offset the loss of natural predators that help to control the mosquito population.

DISCUSSION QUESTIONS

What would be a logical next step for these researchers?

Could the salamanders have been affected by the repellent in the larvae they consumed (in addition to the repellent in the water)?

VOCABULARY

ANTIMICROBIAL BIODEGRADABLE
ECOTOXICOLOGY MESOCOSM



... and a New Solution Using Bacterial Compounds

A recently discovered species of roundworm is host to a bacteria whose molecules may be able to keep mosquitoes away. This discovery provides a potential new option, and may prove to be as effective as commercially available mosquito repellents.

Worms and Bacteria

The mosquito-repelling compounds are produced by *Xenorhabdus budapestensis*, a bacterium that has a symbiotic relationship with *Steinernema bicornutum*. This roundworm or nematode lives in Eastern Europe, and was only recently identified as a unique species. Like many other bacteria in the same family, *S. bicornutum* is parasitic and can transfer bacteria (via defecation) to caterpillars and other insect hosts. The transferred bacteria weakens the host's immune system and eventually digests its internal organs.

“Something seemed to repel the insects before they even got a taste. That was fascinating.”

In the laboratory, infecting mosquitoes with *X. budapestensis* was shown to be as effective at stopping them as treatments with DEET (*N,N*-diethyl-3-methylbenzamide) or picaridin, two common commercial repellents. Scientists have found that other bacteria in the same genus also produce insect-killing compounds, but this is the first that bacterial compounds have been shown to ward off adult mosquitoes.

Although DEET is considered safe for human use, alternative deterrents to disease-transmitting insects are always a positive development. These molecules were effective against three major mosquito species:

- *Aedes aegypti* mosquitoes can carry Zika, dengue and yellow fever viruses
- *Anopheles gambiae* is a major malaria carrier
- *Culex pipiens* carries the West Nile virus

The bacterial molecules may have evolved to prevent other insects from stealing the nematodes' kills. Curiously, the compounds work effectively against mosquitoes, although the soil-dwelling nematode source of the

microbes is unlikely to overlap with mosquito territory in the wild.

Fabclavines as Repellents

Que Lan, the original researcher at the University of Wisconsin–Madison, was looking for microbes that might generate insect-killing molecules. In one experiment, Lan's team tried to test whether the molecules worked as an insecticide by feeding mosquitoes from cotton balls dipped in extracts from the *X. budapestensis* bacteria. But “the mosquitoes wouldn't go near the cotton balls,” said Susan Paskewitz, the researcher who inherited the project after Lan died unexpectedly. “Something seemed to repel the insects before they even got a taste. That was fascinating.”

Paskewitz and her colleagues cultured more of the bacteria, extracted the molecules, and then added the extracts to artificial blood brews. The team created multiple extracts by separating the molecules by physical characteristics. They watched the mosquitoes feed in the lab, noting that extracts rich in molecules called fabclavines were the most effective in deterring mosquitoes from eating their food.

Promising Developments

Paskewitz and her colleagues plan further testing, which include growing bacteria that lack the gene for making fabclavines to test whether those compounds are truly responsible. Even if that phase of testing is successful, it would still be a long time before a commercial product would be available for your next camping trip. Researchers need to test for toxicity and confirm that the molecules are effective not just in the lab but the in the real-world context.

DISCUSSION QUESTIONS

What kind of an organism causes malaria?
What other diseases are carried by viruses?

VOCABULARY

VECTOR NEMATODE SYMBIOSIS



Goose Bumps Could Hold Key to Stimulating Hair Growth

By Kevin Ritchart

You might be familiar with the phrase “bald is beautiful,” but a team of stem cell researchers could be very close to finding definitive proof that “scary equals hairy.”

Harvard University’s Ya-Chieh Hsu has found that the nerves and muscles responsible for raising goose bumps in the skin can also stimulate cells to make hair follicles and grow hair. She reported her findings in December 2018 at a joint meeting of the American Society for Cell Biology and the European Molecular Biology Organization.

Hsu suspects that getting goose bumps when it’s cold could cause animals’ fur to grow thicker.

The sympathetic nervous system controls a number of important functions of the body that we don’t have to think about, including heart rate, dilation of the pupils in your eyes, and other automatic processes.

The sympathetic nerves located next to hair follicles are wrapped around tiny muscles known as arrector pili. When these muscles

contract, they make the hair cells stand on end. This is what causes goose bumps.

Sympathetic nerves situate themselves next to the stem cells that can eventually create hair follicles, Hsu’s team found. Stem cells are unspecialized cells that can mature into many different types of cells. While much of the research is still in its infancy, scientists are constantly working on new and innovative uses for stem cells.

Typically, nerves are wrapped in a protective coating of myelin, much like the plastic outer coating on electrical wires.

In this case, researchers observed that the ends of the nerves are exposed where they meet the hair-follicle stem cells. The nerves secrete norepinephrine, a hormone that plays a part in the body’s many involuntary reactions, like the acceleration of your heart rate when you’re scared or nervous.

Hsu’s team also found that norepinephrine is necessary for hair growth. This could explain why hair loss is a side effect of heart drugs known as beta-blockers since they interfere with the distribution of norepinephrine in the body.

Mice with genetic changes that kept the arrector pili muscles from growing didn’t have the corresponding sympathetic nerves. They also didn’t grow hair normally. Like the genetically altered mice, men with male pattern baldness don’t have arrector pili muscles in their scalps. This told Hsu and her team that sympathetic nerves and the muscles that cause goose bumps might be important in the diagnosis and treatment of this type of baldness.

Restoring the nerves and muscles in the scalp may eventually lead to new hair growth, which may give doctors another treatment option for baldness.

While much of the research is still in its infancy, scientists are constantly working on new and innovative uses for stem cells.



DISCUSSION QUESTIONS

What are some other applications for stem cell research?

Do you know of any other automatic processes in the human body that are controlled by the sympathetic nervous system?

VOCABULARY

MYELIN NOREPINEPHRINE

ARRECTOR PILI

FOR ADDITIONAL READING

In a recent study, scientists found that you can actually learn — and, to some extent, control — how you react to pain.

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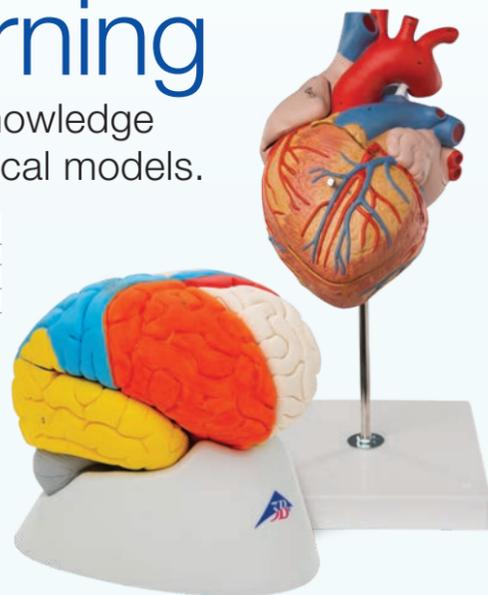
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Shark Embryos and the Search for Food

By Mike Howie

Because traditional ultrasound technology doesn't function underwater, it's difficult to study the inner workings of sharks without performing invasive surgery. But Japanese scientists were recently able to learn unexpected facts about shark pregnancy thanks to a new tool called underwater ultrasound.

Using the tool, divers regularly observed embryos inside the two uteruses of a captive tawny nurse shark. Over time, they noticed that the number of embryos in each of the shark's two uteruses, which are connected in a U shape, would change. When the total number of embryos in one uterus decreased, the number in the other uterus increased by the same number.

Migrating in the Womb

The observation suggested that the embryos were moving between the two uteruses, which contradicted the idea that embryos mostly stayed in one place and couldn't move much. In at least three other shark species, recent evidence has shown that embryos can only move their mouths. When the ultrasound showed an embryo actively moving from one uterus to the other, the scientists had the first conclusive evidence that tawny nurse shark embryos are more active than expected.

The scientists now suspect that all this movement helps the embryo find the food it needs to develop and survive. Tawny nurse sharks feed their unborn young through a process called oophagy, which literally means egg eating. Instead of receiving nutrients through a placenta and an umbilical cord, like mammals, these shark embryos eat their mother's unfertilized eggs. But they have to move around to find these eggs, and sometimes that means they have to move between the two uteruses. According to the researchers' data, published in the journal *Ethnology*, some embryos switched uteruses as few as three times and others switched as many as 24 times.

But that wasn't all the researchers learned. Their underwater ultrasound also recorded that the mother's cervix opened slightly during the

pregnancy. When it did, the embryo exposed its head. This was also in contrast to mammalian pregnancies, during which the cervix is tightly closed until birth.

New Proof for an Old Question

This new data answers a question that scientists began asking in 1993, when Discovery Channel footage of invasive surgery on a sand tiger shark showed embryos moving from one uterus to the other. Because the footage was recorded under unnatural conditions, many wondered if the behavior would happen in the course of a normal pregnancy.

Tawny nurse sharks and sand tiger sharks have similar pregnancies — both feed their embryos through oophagy and give birth to live young instead of laying eggs. In addition to eating the mother's unfertilized eggs, sand tiger shark embryos will even eat their developing siblings, ensuring that only the largest and strongest survive.

Thanks to the scientists in Japan, we now know a little bit more about the mysteries of shark pregnancy, and just how different it can be from mammalian reproduction.

DISCUSSION QUESTIONS

In what other ways are shark and mammalian reproduction different?

What do you think are the benefits of having two uteruses?

VOCABULARY

OOPHAGY EMBRYO

Hybrid Semiconductors Produce More Light with Less Power

By Rita Walmer

Researchers at the Georgia Institute of Technology have found that a new type of hybrid semiconductor material could lead to lights, displays, lasers and solar panels that are not only more efficient but also easier to produce.

Flexible Electronics

The material, called halide organic-inorganic perovskite, or HOIP, is assembled with non-covalent bonds and consists of an organic material sandwiched between two layers

of inorganic crystal lattices. Individual units of the crystal take a form called perovskite, an even diamond shape with a metal center and halogens at the points. The result is a soft, flexible material that is easier to apply to surfaces than typical rigid semiconductors. In fact, the new material can even be painted on.

In addition to making the material easier to work with, the softness and flexibility also make it better suited to producing light from electricity.

Light is produced by applying energy to

the electrons of an atom. When an electron absorbs energy, it makes a quantum leap into a higher orbit and releases the energy as light (or photons) when it returns to its original orbit. In established semiconductors, the electrons are trapped in specific areas that limit their range of motion. This makes it possible to excite electrons in unison, resulting in a more significant amount of light.

HOIPs, on the other hand, participate in the quantum action and facilitate movements that aren't feasible in typical semiconductors.

Less Electricity, More Light

Thanks to their flexibility, HOIPs can support a few particles that typical semiconductors can't. Electrons carry a negative charge, and when they jump from orbit, they leave an electron hole with a positive charge. The electron and hole can then circle around each other to form an imaginary or "quasi" particle called an exciton. The negative and positive attraction in an exciton is called binding energy, a high-energy phenomenon that's great for emitting light.

With so much energy, excitons can escape their atoms and move around the material, where they can connect with other excitons to form biexcitons. They can even circle around atoms in the material lattice to form polarons. All this movement and interaction enhances the material's light-emitting capabilities.

While it's possible for conventional semiconductors to form excitons, they can only reliably do so at extremely cold temperatures. HOIPs, on the other hand, can reliably maintain excitons at room temperature.

Simplifying Production

HOIPs are also easier to produce than other semiconductors. Most traditional semiconductors are made under high temperatures and in small batches, but HOIPs can be made at low temperatures in large batches.

The Georgia Tech researchers predict that the material could be used to make LEDs, lasers and even window glass that could glow in a wide variety of colors. They also believe that lighting with HOIPs would require very little energy. Using the new material, it's possible that solar panel manufacturers could produce higher-efficiency panels while reducing production costs.

A previous revolution in semiconductors gave us LEDs that have made so much of today's technology possible. Similarly, HOIPs may be the technological evolution that lead us to a brighter future.

DISCUSSION QUESTIONS

What other types of technology could HOIPs be used in?

In what ways could HOIPs improve everyday life?

VOCABULARY

EXCITON PEROVSKITE POLARON

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Moon Craters Shed Light on Asteroid Impacts on Earth

By Sadie Laurie

In a recent study of the craters on the moon's surface, scientists gained some insights into the Earth's 4.5-billion-year history.

Planetary scientist Rebecca Ghent at the University of Toronto and graduate student Sara Mazrouei examined the surface of the moon to find out about the Earth's craters. Because the moon is fairly close to Earth, they argued that both entities would have endured the same asteroid storms and impacts that left gigantic scars.

They chose to gather information about craters on the moon because, unlike the Earth, the moon doesn't have an atmosphere or plate tectonics. Evidence of what happened to the moon since its formation has been preserved.

“Right away you could see the young craters popping out.”

Geologists originally thought erosion would have erased evidence of the Earth's craters long ago.

But the team's research showed many of Earth's craters actually withstood the test of time. After mapping and charting the ages and sizes of moon craters, they found that 38 of the Earth's largest craters had similar characteristics.

Making a Map

To plot the dates of the craters, Ghent started with the youngest ones on the moon. In 2014, she realized the craters were surrounded by large rocks dislodged by the asteroids when they struck the moon to form the craters. These rocks are easy to spot because they emit light during the lunar night from the sun's heat they absorbed during the day.

The Lunar Reconnaissance Orbiter (LRO) has been gathering data of the lit-up areas to help planetary scientists map the crater debris. LRO is a robotic mission set in orbit by the National Aeronautics and Space Administration (NASA) in 2009 to map the moon's surface.

“Right away you could see the young craters popping out,” Ghent said. The older craters didn't glow as brightly because the rocks had broken down over time.

By developing a mathematical relationship between the ages of older known lunar craters and the nighttime glow of newly identified craters, Ghent was able to determine the ages of the newer craters. Mazrouei then mapped the 111 craters that are less than a billion years old and larger than 10 kilometers in diameter, and used that data to determine the cratering rate.

New Knowledge

What Ghent and Mazrouei found contradicted the belief held by many lunar scientists that the rate of impact to the moon had been mostly constant since a turbulent period more than 3 billion years ago. Mazrouei's mapping showed the rate wasn't constant. They discovered a rise in impacts by a factor of 2.6 around 290 million years ago.

Some scientists think this spike may be linked to the asteroid strike that killed the dinosaurs. But Ghent hesitates to put an exact date on the period of increased impacts. Estimates could vary by tens of millions of years or the events could have occurred in multiple spurts.

An Alternative Explanation

According to study co-author William Bottke, planetary scientist at the Southwest Research Institute in Boulder, CO, this new research could explain why we see fewer craters on Earth that are between 300 million and 650 million years old.

“We don't see fewer craters because of erosion,” Bottke said. “We see fewer craters because the impact flux was lower.”

As for craters that are older than 650 million years, Bottke thinks they could have been scraped away during global glacial periods like the one called Snowball Earth.

Although planetary scientists have differing opinions on the University of Toronto study because of the low number of craters involved in the calculations, most would agree that it's worth taking note of the research methodology. If other researchers are able to reproduce the team's methods on a larger scale, they will likely play a major role in advancing scientists' understanding of impact fluctuations within our solar system.



DISCUSSION QUESTIONS

- Why can we learn things about the Earth by studying the moon?
- Why do scientists think it's important to learn about asteroids impacting the Earth millions of years ago?

VOCABULARY

ASTEROIDS ATMOSPHERE
LUNAR PLATE TECTONICS

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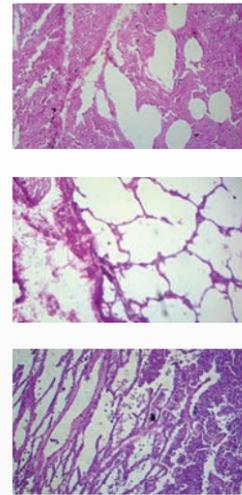
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For Steady Work, Study STEM

By Gina Wynn

According to a recent survey, Americans still believe there is a shortage of workers in science, technology, engineering, and mathematics (STEM) fields in the U.S., despite nationwide efforts to steer students toward STEM careers throughout the past decade.



A Missouri-based technology and engineering company, Emerson, conducted the fourth annual STEM survey of 2,000 Americans. The results show that two out of five Americans say the STEM worker shortage in the U.S. is at a crisis level.

Emerson reports that even though students are now twice as likely as their parents to choose STEM fields, the number of jobs requiring STEM knowledge is growing at a rate higher than the number of people in the workforce.

Choose Your Industry

The skill gap spans a variety of industries. Representatives from Deloitte and the National Association of Manufacturing predict they will need to fill about 3.5 million manufacturing jobs by 2025. But up to 2 million could go unfilled if there aren't enough qualified workers.

Large companies like Google, Apple, and Ernst and Young already consider applicants without college degrees for computer science and engineering jobs if they can demonstrate the necessary skills.

Survey results show people have been expecting these realities: 48 percent of respondents and 52 percent of the parents surveyed believe there will be more U.S. STEM jobs in the next 10 years.

Higher Salaries

If current trends continue, both job opportunities and wages in STEM fields will continue to grow. According to the article *Short on STEM Talent* on usnews.com, Bureau of Labor Statistics data from 2000 to 2013 (adjusted for inflation) showed median salaries for the average U.S. worker were

flat. But wages for computer and mathematical positions, healthcare practitioners, engineers, and other science occupations rose 8, 7, 6, and 5 percent, respectively.

The article's author, Jonathan Rothwell, reported on information he obtained from the market analytics firm Burning Glass. He found that roughly 40,000 computer science majors receive their bachelor's degrees each year, but nearly 4 million vacancies exist for people with computer expertise.

In short, unemployment is low for people with STEM degrees. And among workers with college degrees, STEM majors earn some of the highest salaries.

Opportunities for Women

The STEM worker crisis also means increased opportunities for women — the Emerson survey revealed that less than 50 percent of parents said they encourage their daughters to consider STEM careers.

"Women make up over 51 percent of the laborers in the U.S., but account for less than 24 percent of the technology employees, with less than 18 percent of women being software engineers," said Chief Marketing Officer for Chariot Solutions Tracey Welson-Rossman, as reported in the usnews.com article *STEM Worker Shortage at a Crisis, Survey Shows*. Welson-Rossman also founded the nonprofit organization TechGirlz.

"With a predicted 1 million tech jobs open by 2020 and 2 million cybersecurity jobs open also by 2020 — not all software coding — the need for more women in tech is clear," she added.

Still Work to Be Done

For men and women alike, Emerson's research shows room for improvement when it comes to developing STEM competency. Survey respondents said they don't see enough opportunities for students in the U.S. to learn STEM skills. Roughly 70 percent indicated they do not feel teachers have adequate resources to educate students in STEM areas.

The data collected by Emerson shines a spotlight on the growing need for STEM education and awareness in the United States. Parents, school administrators, and teachers can all do more to encourage young people to pursue STEM careers and to provide them with the training they need to succeed.

DISCUSSION QUESTIONS

If you had to choose any career in a STEM field, what would it be and why?

Why do you think there are so many new jobs being created in STEM areas?

VOCABULARY

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Rewritable Paper Inspired by Erasable Ink

By Moira Bell

Writing or drawing takes patience and foresight — but even with the best preparation, you're bound to make a mistake you wish you could erase. It may even cause you to start over. But what if you didn't have to start with a new piece of paper? What if you could simply make your original prose or masterpiece disappear?

That's the beauty of a new kind of rewritable paper: unlike older iterations, it can be used more than 100 times and your creation will remain visible for at least six months.

Luzhuo Chen, physicist at Fujian Normal University in Fuzhou, China, and team covered their rewritable paper in the same kind of ink found in erasable pens. Heat makes the ink disappear. A heated pen or printer can erase the blue ink, leaving behind your message or design in white. If you want to erase your creation, you

simply rub the paper with the pen's special eraser. To make it reappear, just put the paper in the freezer.

Vanishing Act

This new method turns traditional writing on its head. Instead of applying ink to paper, the ink is erased from the paper, leaving your writing in its place. This seemingly magical occurrence is made possible by a redox reaction. The process combines reduction (when a molecule gains an

electron) with oxidation (when a molecule loses an electron).

In the case of this paper, bisphenol A (or BPA, the color developer) takes an electron from crystal violet lactone (the color-forming agent). The message becomes visible when the color-forming compound and its developer dissolve in a proprietary solvent. Researchers theorize that it's an aliphatic ester or an aliphatic carboxylic acid.



*This new method
turns traditional
writing on its head.*

The solvent melts at 150°F (65°C), causing the lactone and BPA in the ink to dissolve. At this point, the solvent separates the lactone from the BPA so oxidation does not occur. Now the ink that was blue becomes clear, and stays clear at room temperature. Chilling the ink to 14°F (-10°C) causes the lactone and developer to crystallize, which lets the lactone oxidize again. And voilà! The paper is again ready for writing. But be aware that your work will start to fade after six months from the effects of sunlight, cold temperatures or other chemicals.

While the paper is easy to produce and fairly inexpensive, there are potential drawbacks: in addition to requiring a lot of ink, the paper contains BPA, a chemical that may be harmful to health when present in sufficient quantities, according to initial findings by the U.S. Food and Drug Administration (FDA). Perhaps a future version that uses less ink and promises to be hazard free, except for the odd paper cut, will one day have great staying power.

DISCUSSION QUESTIONS

Imagine different ways you can use rewritable paper in your daily life.

Research chemicals with properties similar to BPA. What qualities make them good replacements?

VOCABULARY

BPA SOLVENT OXIDATION LACTONE



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New Method Finds More Species Facing Extinction

By Mae Pyer

Using a new method to assess the risk of extinction for thousands of animal species, researchers discovered that hundreds are more threatened than previously realized. This includes the red-breasted pygmy parrot and the Ethiopian striped mouse, among others.

Room for Improvement

Periodically, researchers evaluate the status of animal species and compile their findings for the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species. This list is made up of five main groups ranging from "Least Concern" to "Critically Endangered."

Animals are categorized based on species distribution, population size and current trends. Unfortunately, this information is limited. What's known is sometimes outdated and therefore inaccurate, leading to misclassification or a label of "Data Deficient," meaning there's not enough information to assess that species' status.

Progress for Preservation

Ecologist Luca Santini and his colleagues at Radboud University recently designed a new method to efficiently and consistently predict an animal's risk of extinction. Their study incorporated species distribution and how it changes over time, as well as models to address the likelihood of survival for animals living in disturbed habitats. Other details included habitat preferences and species abundance. This additional data complements the existing method for determining extinction risk, giving researchers the ability to make more accurate assessments.

Applying their new method, they found that 10 birds and 114 mammals are actually at risk of extinction. This accounts for 20 percent of animals in the "Data Deficient" category. Also, a total of 467 birds and 143 mammals, or 4.2 percent of all species, are more threatened than the current list suggests and should be placed in a different category.

"This indicates that urgent re-assessment is needed of the current statuses of animal species on the Red List," said Santini.

Hopes for Automation

Santini and his team hope to automate this new method, making it easier to assess a species' risk so the Red List is updated more frequently. They propose that the tool work in tandem with the existing strategy so the best conclusions can be reached.

The researchers acknowledge that it's challenging to keep a growing list updated, but they hope this overall approach can act as an early warning system for species under threat of extinction.

DISCUSSION QUESTIONS

Visit iucnredlist.org to learn more about specific animals on the Red List and the categories they fall under. Are there any you're surprised about? Any you haven't heard of before or find particularly interesting?

How does the extinction of plants and animals impact the Earth's overall ecosystem?

VOCABULARY

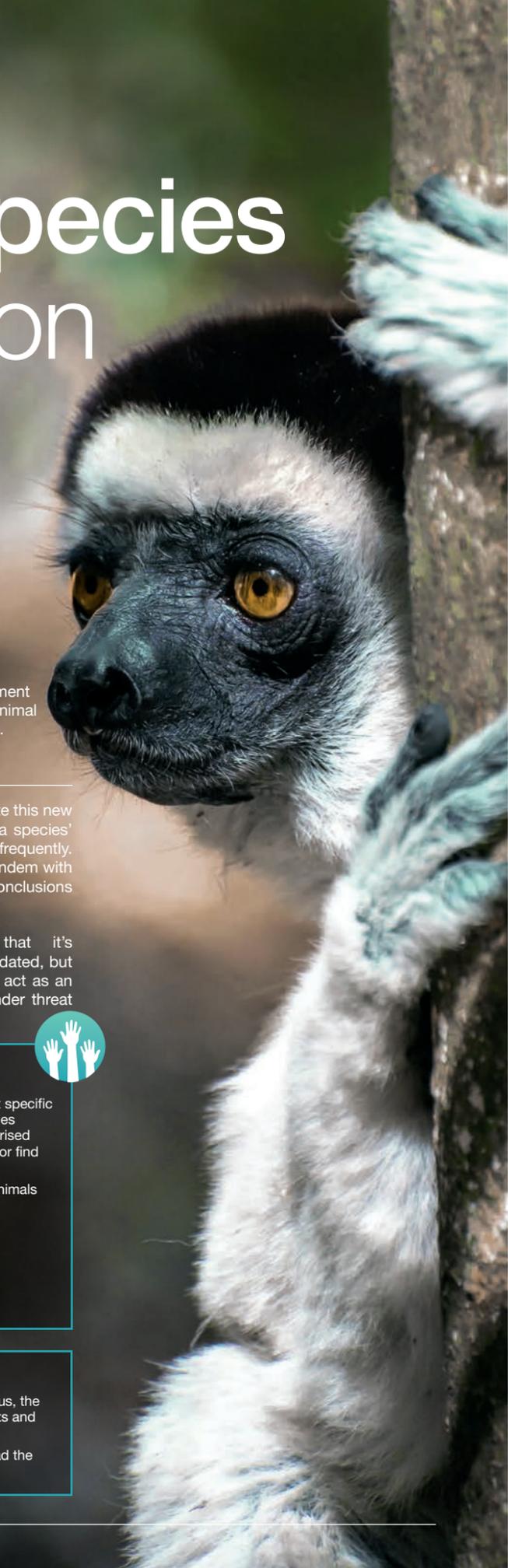
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Careers in Environmental Fields

Are you looking for a profession that supports the natural world, the climate and the environment?

One of the best resources for career and job information is the Occupational Outlook Handbook (OOH), published by the Bureau of Labor Statistics of the United States Department of Labor (www.bls.gov/ooh).

The OOH can help you identify possible careers with information about job duties, education and training requirements, pay range, and job outlook for hundreds of occupations.

Here is a sampling of environmental jobs (listed in order of increasing educational requirements) that are projected to be in demand during the coming decade.

Job Title	Duties	Education & Training	Annual Salary
Solar photo-voltaic (PV) installers	<ul style="list-style-type: none"> Assemble Install Maintain 	High school diploma, one-year apprenticeship or technical school/community college training	\$39,240
Energy auditor	<ul style="list-style-type: none"> Preserve/reduce energy use Inspect buildings Find and fix energy leaks 	High school diploma, certification from the Building Performance Institute (BPI)	\$41,573
Wind turbine technician	<ul style="list-style-type: none"> Install Maintain Repair 	Technical school program and on-the-job training	\$52,260
Environmental protection technician	<ul style="list-style-type: none"> Monitor the environment Investigate pollution and contamination sources Work to prevent violations 	Associate or bachelor's degree	\$44,190
Conservation scientist and forester	<ul style="list-style-type: none"> Manage land quality of forests, parks, rangelands, and other natural resources Protect wilderness areas Enhance animal habitats Facilitate public recreation Put out wildfires 	Bachelor's degree in forestry	\$60,610
Environmental scientist	<ul style="list-style-type: none"> Protect the environment Protect human health Clean up polluted areas Advise policymakers 	Bachelor's degree in natural science or a science-related field	\$68,910
Environmental engineer	<ul style="list-style-type: none"> Recycling Waste disposal Public health Water pollution Air pollution 	Bachelor's degree in engineering (environmental, civil, chemical)	\$84,890
Landscape architect	<ul style="list-style-type: none"> Plan parks and outdoor spaces Create designs Prepare models 	Bachelor's degree, internship experience, other exams and licenses (varies by state)	\$63,480
Hydrologist	<ul style="list-style-type: none"> Study water movement Field work in lakes and streams Perform data analysis and modeling 	Bachelor's or master's degree	\$80,480
Wildlife biologist	<ul style="list-style-type: none"> Study animal behavior Study animal interactions with their natural habitats 	Bachelor's or an advanced degree	\$60,520
Urban and regional planner	<ul style="list-style-type: none"> Develop land-use plans and programs Create communities Accommodate population growth Revitalize buildings 	Master's degree from an accredited planning program	\$70,020
Environmental lawyer	<ul style="list-style-type: none"> Advocate for clean technology Support laws for water and climate change Land management 	Law degree, state bar exam	\$113,530

Source: Occupational Outlook Handbook

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Dozens of job categories are included under headings that start with the word “environmental,” including:

- Accountants and auditors
- Conservation scientists and foresters
- Economists
- Engineers and technicians
- Scientists and specialists
- Epidemiologists
- Fire inspectors
- Geoscientists
- Hazardous materials removal workers
- Lawyers
- Mathematicians and statisticians
- Microbiologists
- Occupational health and safety specialists
- Public relations specialists
- Teachers and professors

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DISCUSSION QUESTIONS

- What is an apprenticeship?
- What is a license?
- What is the difference between an associate degree and a bachelor's degree?

VOCABULARY

- AUDIT
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- PHOTOVOLTAIC
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