The Power of Poison as Medicine

GRADES 9-12

Common Core State Standards:
WHST.9-12.2, WHST.9-12.8, WHST.9-12.9
RST.9-12.1, RST.9-12.2, RST.9-12.4, RST.9-12.7, RST.9-12.10

New York State Science Core Curriculum:
LE 1.2d

Next Generation Science Standards:
PE HS-LS1-3
DCI LS1.A: Structure and Function
Systems of specialized cells within organisms help them perform the essential functions of life. Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

NOTES FOR EDUCATORS

Have students read "The Power of Poison as Medicine." Have them write notes in the large right-hand margin. For example, they could underline key passages or paraphrase important information.

Ask:

- What is a poison? *(A poison is any substance that interferes with the normal functions of life. This may mean changing the way that cells or molecules function, or preventing natural processes from happening. Poisons may stop organs from functioning, or even shut down entire organ systems, killing the organism.)*
- Why are poisons so common in nature? What role do they play? *(Poisons are common in nature because they play an important role; poisons are used to capture prey, and in turn to resist predation. Many poisonous organisms, such as the Chilean rose tarantula, subdue or even kill prey by injecting them with poisons. Others, such as the dart frogs of the Amazon, deter predators with poisons. In both cases, the poisons help these organisms survive and reproduce, and are evolutionary adaptations.)*
- The author states that nature is "one huge laboratory." What does the author mean by this? *(During the course of evolution, many molecules are used by organisms both internally and externally. Organisms are constantly producing new molecules as they evolve, in response to the environment and each other.)*
- How can a single substance be both deadly and a helpful medicine? *(Because poisons can alter the function of body systems within an organism, or even stop these functions, they can be both harmful and helpful. Some poisons can fight off disease, while others can reduce the harm caused by diseases and their symptoms.)*

During class discussion, remind students to use evidence from the text to explain their thinking, and to use specific examples, including specific poisons and poisonous organisms, as well as real examples of poisoning events.

Have students create a chart to communicate the sources of different poisons, as well as ways that poisons can both harm and help a living organism's internal systems. They can work in pairs or small groups.

SUPPORTS FOR DIVERSE LEARNERS: Student Reading

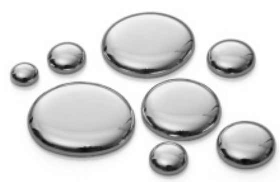
- "Chunking" the reading can help keep them from becoming overwhelmed by the length of the text. Present them with only a few sentences or a single paragraph to read and discuss before moving on to the next "chunk."
- Provide "wait-time" for students after you ask a question. This will allow time for students to search for textual evidence or to more clearly formulate their thinking before they speak.

Student Reading

The Power of Poison as Medicine

The yew tree, *Taxus*, has a legendary connection to death. Its seeds, leaves, and bark are highly poisonous to humans. In recent decades, however, this long-lived plant genus has earned a different reputation: as a potential preserver of life. In the 1960s, researchers working for the U.S. National Cancer Institute discovered that the bark of *Taxus brevifolia*, the Pacific yew, contained a toxic ingredient that could be harnessed on a cellular level to inhibit the progress of some cancers. A derived compound known as paclitaxel, produced in the laboratory and available commercially since the late 1990s, has been found to be effective in the treatment of breast, lung, and other cancers, as well as AIDS-related Kaposi's sarcoma. It has also been found useful in preventing a re-narrowing of coronary arteries in stent recipients. The drug is a prime example of the use of poisons in the service of medicine, a challenge to the modern view of poison as an instrument of death, whether by accident, suicide, or murder most foul.

Of course, nature's poisons have been used for medicinal purposes for millennia. Small doses of opium, mandrake, henbane, and hemlock numbed the pain of surgery for more than 1,000 years. In William Shakespeare's time, 400 years ago, poisonous extracts were combined into cough medicine. Well into the 20th century, mercury was an ingredient in popular remedies, from purgatives to infants' teething powder.



Mercury

But modern scientific techniques have allowed researchers to better understand, and then take advantage of, the underlying mechanisms by which plant toxins and animal venoms attack normal metabolic processes. For example, some neurotoxins block the release of chemical messengers called neurotransmitters; some stop neurotransmitter messages from being received; some send false signals; and still others disrupt nerve cell activity by opening channels in cell walls. If muscles in the heart or lungs fail to get the proper signal to function, the results are fatal. But applying the same effect in nonlethal doses can stem tremors or the registering of pain.

"What is a poison?" asks Mark Siddall, curator in the Division of Invertebrate Zoology who is also curator of the special exhibition *The Power of Poison*. "It's a substance that interferes with normal physiological processes, that alters or stops them, or makes things happen. That is essentially what medicines are, too."

The potential for tapping nature is staggering. By conservative estimates, some 100,000 animals, from lizards and snakes to sea anemones and jellyfish, produce venom, which in turn can contain hundreds of different toxins. So far, only about 10,000 animal toxins have been identified, and 1,000 of these have been studied in depth, with a view to developing drugs. The anticoagulants tyrofabin and hirudin were derived from animal sources, respectively, the blood-thinning venom of the African saw-scaled viper and a substance secreted by leeches. The diabetes drug Exenatide, which lowers blood sugar and increases the body's production of insulin, is a synthetic version of a component in the saliva of Gila monsters, large venomous lizards found in the southwestern U.S. and northwestern Mexico. The development of the first oral ACE (angiotensin-converting enzyme) inhibitor, which treats hypertension, was based on an understanding of how the venom of the Brazilian pit viper, *Bothrops jararaca*, causes a drastic drop in blood pressure in its prey.

Gila monster

Plants are an even richer mine, with more than 400,000 identified species and many of them toxic to one degree or another. Fixed in place, plants are especially adept at producing chemical defenses against insects, larger plant-eaters, and even other plants — a process that has allowed land plants to flourish for about 450 million years. Caffeine and nicotine are both plant-based products with well-known pleasurable effects on the body until taken in excess, revealing their essentially poisonous nature. But just as with animal toxins and venoms, plant compounds that affect the human body can be employed for medicinal purposes. Salicylic acid, the active ingredient in aspirin, for example, is found in a number of plants, including the willow tree Salix, from which it takes its name. Similarly, the antimalarial drug artemisinin is derived from the herb sweet wormword, *Artemisia annua*.

"Plants and animals are doing complex biochemistry all the time, creating things we couldn't imagine making without the temperature of the Sun and the pressure of the center of Earth," says Dr. Siddall.

In many ways, nature is one huge laboratory, making and testing countless plant and animal substances in each species' efforts to prevail. In what has been called an evolutionary arms race, as predators up the potency of their poisons, prey strengthen their resistance. This is especially apparent at the microscopic level, where microbes compete endlessly by developing their own antibiotics to fight off other microbes, teaching us in turn what works and what doesn't. Bacteria, algae, and fungi, including molds, that produce toxins could all potentially yield medicines. As it turned out, *Taxus*, the yew tree, was not the original source of the toxic compound used to create the chemotherapy drug: it was a fungus living in the yew tree's bark. Other examples of small but powerful agents abound. The microbe *Clostridium botulinum*, one of the most toxic substances, is known to most of us as a deadly source of food poisoning in improperly sterilized canned foods. One-millionth of a gram can kill a person, causing fatal paralysis by blocking the release of acetylcholine, a neurotransmitter used by the nerves to signal muscles to contract. In carefully controlled doses, it is famously used as Botox to eliminate wrinkles by paralyzing muscles that, when tensed, cause folds in the face. But it can also be used selectively to treat cerebral palsy spasms, stop uncontrolled jaw clenching, correct crossed eyes, or moderate sweating or twitching.

Whether at the microscopic level or the level of plants and animals, researchers are in a race against time as they seek to unlock the potential of poisons. "Habitat loss from overpopulation, climate change, and other factors have put more species of plants and animals at risk," says Siddall. Consider those toxin-rich snakes: by conservative estimates, one in five reptiles is now threatened with extinction, a loss that could radically diminish a promising source for healing. "If the world was populated by only pine trees and pandas," says Siddall, "we wouldn't have this rich diversity of resources to help us understand the physiology of diseases and find out what's out there that might target them."

This article first appeared in the Fall 2013 issue of Rotunda, *the member magazine of the American Museum of Natural History.*