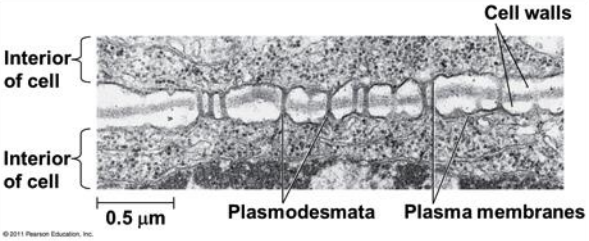
PLASMODESMATA

Channels to exchange information between cells

Hello science fans!

I am excited to send to you the second issue of our science journal, *Plasmodesmata.* For those of you that are new, plasmodesmata (singular: plasmodesma) are microscopic tunnels that form between two neighboring plant cells that allow the exchange of information and other materials. They are very tiny, usually less than 100 nm wide in most plants, which is about a thousand times thinner than a human hair. However, as you can see in the picture below, most plant cells have many of these channels, allowing the exchange of many tiny messages at once.



Our hope is that this journal will provide a portal for us scientists to share information with you from our cells (or labs, as we like to call them) to yours, much like the plasmodesmata of plant cells.

On behalf of all of the authors of the first issue, I thank you for all of the nice letters and thoughtful responses that many of you sent. We learned a lot from reading them and are grateful for your encouragement and constructive feedback. I'm sorry that we are not able to respond to you all individually. It is evident that many of you know quite a bit about science, so in this issue I have included a few articles that are a little more complicated. As always, please let me know what you think. Also, since readers asked about how to become a scientist and what it is like, this issue includes several interviews with distinguished research scientists. Their lists of accomplishments are quite impressive! I hope that you will find them interesting and inspiring, but will keep in mind that you don't need to have a PhD from an elite university to be a scientist.

In the last issue, I asked you to write about environmental problems that you observed at your institution and propose potential solutions. The most popular response was food waste. Many of you suggested this problem could be greatly reduced by simply serving food that people would like to eat. Sounds reasonable enough! There were also suggestions of composting the excess food or feeding it to pigs (although one of you wrote to me that your institution used to do this, until the pigs got sick because the food was so terrible. Hmmm. You have my sympathies!). Several people also suggested that vegetable gardening not only supply much fresher ingredients, but would also be a rewarding way to spend your time—I very much agree! Other major environmental problems identified were not recycling recyclable products and water waste. I didn't realize that toilets were used for so many purposes in prisons other than…the obvious. Very interesting!

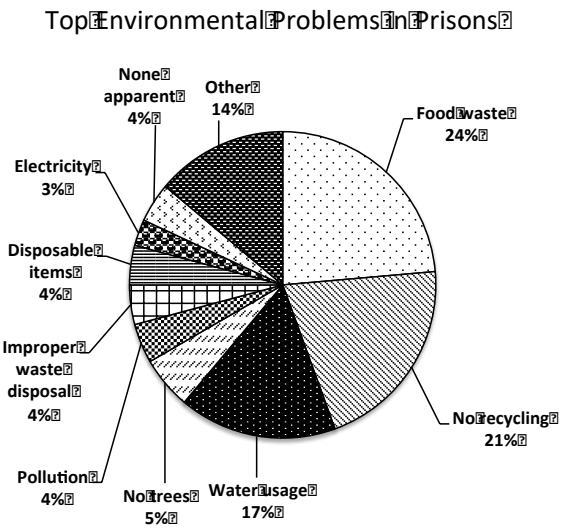


Figure 1. Most prominent environmental problems in prisons, as identified by Plasmodesmata readers (from a total of 72 responses).

Another important thing to know about plasmodesmata is that they aren't just one way channels! We are interested in what you think about these articles we have shared. To continue participating in this program, we ask that you submit written responses to the following prompts:

1) Choose one or two articles that interest you and write a response. Do you agree with the author? Is there other information that you would like to know? If you were a scientist addressing this issue, is there an experiment you would do or data you would want to collect?
2) Last time we asked you about environmental problems you observed at your institution. Looking at things in a more positive light, are there ways in which your lifestyle has become more environmentally friendly in prison?
3) Optional: Try your hand at writing an article about a topic or issue in science. Selected articles will be published in the next issue of *Plasmodesmata!*

Lastly, I am happy to announce that this issue is sponsored by a grant from the Robinson-Appel Humanitarian Award. I recently presented *Plasmodesmata* (using quotes from your thoughtful letters!) to the award committee and they selected our project to fund. If you would like send a letter of thanks and tell them why you subscribe to *Plasmodesmata*, feel free to include a note addressed to Robinson-Appel with your *Plasmodesmata* response and we will pass it along to them.

I hope you enjoy reading this issue and I look forward to reading your responses.

Take care,
Mia

Prisoner Express 127 Anabel Taylor Hall Ithaca, NY 14853
www.prisonerexpress.org prisonerexpress@gmail.com

Plants have defenses up their s-leaves *By Alexa*

Plants are awesome. Darwin and his son knew this to be true; they were the first to identify that the tips of plants can sense light sources and grow towards them. Since then, many studies have continued to support the idea that plants are capable of responding to external cues. As such, many plants have also developed defenses against predators; beautiful roses have their thorns, onions make us cry, cacti have their prickly pricks, and poison ivy has itchy poison.

All these sharp projections and bothersome chemicals may make larger herbivores like us cautious feasters, but what about insects? Thorns and spikes are too big to hurt them, and they are unaffected by poison ivy's itchy spell. As it turns out, a plant's defenses against insects are incredibly interesting and fine-tuned. A recent review by Free University of Berlin's professor, Dr. Monika Hilker and Wageningen University professor, Dr. Nina E. Fatouros compiled the existing literature to characterize plant defense against insect eggs.

There are many different ways a plant can protect itself from insect eggs. The researchers showcased the cherry tree's ability to produce a gummy secretion that seals cicada eggs shut, preventing them from ever hatching. It is in the cherry tree's interest that these eggs never hatch, or else they run the risk of being eaten. But, in the event that larvae are able to hatch, the black mustard plant, *Brassica nigra,* sends out an SOS to other parasitoids that act as hitmen. Parasitoids, are insects that lay their own eggs inside herbivorous larvae so that the parasitoid larvae can eat and kill the herbivorous larvae. Plants either seal an egg shut forever, or they serve up the plump larvae to hungry parasitoids; clearly, plants are not defenseless against herbivorous insects

In addition to having the wherewithal to call on mercenaries, plants can strategize specific defense mechanisms against particular herbivorous insect larvae. Plant defenses differ depending on whether they are protecting against specialist or non-specialist herbivorous insects. Specialist herbivores are specifically adapted to eat particular plant species, whereas non-specialists can feast on a variety of plants. When specialist *Pieris brassicae* lays eggs on the black mustard plant it responds by producing chemicals that attract *Trichograma* parasitoids who then proceed to lay their eggs within *P. brassicae* larvae. On the other hand, when generalist moth, *Mamestra brassicae*, lays eggs, it does not illicit a defense response. Obviously, plants don't cognitively *think* about what they're doing, but it is cool to think about how hundreds of years of plant-insect interactions have driven plants to develop this defensive response.

Plants are also able to alter their very selves to drive off herbivorous insects. Some plants like pine, elm, tobacco and other balsamaceous species can reduce their own nutritional content so that feeding herbivorous larvae eventually die from malnutrition. It was also reported that if plants such as the black mustard plant sensed that some *P. brassicae* eggs were laid on it, then the plant would rush its own maturation process. It grew taller, and produced more seeds before the larvae even hatched. This serves to the plants advantage because by the time the larvae are ready to eat the flower, the plant no longer has any use for it.

In addition to their bold defensive mechanisms, past studies have shown that defenses against insect eggs are remarkably similar to the Hypersensitive-Response (HR). HR describes the defenses against phytopathogens (bacteria, fungi and parasites) capable of infecting and killing a plant. The key defense they share? Necrosis. In plant necrosis, a plant allows its leaf to die and fall off along with the eggs or phytopathogen on it. This is the equivalent to amputating a limb if it got infected. Although losing a leaf or limb doesn't sound very efficient, it really isn't a big deal for the plant since it can easily grow new ones. From the plant's point of view, it is better to lose a leaf than it would be to risk total takeover or imminent death.

Evidently, plant defenses extend far beyond the thorns of a rose. Plants have a lot more defenses hidden up their s-leaves (pun intended!) than we would think. When we look at plants we only see and experience a subset of defenses, but we should acknowledge and probe their secret arsenal as well. Our existence on earth depends on the existence of plants, and their hardiness. Plants provide our oxygen and most basic food source, therefore we must care to know as much about them as possible. We must always stay curious about the world we live in and the life that inhabits it. Scientific wonder and fascination is our inheritance.

In Defense of Vultures, On the Brink of Extinction

By E.Z.

I nearly screamed driving past a dozen turkey vultures hunched over a dumpster in a strip mall parking lot, feasting on lord knows what. The birds themselves were imposing, black, with six-foot wingspans and gnarled ugly bare faces. But what spooked me more was their association with death. Hollywood images of vultures circling around a dead body, and the Greek myth in which Prometheus gets his liver pecked out by vultures after giving man fire swirled in my mind. Given all the bad press vultures have received historically, I wasn't surprised that the sight of a dozen of them at a dumpster provokes such a visceral reaction. I was happy to drive away.

But vultures don't deserve their bad rep. Scavengers, or animals that eat carrion, provide an important service in ecosystems worldwide by quickly consuming carcasses that would otherwise fester with diseases including Ebola, plague, anthrax, and rabies. Vultures, which rely entirely on carcasses as their food source, are the most efficient and sanitary disposal crew we could ask for.

They rarely get sick from diseases in the carrion they eat because they have highly acidic stomachs (a pH of 1!) that kill viruses and bacteria on exposure. Additionally, they can cover huge expanses of land looking for carrion with minimal energy spent. All of this explains why vultures consume a large percentage of carrion globally- more than 90% in some ecosystems.

When vultures are absent, however, carrion is readily available to other opportunistic scavengers, like storks, gulls, ravens, crows, and even rats. Not only do the populations of these highly adaptable and often invasive scavengers soar, but these species also lack the beautiful specialized digestive system of the vulture, with its low pH stomach that destroys viruses and bacteria. These opportunistc scavengers *can* get sick, and ultimately they *can* transfer that disease on to humans. Just look at India, with decimated vulture populations. Feral dog numbers have increased by 7 million, resulting in 39 million dog bites from 1992 to 2003 and an estimated 48,000 additional human deaths from rabies in India. Disposing of carcasses so these disease-spreading scavengers can't get to them is highly controversial, extremely expensive, and risky for humans. For example after the 2001 foot and mouth disease outbreak in the UK, millions of infected animals were disposed of and slaughtered. Carcasses initially buried on farms proved to be infecting water supplies, and entire landfills became biohazard sites as a result. In transporting the infected carcasses to disposal sites, workers risked infection themselves. Vultures, however, do such disposals in the cleanest way possible for free, feeding themselves and unknowingly keeping us safe in the process.

But in the past ten years, vultures have experienced the most rapid decline in conservation status of any group of birds. There are 22 vulture species in the world, and of those, 12 are endangered or critically endangered. A recent estimate disturbingly found that 77% of vulture species are experiencing decline. As my encounter with a dozen of them might suggest, my dumpster turkey vultures are among the lucky few species doing just fine. This is because they are New World vultures: the subgroup of species native to North and South America. It is their Old World counterparts in Africa and Asia that have declined by as much as 99%. Their greatest threat: the livestock drug called diclofenac.

A critically endangered white-rumped vulture, declofenac's biggest victim, demonstrates its impressive wingspan. Between 1992 and 2003, the Indian subcontinent population of these vultures declined by 99%.

Diclofenac is used widely to treat inflammation, fever, and pain in livestock. When sick livestock die, the drug lingers in their carcasses even a few days after treatment, giving plenty of time for vultures to find and eat the poisoned meat. An appropriate diclofenac dose to fight inflammation in a large cow proves lethal in small-bodied vultures: they are poisoned and die of kidney failure shortly after ingestion. Because many vultures cluster around a single carcass, simulation models have revealed that all it took was 1% of carcasses contaminated by diclofenac to wipe out vulture populations. Between 1993 and 2002, the white-rumped vulture population fell 99.7%, and the Indian and slender-rumped vulture populations fell 97.4%.

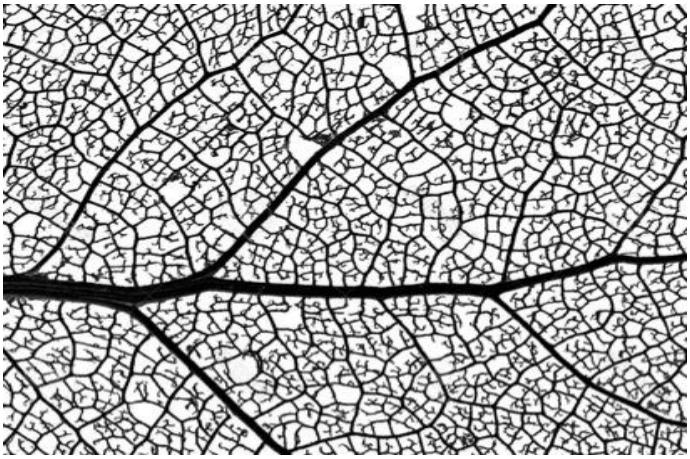
So, what is being done for the vultures that do so much for us? In 2006, India, along with many other countries, banned veterinary use of diclofenac. Unfortunately, however, a loophole exists that allows diclofenac to treat arthritis in humans, and it's being prescribed in quantities large enough to give to livestock anyways. Many veterinarians and livestock owners continue to seek out diclofenac because it's cheaper than the vulture-safe alternatives. One strategy to discourage diclofenac use in livestock is limit its prescriptions in humans to 3 milliliters, a quantity too small to have much effect in the large body of a cow. But this alone is not enough. We must regulate diclofenac and other vulture dietary toxins at local, regional, and international levels to reduce their production, import, and distribution. For those of you separated from Old World vultures by entire oceans, I encourage you to check out the on-the-ground efforts of Saving Asia's Vultures from Extinction (SAVE) and consider making a donation. SAVE works in collaboration with the World Wildlife Foundation, and national conservation and natural history agencies in India, Bangladesh, Pakistan, and Nepal to coordinate international recovery efforts. They are stimulating research to analyze vulture populations and strategies to overcome decline, advocacy to change local and political perception of vultures, and are making a direct impact on vulture populations through captive breeding programs and establishing vulture safe zones. North American vultures, like the California condor have become heralded stories of population restoration success, following dedicated captive breeding programs and conservation efforts. Perhaps, with the same support and attention, their Old World cousins, so vulnerable to extinction in this moment, can have the same happy ending.

Novel Findings on Leaf Venation Offer Insight On Evolutionary Niches *By Z.P.*

Reminders of Earth's extensive biological history are all around us. Take ferns, for example. As the relatives of early vascular plants, ferns' evolutionary lineage goes back over 350 million years, when they monopolized the land. As Earth's climate changed over time, ferns' limited capacity to compete ecologically with other plants forced them to give way to angiosperms—faster-growing, flowering plants that can survive greater fluctuations in the environment around them. One factor that makes angiosperms more successful than ferns in variable environments is their leaf venation patterns. As elucidated by a recent study published by researchers in Australia and France, differences in vein thickness and branching patterns significantly influence a plant's ability to survive in environments where water is scarce. The study focuses on understanding the development of embolisms, or large bubbles that form from the expansion of dissolved gases in the water that plants pull up from the soil. When the soil is dry, these gases are able to expand, forming dangerous embolisms that obstruct the plant's water-carrying vessels, or xylem. The researchers show that during dry spells, the size and pattern of leaf veins, which contain xylem, are key determinants of a plant's ability to withstand embolisms.

In a normally functioning plant with an adequate water supply, water is drawn up through the roots via a phenomenon known as transpirational pull. Driven by the constant evaporation of water from the plant's leaves, transpirational pull induces more water to be taken up from the soil, carried up to the leaves via the xylem, and spread within the leaf. If the soil is dry, though, the water column breaks and an embolism results, preventing water from flowing upwards and throughout the leaf. Many plants are able to withstand embolisms by growing new xylem or circumventing the air pockets so that water takes another route to the leaf's surface. However, if there aren't alternate paths or the soil isn't re-watered, the leaf is left to die. Differences in venation patterns and the spread of embolisms are therefore important in determining a plant's susceptibility to drought and its ability to survive in low-moisture environments.

To better visualize and understand the spread of embolisms throughout a leaf's venation system, the researchers devised a method by which they could transmit light through leaves and veins at high frequency. Modeling drought by cutting leaves off their water sources, the researchers observed the spread of embolisms over time in the leaves of several different plants, including three types of ferns, as well as eucalyptus and oak, which are angiosperms. They showed that thicker veins are actually more susceptible to embolisms than thinner veins are. This means that major veins, which are more efficient than peripheral ones in carrying water, are particularly vulnerable to being damaged in periods of low water availability



Intricate venation pattern of a leaf. Photo: R. Bair

Through their imaging techniques, the researchers also discovered that the downstream effects of an embolism in the largest vein vary between different types of plants. For example, there are few peripheral veins off of the fern's main xylem, which can lead to rapid loss of function in vasculature once the larger veins are blocked off. This puts ferns at a higher risk of damage from embolism, compared to angiosperms such as oak and eucalyptus. Furthermore, when the researchers compared their discoveries in ferns to the vascular structures of angiosperms, they found that in the minor veins of angiosperms, there is no relationship between size and susceptibility to embolisms—rather, embolisms occur randomly in these veins once the large major veins are cut off. Paired with angiosperms' branching vein structure, which enables embolisms in minor veins to be better circumvented, this helps the rest of the leaf's vascular network to maintain a connection to the source node, thereby preserving some function. This study's findings also help us better understand why ferns are restricted to growing in humid, rainy environments. With venation patterns that make them more susceptible to damage by embolisms, ferns are more successful when the soil is kept wet, which mitigates the possibility of embolisms.

Although the researchers are uncertain whether vascular distribution or vein size most influence the differences in embolism propagation between ferns and angiosperms, their general conclusions on vein size and embolism patterns, as well as their creation of this novel method for studying embolisms, have great potential in fueling future drought-related environmental and biological research. Evolutionarily, their insight on the form and function of leaf venation patterns give us a more detailed picture of how structural differences in ferns and angiosperms contribute to their physiology, and why ferns gave way to angiosperms so long ago. We can use the foundations set by this study to learn more about how venation patterns contributed to the success of certain plants in different environments throughout Earth's history, as well as how these plants will be impacted by changing climates in the future.

Behind the Pristine Greens: Evaluating Golf Course Environmentalism *By CeeCee W.*

It's the final putt of the Master's and you're probably focused on how the grass will cut Jimmy Walker's last shot, but have you ever considered what goes into keeping the green weed free and PGA fit? Or, imagine the back nine of Palm Springs; how does the turf remain luscious in the midst of a desert? In addition to irrigation and intricate sprinkler systems, golf courses typically utilize synthetic fertilizers, pesticides, and herbicides to keep their fairways flawless. While the use of such chemicals may be beneficial to the grass's growth rate and appearance, surface run-off water can pick up these compounds and deliver them to freshwater sources. Not only can these compounds cause water contamination; repeated human exposure to such compounds is a known contributor to certain cancers. Though the typical golfer is safe walking through the dew for that early morning tee time, in the 1990's a study came out concluding that male golf course superintendents, who were consistently exposed to these chemicals as an occupational hazard, had elevated levels of fatal Non-Hodgkin's Lymphoma, brain, and prostate cancer. Though this study prompted golf courses across the country to revaluate their environmental practices, without strict federal regulation golf courses often downplay their obligation to eco-friendly promises.

In the United States golfing is more than a sport; it's a $70 billion industry composed of 2.7 billion acres of land across the country. But that green grass comes at a price, where the initial course construction leads to an overhaul of natural topography and destruction of existing ecosystems. Further, course maintenance is often riddled with inefficient water consumption and outdated land management practices. In a recent review of 18-hole American golf

courses, while 49% had a written turf and chemical management plan, only 9% were required by the government to have them. Because chemicals like pesticides are legal for agricultural use, limited governmental accountability of golf courses lead to a discrepancy in environmental expectations and the regulation of hazardous environmental practices. Though good at clearing harmful pests and weeds, pesticides have many secondary affects targeting aquatic life, birds, and plants. With the flow of chemicals from one organism to another up the food chain, it's not long before humans become linked to toxic chemicals too. Even if you're not particularly environmentally inclined, the threat of human exposure to dangerous compounds and the potential for those chemicals to contaminate your local groundwater should raise questions about the practices of your local Country Club.

Yet all is not lost for our beloved courses; many have taken actions to be more eco-friendly and innovative in their land management. In 1998, the Audubon Cooperative Sanctuary Program for Golf was founded as a way for golf courses to be kept accountable for their environmental practices and earn prestige in the golf community for being eco-friendly. Once a member of the Audubon, golf courses gain access to support systems for budgeting, staff training, chemical use reduction and safety, water quality management and wildlife conservation. With PGA support, the program serves as a means to entice and empower courses to maintain their lands in a healthy and environmentally friendly way.

Under pressure from the media and governmental regulation, many golf courses have vowed to join the Audubon Program and adapt their environmental practices. The Golf Course Superintendents Association of America established guidelines for course management, where they hoped that adopting new regulatory practices could mitigate damage. The superintendents called for already developed courses to adapt practices such as more efficient watering techniques, a reduction of maintained land, and investment into biodiversity were encouraged for already developed courses. Further, new courses were encouraged to consult with the turf science industry for climate appropriate grass planting, fairway design techniques, and the incorporation of locally found flora. With the implementation of such practices, golf courses are enabled to integrate the native vegetation and optimize local conditions.

Though many may associate golf with courses like Pebble Beach and Augusta, it's important to remember that local courses, municipal and privately owned, contribute the most to the overall course-acreage, and those courses are subject to civil and member-owned pressures. Without specific governmental regulation, it's up to golf course constituents to keep management accountable for the design and management of each individual course. By bringing attention to this issue and making it important for the wellbeing of the local community, chemical usage and water consumption are made integral to public health and environmental awareness.

Whether you're a regular for shooting double eagles or struggling to make par, it's important to recognize your ability to open discussions of environmental practices and maintenance at your favorite golf courses. Management and Superintendents should become educated and aware of the side effects of their chemical usage, water consumption, and mowing habits. Golf is a great way to stay active and enjoy nature, but that recreation should not come at the price of the environment.

The Ability to Eat a Balanced Diet is Threatened by Declining Honeybee Populations *By S.A.K.*

The decline of honeybee populations in the United States presents a grave global problem because of the important role that honeybees play in crop pollination. Although the cause of honeybee decline is a complicated issue and requires more research, we can take steps now that we know will help struggling populations. These steps include supporting local beekeepers, not purchasing pesticides with neonicotinoids, and petitioning the government to ban bee-harming pesticides.

Honeybees are the most common pollinators of food crops, but populations have decreased in many regions of the world with the most pronounced changes in North America and Europe. The number of managed hives in the United States has declined from to 2.3 million in 2008 from 6 million in the 1940s. Many crops either need or greatly benefit from bee-assisted pollination; the production of apples, strawberries, tomatoes, and almonds are most at risk without honeybees. While we could live without these crops, the productivity of 75% of crops would decrease with the disappearance of bees. Without bees, the availability of the crops that we depend on to eat a balanced and varied diet would decline. A varied diet, which includes a variety of fruits, vegetables, and legumes, is important to maintain because it gives us access to different vitamins and nutrients, and contributes to our health.

While honeybee pollination is critical to our ability to eat a varied diet, beekeeping is not a simple or easy practice. A few years ago, my aunt was tending a couple honeybee colonies in her backyard. She attended beekeeping classes and had a mentor that she was extensively in contact with to talk about how to deal with any issues that popped up. Despite her commitment to the health of her colonies, both of her colonies collapsed and she had to start over. My aunt is not alone in her struggle to successfully rear a honeybee colony.

Photo from Long Island Bee Keeper's Club

The success of bee colonies requires an attention to difficulty and a lot of work on the part of the beekeeper. Beekeepers must balance providing their bees with enough pollen for nutrition, ensuring their bees are warm enough, and monitoring the presence

of the varroa mite, which is the main parasite of honeybees. Tending honeybee colonies is extremely time consuming and some beekeepers have become discouraged by recent colony losses. It has become more costly and less profitable to manage hives due to higher rates of bee loss. In fact, the membership of the American Beekeeping Federation has fallen to half the members it had twenty years ago. The loss of beekeepers in the United States exacerbates the problem of not having enough honeybees to pollinate our crops. Bees and other pollinators are not naturally present in agricultural areas in high enough numbers to successfully pollinate all of the crops on a farm. Instead, farmers often have honeybee hives brought to their farms for pollination. Therefore, beekeeping is immensely important for maintaining current crop yields and for providing Americans access to a balanced diet.

Another threat to honeybee populations comes from pesticides, which negatively affect bee feeding behaviors, learning abilities, and development. Although pesticides help prevent crop loss from insect consumption, the benefits of bee pollination outweigh the benefits of pesticides. In fact, the decline of bees in some regions of North America would cost farmers $1,500 per hectare due to decreased crop productivity. Bees are exposed to pesticides through their consumption of pollen, a grain of which often has several pesticides attached. While all pesticides pose a threat to bee populations, one class of pesticides in particular has really worried environmentalists: neonicotinoids.

Neonicotinoids pose an even greater risk to bees than other pesticides because the chemical becomes incorporated into the plant, including the nectar and pollen, both of which are consumed by the honeybee. These pesticides are widely used, from treating seeds before planting in agricultural plots to home gardening. You might find insecticides containing neonicotinoids at your local gardening store. The European Union has recognized the dangers of these effective, but dangerous pesticides and has restricted the use of three neonicotinoids. Eliminating the use of neonicotinoid pesticides in the United States would be an effective first step toward addressing bee decline.

Knowing about the risks to our nutrition that continued honeybee decline poses, what can we as responsible American citizens do? We can support our local beekeepers. Many honeybee beekeepers collect and sell honey from their hives. Buying honey sold by local beekeepers can help offset their increased operation costs. We can ensure that any pesticides we are buying are neonicotinoid-free and we can ask our government to ban neonicotinoid pesticides.

Patronizing Animals: Are You Guilty? *By D.H.W*

What animal can lay claim to the discovery of gravity, the invention of the computer, and the building of the Great Wall of China? How about the investigation of space, creation of The Last Supper, and navigation of global commerce and trade? Humans can. Evolution's generous gifts of opposable thumbs, an upright walking position, and social organization, among others, have positioned humans on a path to do what no other animal can or likely will. Acclaimed Dutch primatologist, professor and author, Frans de Waal doesn't argue with that. He would like to remind everyone, though, that evolution didn't forget about other animals' intelligence. The question is though, are we smart enough to know how smart animals are?

Now a professor at Emory University, Frans de Waal has had an expansive career in the sciences that has defined him as a leading primatologist and a respected author. His research, primarily focusing on the social behavior and intelligences of primates, has been published in hundreds of articles in journals like *Science*, and *Nature*. He has authored over fifteen books, one of which was given the Los Angeles Times Book Award, and in 2007, Time Magazine named him among the 100 World's Most Influential People.

De Waal maintained his status as a prolific writer in early 2016, coming out with a new piece of nonfiction, entitled Are We Smart Enough To Know How Smart Animals Are?. Woven into the book are countless examples of animals' cognitive intelligences: studies have shown that apes can delay gratification, octopi use coconut shells as tools, and orcas can team up in the fours and fives to coordinate a pushing-off of a seal on a select piece of ice. Simultaneously, however, de Waal draws necessary attention to how human bias and poor experimental questioning have inhibited proper acknowledgement of animals' cognitive capabilities in the past. While readers are never given an explicit answer to the book title they were baited with, this authorial choice ends up stimulating thought and discussion long after the book's end.

As a good scientist does, de Wall develops his message logically, by separating the book's passages into cognitive categories like memory, language, and social behavior. While De Waal's 30-page bibliography suggests how much research was used in this nonfiction piece, the effect of his work is much greater than a sheer compilation of studies.

Only by reading the book can one experience the extent of his vast knowledge, which is rooted, in great part, from years of animal observation and research of his own. For example, he and fellow primatologist, Sarah Brosnan, discovered that monkeys respond to inequality similar to how humans do. The scientists initially rewarded two monkey subjects that completed a task with cucumbers and grapes. While they knew that monkeys preferred grapes, the monkeys were satisfied if both received the same food, even if that meant cucumbers. But if one got a grape and the other got a cucumber, the hoodwinked money would stage revolt, "[shaking] the testing chamber with such agitation that it threatened to shake apart." Such descriptive summaries of the experiment and of animal behavior, made possible by de Waal's personal research involvement, give substantial authority to his writing and arguments.

Non-biased observation and experimentation, evidently, can elucidate animal's cognitive capabilities. Unfortunately, however, it doesn't always happen this way. Another one of many skills, de Waal's masterful synthesis of complex animal cognition research allows him to highlight where human scientists have trivialized animal cognition in the past. As he argues, "the zeal to find out what sets [humans] apart overrides all reasonable caution" when it comes to making claims about an animal's skill or lack of skill. Take the ape-child comparison, for example. For years, scientists claimed that apes, while performing comparably to a human child in areas like memory and tool-use, were inferior in social capacities. This claim was widely accepted until a closer look at the experimental setup

years later suggested the questionable ways in which this conclusion was made. To perform the social tests, apes had to interact with unfamiliar, white-lab-coat-donned researchers, despite research showing that apes focus on members of their own species more than they do of others. In contrast, human child subjects got to interact with members of their own species: both the researcher administering the test, as well as a parent who was often present. Clearly, the child had an advantage in these social tests, leading to the misinformed interpretation of apes' subordinate social ability.

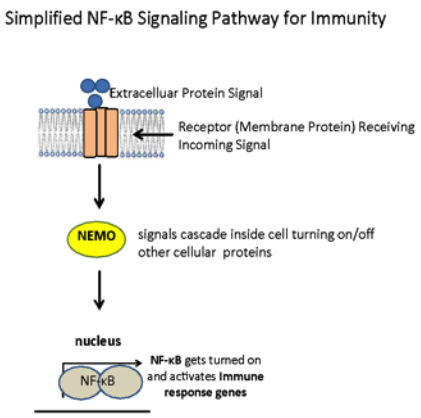
De Waal also notes that inappropriate experimental questions can lead scientists to minimize animals' cognitive capacities. Scientists used to argue that that the domestication of dogs, including the ability respond to human finger-pointing, made them more intelligent than their ancestors. Sure enough, if you look at wolves, they tend not to follow a finger point. De Waal notes, though, that with brains three times the size of the dog's, the wolf's strategic abilities, for example, would far surpass that of the dog's. So why do we assume the dog's response to a finger point suggests anything more than their reaction to humans? If the answer is "I don't know," than de Waal is right there with you—and has done his authorial and scientific job by exposing groundless research conclusions and the misinformation they have spread.

Through his research and critique, de Waal hopes to dismantle an idea that has blinded researchers and historically discounted animals: that there is a vast difference in cognition between humans and animals. A human might be able to assemble a car, but a squirrel can recall the location of thousands of acorns in three miles. For each animal, that ability is critical. But do either the human or the squirrel use each other's skill in their own worlds? They do not. Instead, they have evolved certain cognitive, social, and strategic abilities that help them succeed. In other words, ecological context is critical when examining similarities and differences between species. "Instead of a gap [in animal cognition], we face a gently sloping beach created by the steady pounding of millions of waves. Even if human intellect is higher up on the beach, it was shaped by the same forces battering the same shore" (163). In pointing this out, de Waal doesn't challenge the intelligence of humans, but offers a convincing argument for why we should rethink how we interpret the animal life around us.

De Waal's inclusion of personal experience and research, as well other's research he compiles, shines through in this book. His added strength of intelligent and streamlined analysis, too, makes understanding such wide-ranging and complex topics possible. There can be no doubting that every page is an education. However, reading 40 pages of summarized research studies about a single area of cognition was not without its challenges at times. Do not despair, though, if that sounds daunting to you as well. De Waal's book is accessible enough to open up to a chapter and read only a few pages. His humor and occasional diagrams to help visualize animal behavior or behavior setup make the read enjoyable. On top of that, you will be more knowledgeable for it, more cognizant of the bias that humans can have, and will position yourself to look at the animal world around you in a brighter—and more level—light.

Focusing On The Pathway To Scientific Success *By S.P.*

Explaining that many people today look for instant gratification, Dr. Thomas David Gilmore claims "in science it just does not work that way; there has to be patience and it requires a good work ethic." Dr. Gilmore exemplifies what a person with a focused mind and a good work ethic can accomplish, even if his original path did not start off so focused on science. Dr. Gilmore has focused on the NF-κappaB (NF-κB) immune pathway since he established his lab at Boston University, fitting his own model of what you need to be a successful scientist. He pointed out that to be a good scientist you have to learn to stick to a topic, while still find a way to keep learning new things, approaches or find new problems within your topic. Moreover, you can't get bored with your science. "There will be days when your experiments don't work". Dr. Gilmore emphasized that it's during those times you have to work even harder to persevere and get experiments working again. From the time he entered graduate school he was interested in the molecular processes underlying cancer. He has been a living example of what it takes to be a scientific success, especially for the countless students he has mentored through out these years.



He has an uncanny memory, remembering the exact date he started at Boston University nearly 30 years ago on November 9, 1987. Dr. Gilmore has not only had great success in his research with publishing approximately 130 scientific journals, 9 Encyclopedia articles, and published letters to the editor in the journal *Science*, but he has also served as a mentor to many graduate and undergraduate students. The different disciplines of research conducted in his lab include molecular biology, cell biology, and molecular ecology. This allows the lab to separate the research into three independent projects that all focus on the activation of a specific immune response signaling pathway. When this immune pathway is triggered it can activate different responses at the cellular level involving the inflammatory response when there are no foreign invaders to fight off, cell development, and programmed cell death. In addition, alterations in this pathway are implicated in a number of disease states including asthma, heart disease, Crohn's disease and cancer.

Despite his research success, Dr. Gilmore didn't think he would end up as a scientist when he graduated from college. He didn't know what he wanted to do with some of his initial interests being math, reading, and writing; even vet school could have been a possibility. After receiving a degree in English from Princeton University, Dr. Gilmore explored writing poetry and novels as a career for the first four years. He delved into writing, but was not making any money so he decided it was time to get a job. Even then sticking true to his character, he sought to learn something new.

Dr. Gilmore started working as research assistant at Comprehensive Health Labs in San Francisco. And so, he found his first research position around the age of 23; his road to science began later than most. After working there for two years and becoming interested in science, he decided that to do more in science, he would need to go to graduate school. Being great at standardized tests, he believes it was his high GRE scores that helped him get into a graduate program at the University of California, Berkeley. He completed his graduate degree in 1984, obtaining a PhD in zoology. Dr. Gilmore proceeded to take a postdoctoral position at the University of Wisconsin in Madison for three and a half years before he established his own lab as a professor at BU.

The NF-κB signaling pathway shows an outside signal activating the pathway. This activates a cascade of protein activation, one of these proteins being NEMO (yellow). Ultimately, in the nucleus NF-κB is activated and immune response genes are turned on to activate an immune response.

While at Madison he was studying a somewhat obscure viral oncogene, a gene that in certain circumstances can transform a cell into a tumor cell, and how it caused B-cell lymphoma in chickens. Once at Boston University he continued his work with the viral oncogene in B cells, which are involved in the immune response. Shortly after he started, a group of scientist at MIT, partnered with scientists from France to clone the gene for the NF-κB protein. From that work, it was clear that the nuclear viral oncogene that Gilmore was studying was essentially the same as human NF-κB protein. From there, Dr. Gilmore said it was "a natural progression" that led him to his long-term focus on the NF-κB signaling pathway, also part of the immune response. In a signaling pathway there is a protein that is integrated in the cell membrane and it can bind other proteins or signals outside the cell membrane. That embedded protein that is receiving the signal takes the signal and passes it on to another protein causing a signaling cascade until the signal results in either the turning on or off of genes in the nucleus. These cellular signaling pathways are like the game telephone, where the first person gets a message and then that message gets passed down from one person to the next until it reaches the last person. The last person to get the message then has to actually follow the instruction given in the message. In this case, it results in the activation of the NF-κB protein responsible for turning on immune response genes in B cells.

The first of his three main projects focuses on a protein that is found within the NF-κB signaling pathway. This protein is named NEMO (standing for NF-κB essential modulator), and NEMO helps regulate the activation of NF-κB. A mutation in NEMO is a rare X-linked disorder that many readers may not have heard of, but is under diagnosed. Mutation in the NEMO gene is characterized by an impaired ability of B cells to activate NF-κB in response to many pathogens. To better understand how this protein function inside a cell and to elucidate its interaction with other downstream proteins, Dr. Gilmore's lab has generated different mutated versions of the protein.

More specifically, this allowed Dr. Gilmore to investigate the functional importance of a previously uncharacterized section of the NEMO protein. He continues to characterize NEMO with the hope that these studies may have diagnostic and therapeutic importance for the human immune diseases caused by these mutations.

The second project focuses brings something new to the lab, evolution and ecology. This project is fostering his need to continue to learn something new, while "appeal(ing) to the green side of" his personality; helping "save the planet." This project focuses on understanding the evolution of the immune system by characterizing the NF-κB pathway, genes, and proteins. Dr. Gilmore tackles this question by investigating the mechanisms by which sea anemones and corals are dealing with the current impact produced by environmental stress, such as rise in water temperature, coral bleaching and rise in pH. He currently has evidence that connects an elicited immune response that is directly correlated to these environmental stressors.

Sticking true to his philosophy of keeping focused, the third project still centers around the NF-κB pathway and cancer. The project essentially stems from his research from his post-doc days 30 years ago. "It is kinda cool… to think that we are studying mutations that very directly affect individuals lives." Understanding NF-κB's cellular and molecular mechanisms is important because when it's overactive or altered it contributes to human cancers. For example, in the blood, cancer known as B-cell lymphoma, the NF-κB proteins are produced at higher levels in the nucleus. In a normal B cell, activation of the NF-κB pathway will only happen when a pathogen like a bacteria or virus turns it on. But in B-cell lymphoma, there does not have to be stimulation from bacteria or viruses for the NF-κB pathway to be activated, therefore the gene is on when it should not be, and the B cells continue to grow and divide uncontrollably.

Outside of research Dr. Gilmore works to leave a great legacy. Through his dedication to mentoring undergraduate and graduates students he finds the cream of the crop and encourages them to get into research. Dr. Gilmore's passion for mentoring was evident, "It's like having kids. They come back. I don't care if they end up like me, but you train them to do something creative." In the lab they each are actively researching and play an active role in the projects. It is clear that no matter what Dr. Gilmore focuses his attention on, whether its going into the lab and finishing up his students experiments, taking the time to take his mentees' kids to the fly room, or teaching his mentees to do new experiments, his enjoyment and passion is evident when it comes to research.

The microbial key to unlocking Earth's past *by C.G.* Billions and billions of tiny organisms live around us, on us, and even in us. Yet, for the most part, we don't seem to care about them or what they're doing, unless they're causing disease. But, for over a billion years microbes were the only life on earth and they played a huge role in shaping the environment. Recently I had the opportunity to speak with Dr. Paula Welander, an associate professor at Stanford University about how her research uses microbes to understand Earth's past. Understanding how life on Earth has responded to dramatic changes in climate is crucial given the very real possibility of future dramatic climate change.

Dr. Welander is a big proponent of the importance of microbes' impact on the earth, today and in the past. At Stanford, she teaches an introductory class called The Invisible Majority: The Microbial World That Sustains Our Planet in which she aims to teach students about the impact that microbes have had and continue to have in shaping our planet. She explained to me that the reason that our atmosphere has oxygen is due to microbes. About 2.4 billion years ago a certain group of bacteria called cyanobacteria began to produce oxygen as a byproduct of photosynthesis, much like trees do today. Called "The Great Oxidation Event", this rise in atmospheric oxygen is one of the changes that contributed to creating an atmosphere suitable for organisms like humans to eventually evolve.

Although she studied microbiology in graduate school, as a geobiologist Dr. Welander's work now focuses on the intersection of the biosphere and geosphere. Specifically, she works on "molecular fossils" called biomarkers, which are molecules produced by living organisms that can be preserved in the rock record for billions of years. Simple organisms like bacteria were the first to evolve in early earth, about 3.8 billion years ago. However, bacteria don't have hard skeletons that can be fossilized in rock. So how can scientists tell that they existed so long ago?

Dr. Welander explains that her work focuses mostly on lipids, a category of molecules that are insoluble in water, because they are preserved in the ancient rocks that geologists examine, called the rock record. She elaborates, "[lipids are] a few of the molecules… that can be preserved in the rock record, things like DNA, protein and all that stuff, that's not there." Scientists have primarily focused on groups of lipids called sterols and hopanoids because they are complex and have a fair amount of variation between organisms, but are resistant to degradation and so are preserved over billions of years. Biomarkers like sterols and hopanoids can give clues about when life first evolved, what types of organisms were present at the time, and what kind of environment existed.

Many of the scientists that study biomarkers are geologists or chemists, and while they have a good understanding of the geology and the chemical composition of the molecules, they don't have a good grasp of the biological mechanisms required to produce biomarkers. Dr. Welander's background in microbiology allows her to take a biological approach to studying these molecules. Throughout college she planned on going to medical school and becoming a doctor. She recalls, "it wasn't until I took molecular biology, of all courses, I was just completely blown away by this class." When she discovered that she could actually go to graduate school in microbiology, she left her plans to become a doctor of medicine, and pursued a PhD at the University of Illinois at Urbana-Champaign studying methane producing bacteria.

She planned to do her postdoctoral research with Diane Newman doing microbial genetics but Dr. Welander explained, "[Diane] introduced me to the world of geobiology and seriously, after spending time with her, and [attending] this organic geochemistry conference … I said to Diane, OK, this is the field we need to be in." Dr. Welander realized that there was a largely unexplored niche where microbiology overlaps with geology. While the geologists were attempting to learn microbiology techniques to better interpret the biomarkers they found, her skills and perspectives as a microbiologist could help this field. "It's not that I'm some brilliant person, I just come in with a different perspective," she told me.

Much of Dr. Welander's work has been showing that previous interpretations of biomarkers were too simplistic. Often, scientists would simply assume that if they found a molecule in say, organism A, that everywhere they found that molecule it indicated the presence of organism A. But what Dr. Welander has found, is that there are many cases where other organisms also make that same molecule. What she aims to do is link these molecules to a specific environmental condition rather than an organism. "So instead of saying this molecule represents organism A, you say this molecule represents this type of environmental condition. Something like oxygen stress, or an environment where the pH is fluctuating" she explains. One of the ways that she does this is by finding out what proteins are involved in the biosynthesis (making) of the molecules. Once she knows the protein, she can monitor the expression of the protein in the lab under certain conditions, like low oxygen, or low pH and see if the protein is being expressed under those conditions, indicating that the molecule is being made. By better understanding under what environmental conditions bacteria make these molecules, geologists can make more accurate predictions of what the environment was like when they find these molecules in billion year old rocks.

Just recently, Dr. Welander's approach lead her to an incredibly exciting discovery that solved a 20 year mystery about an orphan biomarker. An orphan biomarker is one that geologists have identified in the rock record but that is not attributable to a specific type of organism. One such orphan biomarker is isoarborional, a lipid

produced by flowering plants, such as trees. As Dr. Welander explains to me, "about 20 years ago they found [isoarborional] in rocks that were dated to the Permian and Triassic [periods], which is 200 million years before flowering plants evolved." Scientists proposed that there might be a microbial source, but no one had ever found one until Dr. Welander's latest project showed that an aquatic microbe called *Eudorena adriatica* produces two isoarborional-like lipids.

Dr. Welander was using bioinformatics to look for more bacteria that produce sterols when she became intrigued by the bacteria *Eudoraea adriatica.* She decided to investigate it further by growing *Eudoraea* in the lab and finding out what lipids it produces. What she found was puzzling. There was a very small amount of sterol, but there were also two other lipids that had a similar structure but were not familiar to her. She consulted with her old advisor, who was visiting in the lab at the time. She described to me excitedly, "he comes back like an hour later, all frazzled, 'I've never seen this molecule before!'"

It wasn't until Dr. Welander reached out to a colleague who specializes in plant sterols that she realized the importance of the molecules she had just discovered. He confirmed that these were the first new isoarborional-like lipids he had seen in 30 years. He also mentioned that there was a paper from 20 years ago where they were looking for a microbial source of isoarborional. The two molecules that Dr. Welander discovered are the first evidence of a microbial source for isoarborional-like lipids.

Previously, when geologists found isoarborional in the bottoms of lakes, or where lakes once were, they assumed there had been terrestrial input. Terrestrial input means that land from the edges of the lake where the flowering plants that produced isoarborional lived had slid into the lake. Now Dr. Welander has shown that an aquatic microbe also produces isoarborional-like lipids, and so not all evidence of isoarborional indicates terrestrial input into aquatic environments. Although she claims that "it was completely by accident," it's a story that perfectly exemplifies how Dr. Welander's perspective as a microbiologist and her combined bioinformatics and biochemical approach to these questions is successful.

Unlike many scientists, Dr. Welander didn't plan on becoming a professor. "A lot of times you talk to people about science, particularly people in my position, and they came to science at a really young age. And that wasn't my path." She explains, "my parents didn't go to college. They didn't even graduate from high school. And so really, science was not a part of our lives." Although she only started her lab in 2012, Dr. Welander will undoubtedly have an incredibly impactful career as a scientist and as a role model for aspiring scientists, especially minorities and young women.

Mulling over Mullerian Inhibiting Substance with Dr. Patricia K. Donahoe, MD *by C.H.*

Dr. Patricia K. Donahoe, MD has been a pioneer for her entire life. When she attended Harvard Medical School in the early 1960s, only ten other women were in her class of 120 students, with only six of them making it to graduation. Later on, she entered pediatric surgery practice and became the very first woman to become a professor of surgery at Harvard Medical School. In the beginning, she constantly felt pressured to prove herself, but she remained steadfast and determined in her pursuit of science. Now, with over fifty years of experience, she is one of the most recognized women in science in the Boston area. Although she has recently retired from her surgery practice, she continues to serve as the director of Pediatric Surgical Research Laboratories at Massachusetts General Hospital, where she remains a pioneer and powerhouse on Mullerian Inhibiting Substance (MIS) research. Currently, she is focusing on MIS for fertility preservation during chemotherapy, a concept on which she has predicated her new company, Provulis LLC.

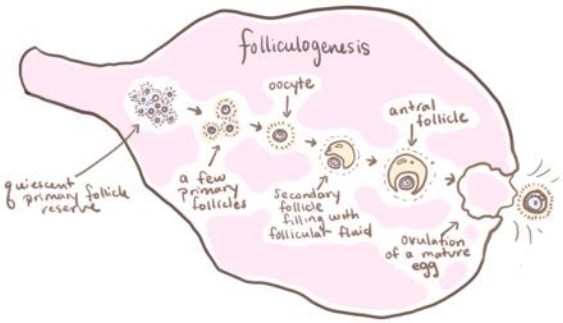
Mullerian Inhibiting Substance, also known as Anti-Mullerian Hormone, has traditionally been known for its integral role in embryonic sex differentiation. As an early embryo, our gonads are comprised of the Mullerian duct and the Wolffian duct, able to differentiate into female or male reproductive organs, respectively. During normal male development, the fetal testes express MIS in order to inhibit the growth of the Mullerian duct, which would otherwise give rise to the ovaries, uterus, and the vagina, leaving only the Wolffian duct to yield typically male structures. However, sex differentiation does not always boil down to XX = female organs and XY = male organs, and deviations from this norm fall under the *intersex* umbrella. For example, if an XY individual has a mutation that prevents proper expression of MIS, they may develop both male and female sex organs.

In the 1980s, sex differentiation was of great interest to scientists like Dr. David Page, director of the Whitehead Institute and famous sex-chromosome researcher known for his work on mapping the Y-chromosome. During this time, Dr. Donahoe had collaborated with Dr. Page on a number of projects involving intersex children. It was during these projects that Dr. Donahoe consulted closely with a pediatric endocrinologist, an expert of children's hormones, and first took interest in MIS as a sexual differentiation hormone in intersex children.

Although MIS was and is often thought of in the context of embryonic development, its expression levels persist even after birth and into adulthood in both the ovaries and the testis, suggesting that MIS must have some continued relevance to reproduction, even after our gonadal fate has been locked into place. Eventually, MIS expression was pin-pointed to growing reproductive support cells, known as egg-supporting granulosa cells in females, and sperm-supporting sertoli cells in males.

You know the saying that a woman is born with all the eggs she will ever have? This is partially true – women are born with a large ovarian reserve of *primordial follicles*, immature oocytes surrounded by a halo of granulosa cells, that each have a small chance of maturing into an egg and being ovulated in a lifetime. In females, the MIS receptor is expressed in these primordial follicles. "It seems in the ovary that [the function of MIS] is to help select the primordial follicles that will develop and undergo advancement in the ovarian cycle and be ovulated, while suppressing the progression of development of the others," says Dr. Donahoe. "So, if you take away the endogenous MIS, then *all* of the follicles advance out of the primordial stage and you lose your ovarian reserve quickly." Imagine,

instead of ovulating one egg per month, ovulating *thousands*.



A simplified representation of monthly follicular development and ovulation in the ovary.

This principle is part of the reason why women of childbearing age who undergo chemotherapy treatment become infertile. During chemotherapy, a woman's endogenous MIS levels go down, causing an abnormal amount of primordial follicles to 'wake up.' On top of this, chemotherapeutic agents target fast-dividing cells, making highly active developing follicles victims of friendly fire. The theory goes, if you supplement MIS and keep all the follicles in their quiescent, low-activity primordial state, the ovarian reserve will be protected from chemotherapy. In a paper that has not yet been released, Dr. Donahoe and her postdoctoral student, David Pepin, demonstrate that while mice undergoing chemotherapy alone become infertile, co-treating the mice with MIS provides up to 70% protection against ovarian reserve depletion during chemotherapy with doxorubicin and carboplatin, two of the most commonly used chemotherapeutic agents on the market.

Dr. Donahoe has big dreams for MIS. Although she is working on several different application of MIS which include cancer gene therapy and birth control, she has based a company, Provulis LLC, on the fertility preserving potential of MIS, which can potentially aid pre-menopausal women undergoing chemotherapy against any cancer. It is much less invasive and potentially less expensive than the currently used (but still very new and underdeveloped) cancer fertility preservation method of ovarian cryopreservation and transplantation, which requires pieces of a patient's ovary to be cut out, frozen, and then grafted back in after chemotherapy has concluded. Indeed, MIS is an attractive treatment, since it is an endogenous hormone and can therefore be classed as a hormone replacement therapy rather than a "drug," per se.

However, MIS too is not without limitations. "The major limitation [of MIS] right now is its complexity as a molecule, so commercial entities are unwilling to make investments to scale up production for clinical use," explains Dr. Donahoe. While her lab has already developed purified MIS recombinant protein that can be used safely in mice, the protocol is not efficient enough to produce sufficient quantities for clinical applications. "We have to go through what are called Contract Research Organizations that will produce this material, so that it is FDA approved with good manufacturing standards. The scale-up has to be done in a particular facility in a particular way." Though she has already received some support from smaller pharmaceutical companies, she still needs approximately $10 million dollars for Provulis, LLC in order to begin scaling up the production of MIS to clinical standards. Only then can she to move on to human trials, which she has already prepared designs for. Everything is perched to set in motion, now the future of Provulis and MIS treatment lies in a waiting game with venture and pharmaceutical investors.

The potential of MIS is profound and far-reaching, with potential applications not only for cancer fertility preservation, but also for birth control and treatment of ovarian, cervical, and endometrial cancer, as well as endometriosis. If Provulis LLC can get some wind under its wings, MIS research will have a chance to improve the lives of huge populations of women affected by a myriad of female reproductive health issues – not just for cancer fertility preservation alone. How fitting for a pioneer of women in science to wind up a pioneer in women's health as well! But just as Dr. Donahoe's journey has highlighted the amazing achievements of a determined woman and the advancements in understanding MIS, it also reveals the complex and lengthy process one must go through to bring research implications to reality. Despite the obstacles, Dr. Donahoe remains as eager and ambitious as she has always been.

Hi Thanks for reading. This packet contains a lot of information, and we encourage you to reread it to practice reading comprehension. Even if you don't have to "Mull over a Mullerian Inhibiting Substance" later in life, learning to read complicated stories and extract the information is a great skill. It takes time and patience to train the mind.

Please read each packet at least twice and see if you understand more the after a second read. These packets are for study as well as to read for pleasure. Do you want more articles like this. What are your suggestions for future PE science education packets? Please include MIA's name on any correspondence with PE regarding this packet. It will help us direct your mail in the maze of PE correspondence projects. We at PE send best wishes for a brighter tomorrow. Be strong, be mindful Gary

CTA/Durland Alternatives Library
127 Anabel Taylor Hall
Ithaca, NY 14853
Change Service Requested

Non Profit Organization
US Postage Paid
Permit 448
Ithaca, NY 14850

Plasmodesmata Vol 2

Science education for the inquiring mind

This packet was funded by through Robinson-Appel Humanitarian Award

Official poster from the March For Science on April 22, 2017