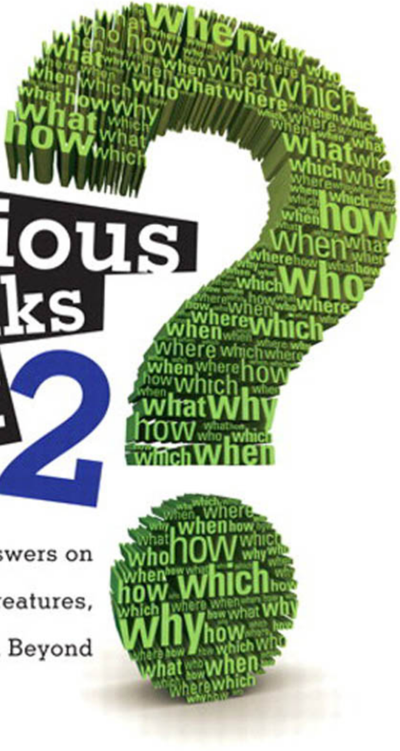
Curious Folks Ask 2



188 Real Answers on
Our Fellow Creatures,
Our Planet, and Beyond

Sherry Seethaler

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For everyone who has ever wondered

Contents

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About the Author

Sherry Seethaler is a science writer and educator at the University of California, San Diego. She also writes a weekly column for the *San Diego Union-Tribune* in which she answers readers' questions spanning nearly every imaginable science topic. She earned a Bachelor of Science in biochemistry and chemistry from the University of Toronto, a Master of Science and a Master of Philosophy in biology from Yale University, and a Doctor of Philosophy in science and mathematics education from the University of California, Berkeley. She is also the author of *Lies, Damned Lies, and Science* (FT Press Science, 2009). It serves as a guide and set of tools for making sense of the health- and science-related issues we encounter in our daily lives. A previous anthology of her columns, *Curious Folks Ask: 162 Real Answers on Amazing Inventions, Fascinating Products, and Medical Mysteries* (FT Press Science, 2010), explores the mysteries of humans and our creations.

Preface

The poster for the movie *Cane Toads: An Unnatural History* shows a grinning young girl holding up her enormous and, to put it mildly, not especially aesthetically pleasing pet toad. I don't know what it is with girls and toads, but when I was about the same age as Cane Toad girl, I tried to adopt a toad. My parents stymied the adoption, claiming I'd get warts.

So far, no one has written to my science Q&A column in the *San Diego Union-Tribune* to ask about the putative link between warts and toads, but just for the record, toads don't cause warts. Their rough, wart-like skin is an adaptation to protect them against the elements. It may also be a failed adaptation to stop little girls from dressing toads in dolls' clothes.

Young minds have an insatiable curiosity about the world. Most of us don't remember our own "why phase," but we can recall those moments when, in retrospect, our curiosity seems a little off-color, or even dangerous. For instance, I didn't really believe that kissing a frog would turn it into a prince, but I still felt the need to do the experiment. *Conclusion:* Unfortunately, no prince. Fortunately, no salmonella.

Reptiles were just as intriguing as amphibians to curious young me. Snake handling seemed like a reasonable way to understand these misunderstood creatures (only nonvenomous ones, of course). *Conclusion:* Snake poo smells very, very bad and is difficult to wipe off your hands.

Looking at things under a microscope sounds benign compared to running with wild things. Then again, that depends on what one puts under the microscope. Say…um…let's call them nasal samples. *Conclusion:* Everything looks cool under a microscope, but if you tell anyone, they will pretend to think you are highly uncivilized for extracting the sample in your quest for scientific knowledge.

The parents of children who grow up in the Great White North feel the need to pass along this piece of advice: "When it's freezing outside, don't put your tongue on anything metal." I can't imagine I would have ever thought to lick a frozen railing if my parents hadn't piqued my curiosity. *Conclusion:* Ow. 'ongue 'ill 'ick oo 'ozen 'ailing.

Curiosity isn't just for kids. Inquiring minds of all ages write in to my science question-and-answer column seeking explanations for life's mysteries.

- Do spiders dream?
- Why do lizards do pushups?
- How do animals change color to match their surroundings?
- What's that substance that accumulates in the corners of some dogs' eyes?
- How is seedless fruit possible?
- Why aren't there any blue roses?
- Why does the outside of the yolk of hard-boiled eggs turn green?
- Why does hot water freeze faster than cold?
- What causes tornadoes?
- Is the burning of fossil fuels changing the amount of oxygen in the atmosphere?
- Will another ocean ever form?
- Why do some volcanoes explode much more violently than others?
- Is Earth lighter or heavier than it was 50 years ago?
- What forms stationary clouds over mountain peaks?
- Could we get along okay if the moon wasn't there?
- Is time less understood than gravity?
- With a powerful enough telescope, could we see the beginning of the universe?
- What could be beyond our universe?

These are just 18 of the 188 questions that appear in *Curious Folks 2: 188 Real Answers on Our Fellow Creatures, Our Planet, and Beyond*. The anthology includes questions and answers about all aspects of the world around us, including our fellow creatures big and small, strange everyday phenomena, the natural systems that drive weather and climate, human impacts, the forces that shape our home planet, the enigmas in the sky, and the mysteries of our solar system and beyond.

Each Q&A stands alone, and the Q&As can be read in any order, savored a little at a time, or devoured. Within each chapter, the topics are arranged thematically. The whole becomes greater than the sum of parts as the Q&As cover significant ground in astronomy, geology, physics, atmospheric and environmental sciences, animal biology, and more, in a way that puts the real world front and center. The answers explore what science knows and what is still in the realm of the unknown—mysteries that perhaps today's budding scientists will one day solve.

The book is divided into eight themes.

- **Chapter 1, "Creepy crawlies"**—Sometimes they bug us, but insects and spiders have fascinating adaptations that allow them to eke out their existence. Arachnid athletes, ant architects, brainy bees, brisk butterflies, and cellist crickets are among those deserving a critter talent award.
- **Chapter 2, "Amazing animals"**—Animals inspire our admiration and our imagination, often in the form of widespread myths. Separate fact from fiction about suicidal lemmings, elephant fears, dogs' saliva, mules' sterility, flocking birds, camels' humps, and more.
- **Chapter 3, "Vitally vegetal"**—Early classification systems divided living organisms into the animate and the inanimate. Plants, lichens, fungi and coral, and other seemingly inanimate multicellular organisms are now split among three kingdoms, and the secrets beneath their quiet veneers are coming to light.
- **Chapter 4, "Funky phenomena"**—Stuff happens. Strange stuff. And curious folks want to know why. This chapter is a collection of questions about everyday oddities, from mealtime mysteries to agitated atoms and flummoxing forces.
- **Chapter 5, "Environmental effects"**—Nature unleashes her fury upon us in the form of powerful winds, deluges, droughts, and ice ages. Folks want to know how weather and climate are controlled and how to be good stewards of our blue marble.
- **Chapter 6, "Home planet"**—Earth's atmosphere isn't the only aspect of the planet that keeps us guessing—the planet's surface and its depths are also very dynamic. Those of us who live near active faults get constant reminders that geology is relevant to our lives, but earthquakes are just one of the planet's plethora of puzzles.
- **Chapter 7, "The heavens"**—Humans have always pondered the sky. Even in today's electronics-obsessed civilization, people seem to find the time to look up from their texting and wonder about what they observe.

- **Chapter 8, "Far out"**—Earthlings no longer have to rely on what their eyes can see to study the universe. Powerful telescopes; the ability to detect signals across the electromagnetic spectrum, from radio waves to gamma waves; space missions; and computational modeling are deepening our understanding of the great beyond.

This volume of questions about our fellow creatures and the world and universe around us stands alone, but a complementary volume focuses on humans and our creations. *Curious Folks Ask: 162 Real Answers on Amazing Inventions, Fascinating Products, and Medical Mysteries* is divided into a different eight themes: Ingenious Inventions; Chemical Concoctions; Body Parts; Bodily Functions; Pesky Pathogens; Assorted Ailments; Uniquely Human; and Health Nuts. The 16 science themes in the two books encompass 6 years of question-and-answer columns, a total of 350 questions asked by curious folks.

Since I have been writing my weekly science Q&A column, I have learned something new every week. Questions range from things I would never have thought to ask, to those about which I think I know the answer but that always become richer and more intriguing as soon as I start digging deeper. I do not answer the questions off the top of my head without researching the answer. Whenever possible, I carefully search the primary, peer-reviewed scientific literature for new findings and a wider range of viewpoints. Because science is constantly changing and because it advances one small piece at a time, researching the columns is a lot like sleuthing.

Each column is its own story, which I hope you will find both satisfying and enticing. Curiosity begets more curiosity. That is why science is such a magnificent endeavor. The more we learn about particles, forces, cells, genetics and development, ecosystems, atmospheric processes, planetary dynamics, and the vast expanse beyond our solar system, the more magical and beautiful it all becomes. So keep wondering, keep asking, and be extra kind to toads in pink tutus.

1

Creepy crawlies

Eight-legged epicure

Do some spiders trap and feed on mosquitoes? Considering that the female mosquito, after feeding, would be a great source of protein, it would seem a good target. Or have mosquitoes evolved an evasive technique for spider webs?

Just as we humans have individual, sometimes unusual, tastes—such as liverwurst, Jell-O with shredded carrots, and stinky cheeses—our eight-legged friends have theirs. Although spiders mostly dine on whatever potential prey comes their way, some spiders find mosquitoes particularly pleasing to the palate.

One species, a jumping spider from East Africa, seems to have a special preference for female mosquitoes that have had a recent blood meal. In laboratory studies, the spiders consistently choose blood-fed mosquitoes over sugar-fed ones. In doing so, the spiders feed indirectly on blood from vertebrates. No spiders are known to feed directly on vertebrate blood because they lack the necessary specialized mouthparts.

When a female mosquito gorges on blood, her mass may increase more than 200 percent. The increase in mass makes the mosquito slower and less agile, and, therefore, an easier target for predators. East African jumping spiders do not pursue blood-fed mosquitoes simply because they learn that full mosquitoes are easier to catch. The preference is instinctive. Even captive spiders that had no prior experience with mosquitoes prefer the smell of blood-fed mosquitoes.

Juvenile East African jumping spiders prefer mosquitoes from the genus *Anopheles,* the type of mosquito that carries the parasite that causes malaria. *Anopheles* mosquitoes have a distinctive resting posture, with their hind legs raised and their abdomen angled upward at 45° to the surface on which they are standing. Other species rest parallel to the surface.

Anopheles mosquitoes' posture makes them vulnerable to attack by the young jumping spiders, which sneak up behind the mosquitoes, crawl under them, and grab them from beneath. The tactic allows a young spider to overpower a mosquito many times its size.

Another type of spider, found in Thailand and of interest because it attacks a species of mosquito known to carry the virus that causes Dengue fever, is less of a wrestler and more of a cowboy. It captures mosquitoes by lassoing them with a strand of silk that it throws with its hind legs.

Spiders around the world eat mosquitoes. Spiders do not have to be cowboys or wrestlers to nab mosquitoes, though. They can also catch them the old-fashioned way, because mosquitoes do get caught in webs.

Fancy footwork

Do spiders ever get tangled up in their own webs or in other spiders' webs?

A few clever adaptations generally prevent spiders from becoming ensnared in their webs. Spiders that make sticky webs leave some strands, often the radial strands, glue free. When maneuvering around their own webs, spiders tread carefully, differentiating between sticky and nonsticky threads.

Claws and spines on the feet of spiders also make it easier for them to move around the web. They can grip a thread between the claw and spines. Upon release of the claw, the rebound of the spines pushes the thread away from the foot. This facilitates release of the thread even if the spider happens to grab one of the sticky ones. For some spiders, a fluid excreted through hollow hairs on the legs may also offer some stick prevention.

Even if a gust of wind tosses a spider onto the sticky strands of its own web, it can work itself free. Insects can sometimes escape from a web if they have enough time. For example, green lacewings tug and cut strands of the web until they have freed everything but their wings. Their hair-covered wings don't stick to the web very well, and eventually the insect falls free, but only if the spider doesn't get to it first.

Spiders have no qualms about eating each other. If a spider is unlucky enough to get stuck in the web of a larger spider, it will likely end up as dinner. A male spider courting a lady spider doesn't even need to get caught in her web to find himself the main course.

Silk architecture

How can a spider make a web 20 feet apart from pole to pole?

The most difficult part of building the web is the first strand, which forms a bridge between the two poles. The spider makes the bridge by releasing a length of sticky thread and kiting—letting the thread blow in the breeze. With a bit of luck, it will catch on another object. When the spider feels the thread catch onto something, it pulls it tight and attaches it to the starting point.

Next the spider walks the high wire, using special claws to grip the thread. As the spider does so, it releases a slack thread beneath the bridge thread. With the slack thread attached to the other side, the spider usually climbs back to the middle of it, lowers itself, and attaches the thread to some object to form a Y-shape. This strategy does not work between the poles, so the spider has to attach it to a spot lower on the pole, either by kiting or by climbing down the pole.

When the difficult main support structure of the web is in place, the spider can complete the frame, add radius threads from the frame to the center of the web, and create a spiral from the center to the frame.

Let sleeping spiders lie

Do spiders sleep—perhaps dream?

"To sleep, perchance to dream," pondered Shakespeare's Hamlet in his famous "To be or not to be" soliloquy. He was contemplating what happens after people die, but sleep researchers get equally ponderous about why we need sleep and whether sleep and dreaming are universal across the animal kingdom.

Even single-celled organisms have a circadian rhythm, a daily pattern of activity and inactivity. Spiders do, too. Some spiders are active during the day and inactive at night, and others are active at night and quiescent during the day. Of course, an inactive spider is not necessarily asleep.

Sleep is defined as a period of inactivity with reduced responsiveness to sensory information that is rapidly reversible (unlike hibernation or a coma). To be considered sleep, the rest period must also be homeostatically regulated—that is, disrupting it creates an increased need for sleep.

No published studies have measured changes in spiders' behavior when their rest period is disrupted to determine whether it meets the strict definition of sleep. Anecdotes from tarantula owners that their pets are sometimes difficult to rouse suggest that they sleep.

Laboratory studies on fruit flies also support the notion that spiders sleep (or, at least, that invertebrates sleep). Fruit flies have periods of inactivity in which they are unresponsive to small vibrations that would ordinarily make them respond. During the inactive state, gentle tapping on their container disturbs them. If they're deprived of a night's rest this way, they compensate by resting more the next day.

Not only does their behavior fit the definition of sleep, but it also bears similarities to sleep in mammals. Young fruit flies need more sleep than older fruit flies, and sleep is more fragmented in older flies. Mutant insomniac flies exist. In addition, caffeine, antihistamines, and amphetamines have similar effects on sleep and waking in flies as they do in mammals. As appears to be the case in mammals, the activity of about 1 percent of genes in flies is different during sleep than during wakefulness.

Researchers are not particularly interested in drowsy fruit flies. They are using fruit flies as a tool to understand the genetic and biochemical mechanisms that control sleep, with the goal of developing ways to treat sleep disorders in people.

No one knows whether fruit flies and spiders dream of each other, or anything else. The scientific literature does not contain any reports of invertebrate rapid eye movement (REM) sleep—the type associated with dreaming.

Lazarus fly

I found a dead fly in my refrigerator (days unknown) and threw it in the sink. A few minutes later, it flew away. How is this possible? Can a fly live in the refrigerator? How long do flies live?

It was not dead, just in a cold-induced stupor. In northerly climates, it is not unusual to see cluster flies literally crawling out of the woodwork on the first warm day after a cold spell. The flies are quite slow until they warm up. If you had not rescued your fly, it would have eventually died because it was too cold to move, eat, or drink.

Different species of flies have different life spans. Flies' life spans also depend on temperature; for example, their life cycle is quicker at 85°F than at 65°F.

Researchers have identified specific genes in fruit flies that play a role in longevity. For example, one such gene is called *methuselah;* another is *I'm not dead yet.* (Who said scientists take themselves too seriously?) Mutations in these genes can double the approximately month-long life of the fly.

Research on fly longevity is not aimed at making wise old flies, but instead at understanding the mechanisms of the aging process in flies and humans.

Mile-high club

How high can a common housefly fly? How high can a mosquito fly? Does the answer depend on the elevation at ground level, or would the answer be the same in Denver as it is in San Diego?

A zone about 25 feet above Earth's surface (depending on atmospheric conditions and species of insect) is known as the flight boundary layer, where wind speed is equivalent to maximum insect flight speed. Because wind speed increases with height, an insect needs to hang out below the flight boundary layer if it wants to be able to fly in any direction in its quest for food, a mate, or shelter.

Nonetheless, insects are commonly found at much greater heights. Mosquitoes have been collected at 1,000 feet. Houseflies can probably get that high, too. Migrating insects such as locusts and butterflies ascend much higher. Ground-based radar has detected insects nearly 2 miles above the surface.

At these heights, insects can maneuver, but the wind is too strong for them to travel upwind. For example, this explains why plagues of locusts lasting several years tend to spread according to the direction of the prevailing winds.

Insects cannot fly if the air is too cold. Temperature decreases with altitude, but in a temperature inversion, a layer of warm air sits atop cooler, denser air. Temperature measurements with kites have shown that migrating insects concentrate in the warm air at the top of temperature inversions.

An exception is passive migrators, including tiny moth larvae and tiny spiders (albeit not insects) that don't need to flap their wings to stay aloft. They migrate on silk threads and can be lifted to great heights by updrafts of air and carried long distances. They are deposited when winds change, or heavy rainfall can wash them out.

Topography—features of a particular area of land—influences movements and layering of air in the lower atmosphere. Therefore, mountain ranges can alter insect flight. Air on the upwind side of a mountain is forced to ascend, creating an updraft that migrating butterflies take advantage of to gain height by gliding in circles.

Because elevation influences average temperatures, it also determines what species live in a particular area. In the past, mountain ranges have limited the spread of diseases carried by insects. But this seems to be changing as annual temperatures rise. For example, mosquito-borne diseases such as malaria and Dengue fever are being reported at increasing elevations in Asia, Africa, and Central and South America.

Colorful compass clocks

How do monarch butterflies migrate and navigate such great distances?

North America has two migratory populations of monarch butterflies. One breeds west of the Rocky Mountains and overwinters in forested areas along the coast of California. A much larger population breeds east of the Rockies and migrates up to 2,500 miles (4,000 km) from southern Canada to overwintering sites in mountain forests near Mexico City.

As autumn approaches, decreasing daylight triggers hormonal changes in monarchs that lead to reproductive diapause, the cessation of mating behavior. In addition to their overwhelming urge to fly south, migrants have greater fat stores, enhanced cold tolerance, and increased longevity.

Migrating monarchs appear to use tail winds to conserve energy and reduce wing wear. At their overwintering sites, monarchs are mostly quiescent but occasionally leave their roosts to drink water from dewy fields and streams nearby.

Around spring equinox, monarchs begin the journey northward from overwintering sites. They breed and lay eggs on newly emerged milkweed in the southern part of the United States, and then they die. As milkweed returns to the northernmost portions of the breeding range, adults of the new generation finish the journey their parents started. During the summer, two or more short-lived generations are produced.

Because the populations that migrate in the autumn are three to five generations removed from those that occupied the overwintering sites the previous year, the fidelity with which monarchs return to the sites is remarkable. It also indicates that migration is genetic instead of learned.

Monarchs have a time-compensated sun compass—they use the sun to determine their flight orientation and have an internal clock that allows them to maintain their flight orientation in a south or southwest direction as the sun moves across the sky during the day.

Researchers have demonstrated the time compensation of the sun compass by shifting migratory monarchs' day and night cycle in the laboratory and then exposing them to sunlight. Jet-lagged butterflies flew in the wrong direction.

The day and night cycle sets the monarchs' internal clocks. The clocks themselves have "molecular gears"—several genes that interact to switch each other on and off in a cyclic manner. Scientists initially identified four cells in monarchs' central brain as the clock, but a recent study found that monarchs also have clocks in their antennae.

The compass portion of the time-compensated sun compass consists of cells in the eye that respond to ultraviolet light. Scientists are still researching how the monarchs' compass and clocks interact, as well as how monarchs may use Earth's magnetic field to guide them on their incredible journey.

Reinventing oneself

Does an insect undergoing the three distinct stages of metamorphosis (larva, pupa, adult) retain the identical DNA profile? And does the DNA profile vary among individuals?

The dramatic remodeling of an insect's body that transforms a crawling, food-minded larva into a walking, flying, reproducing adult is not the result of changes in the insect's DNA. Similar to us, each insect has a unique DNA profile and the cells in its various organs share the same genetic blueprint.

Specialized cells differ in which genes are switched on and, therefore, what proteins are produced. An egg cell contains a concentration gradient of signaling molecules that assigns the initial pattern of cell identities in an embryo. Throughout development, a plethora of chemical signals prompts genes to switch on and off.

Two hormones, juvenile hormone and ecdysone, are the master signals for insect metamorphosis. A larva morphs into an adult in response to declining levels of juvenile hormone and simultaneous spikes in ecdysone. The hormonal changes cause some larval cells to die and also lead to the production of new cells and the repurposing of other cells.

Among the cells that die during metamorphosis are the larval muscles. Adult muscles use remnants of the larval muscle fibers, but mostly they develop from cells in imaginal disks—hollow sacs of unspecialized cells that form in the embryo and remain throughout larval life. Flight muscles can constitute more than 10 percent of an adult insect's mass and contract about 60 times faster than the larval muscles; they also differ in protein content.

Most larval sensory nerves die and are replaced, but motor neurons—the nerves that move the muscles—are reused. The larval motor neurons retract their branches as the larval muscles die, and serve as templates for the developing adult muscles before growing new branches to them.

Economizing by recycling instead of disposing of larval cells also occurs in the central nervous system. Although larval and adult behaviors are divergent, some behaviors survive metamorphosis. One study showed that a moth can remember what it learned as a caterpillar. Caterpillars that were exposed to an odor paired with a small shock learned to avoid the odor and continued to avoid it as adults, whereas untrained caterpillars did not.

Only holometabolous insects—including butterflies, beetles, bees, and flies—go through complete metamorphosis. Hemimetabolous insects—including cockroaches, grasshoppers, crickets, and dragonflies—do not have a larval stage. They hatch as mini adults that lack wings and reproductive organs. The benefit of being holometabolous is that larvae and adult insects can exploit different habitats and food sources.

Bug brain

Do insects have brains (actual brains, as we know them)? If so, how big is a flea brain or an ant brain? If they don't have brains, how do they "think"?

Insects have brains. They may bug us, but insects are capable of complex behaviors and can even learn. For example, leaf-cutting ants collect leaves and use them to farm fungus for food. Honeybees dance to communicate the location of a food source to hivemates.

Fruit flies learn to avoid an odor when scientists have previously paired it with an electric shock.

Insect brains are as large as 7.5 millimeters (mm), about one-third of an inch, in diameter. An ant brain is around 0.15mm in diameter but contains some 250,000 nerve cells. A housefly's brain weighs less than half a milligram (about the mass of a fine grain of sand) and has around 350,000 nerve cells. Based on their relative behavioral sophistication, I would estimate that fleas have smaller, less complex brains than ants and flies. At the other end of the scale, a bee's brain contains about 850,000 nerve cells. The human brain has an estimated 100 billion nerve cells.

Two predominant features of the insect brain are optic lobes and mushroom bodies. The optic lobes contain about three-quarters of the nerve cells in a fly's brain. They join the compound eyes and are responsible for filtering and integrating visual information. The mushroom bodies—so called because of their shape—synthesize sensory information, particularly chemical signals, and are largest in bees and other insects with a keen sense of smell. The mushroom bodies may also play a role in memory formation. For example, blocking nerve activity in bees' mushroom bodies with a thin, cold needle prevents bees from learning the association between a novel odor and food.

My (six) aching knees

Do insects experience pain if you mistreat them? Will they know pain in any way relative to a human's experience of pain?

Two scientific papers summarize the lack of consensus on this matter. One claims that invertebrate organisms do not experience pain (*Nature,* September 13, 2001). The other states that invertebrates might suffer the same way as vertebrates (*Animal Welfare,* February 2001).

Insects and other invertebrates certainly can detect noxious things in their environments. For example, they withdraw from toxic chemicals and hot surfaces, and they attempt to escape mechanical compression. Avoidance or escape behavior could indicate that an insect is in pain. On the other hand, insects also attempt to escape from non-noxious things, such as gentle touch or a sudden change in illumination.

Recent studies on fruit fly larvae show that they detect noxious and non-noxious things in fundamentally different ways. A light touch usually causes larvae to halt and reverse slightly, but larvae touched with a heated probe launch into a sideways roll. Unlike these gymnastically gifted maggots, researchers have discovered mutants, dubbed *painless,* that respond normally to gentle touch but fail to respond to a heated probe and other harms.

Painless mutants lack a certain type of protein molecule called a nociceptor that detects noxious heat, chemicals, and pressure. In normal fruit fly larvae, detection of these dangers activates the nerves in which the nociceptors reside.

Similar nerves and nociceptors exist in humans. We usually feel pain when they are activated, which suggests that insects can feel pain, too. Because our brains play a significant role in our perception of pain, and insects' brains are much more rudimentary than ours, their experience is probably different.

Our brains do not simply act as "pain-o-meters" that register the signals coming from the nociceptor-containing nerves in our bodies. Brain-imaging studies show that several different areas of our brains process the incoming signals. For example, activation of regions in the limbic system of the brain influences our subjective, emotional experience of pain. Different regions of the brain's cortex—the part of the brain involved in higher thinking—also actively process pain signals.

In humans, several lines of evidence show that pain is much more than a sensory experience. Our expectations about how bad the pain will be influence how bad it feels. When we think that we have control over pain, it increases our pain tolerance. Our emotional state can influence pain perception. Finally, we may still experience pain even after the nerves that carry the pain-related signals from the body are removed.

The ants go marching

Whenever I observe a line of ants traveling in opposite directions, individual ants always appear to be "touching noses" as they pass one another, as if in communication. Is this really what they are doing?

Yes, they are communicating with each other. Ants live in social groups and have developed a highly sophisticated chemical communication system. They leave chemical trails to lead their comrades to a newly discovered food source (to the dismay of picnickers everywhere), release chemical alarm signals to warn of predators, and have a personal chemical "signature" that lets ants know who is a member of their colony.

Chemical signals that one animal releases to influence the behavior of another animal, usually of the same species, are known as pheromones. Ants have different types of glands that release pheromones, several of which are in the head of the ant. Ants detect pheromones using their antennae.

When ants encounter their nestmates on the trail, they also sometimes offer them liquid food that they can store for long periods without digesting in an expandable sac called a crop. This exchange may excite the ant receiving the food and make it more likely to follow the scent trail.

Foreign invasion

Tiny black ants are invading my kitchen. Where do they come from? They seem to like anything sweet. How do I prevent them from appearing on my sink, in my breadbox, and in other places in my house? I'm using Raid wherever I find them and keeping all edibles in the refrigerator.

They are Argentine ants, an invasive species native to northern Argentina, Paraguay, and surrounding regions. Their ancestors likely hitched a ride on ships carrying coffee from South America in the late

1800s, and Argentine ants now reside in many Southern states, including California.

According to David Holway, a professor of biology at the University of California, San Diego, Argentine ants like damp soils. In arid regions such as southern California, they would primarily live along creeks and the foggy coast if it weren't for extensive irrigation. Irrigation has allowed Argentine ants to spread throughout many otherwise inhospitable areas. If you live in a place with low rainfall, try to convince your neighbors to stop watering their lawns and landscape with native plants instead, as that should help your ant problem.

When ants have taken up residence in your home, they can be difficult to eradicate. I, too, turned to synthetic pesticides out of desperation the day I woke up and found the ant equivalents of Lewis and Clark exploring my hair. Synthetic pesticides can keep killing ants that walk across the pesticide residue for weeks after you spray. Unfortunately, this also means the people and pets in your household are being exposed to these toxins.

Some pesticides are safer for people and pets. For example, ants don't like to walk through talcum powder because it is like walking through broken glass from their perspective. Powdered boric acid is another effective remedy. Sprinkle it behind appliances or dilute it in water and use as a spray. Commercially available alternative pesticides, such as a mixture of peppermint and soap, also work, albeit mostly to reroute the ants.

If you have recurring problems with these ants, try treating the perimeter of your house with pesticides. Spray them right against the foundation, and in places where water pipes come into your house. Sealing cracks in the foundation, around windows, and in similar locations can also help reduce their points of entry.

Argentine ants do like sweets, but they are scavengers that also feast on dander, dead insects, and anything else they can get their tiny mandibles around. So they may infest your house even if all your food is in sealed containers. They also collect water, which explains why they often appear in sinks and water fountains, especially in late summer and early fall.

Snorkeling in the rain

Do ants breathe? If so, what happens to them when it rains? Do they drown? Do their breathing apparatuses get flooded, killing them?

Ants and most other insects breathe through a complex system of flexible tubes called trachea. Large tracheal tubes branch into successively smaller tubes that extend throughout the body, including the legs and the wings of flying insects. The smallest tubes, tracheoles, are less than a micrometer in diameter (about one-hundredth the size of a human hair), and they exchange gases with the tissues of the body.

Because insects lack lungs, scientists previously thought that gas exchange through the trachea was completely passive—that is, the tendency of gases to move from high to low concentration caused oxygen to flow into the body and carbon dioxide to flow out of the body. Insects use passive gas exchange, but they also breathe through an active mechanism, controlled similarly to how an accordion is played, with its switches and bellows.

As the switches on an accordion open and close banks of reeds, the insect nervous system switches open and closed spiracles—gateways between the tracheal system and the outside air. The insect "bellows" are the muscles that compress the exoskeleton—an insect's tough outer casing—which, in turn, puts pressure on the hemolymph—insect blood that fills the body cavity—and causes it to compress the trachea. The muscles attached to an insect's exoskeleton thus control a cycle of inflation and deflation of the trachea.

The capability to open and close spiracles helps protect insects against drowning. A partially submerged insect could selectively open the spiracles not under water. A fully submerged insect could close all its spiracles. Because insect respiratory systems are very efficient, resting insects sometimes stop breathing for a half-hour at a time, so they could wait out a short rain. For longer rains, they would need to take shelter.

Underground colonies have an intricate architecture that protects ants from the elements, as revealed by research not for the faint of heart. Biologist Walter Tschinkel from Florida State University excavated colonies of Florida harvester ants and made metal and plaster casts of their entire network of shafts and chambers. The largest nests are about 12 feet deep, made by worker ants that had to dig out almost 90 pounds of sand. Young worker ants and the ant brood pack densely into the nest's lower chambers, where air pockets would be found even when it rained.

Sunny honey

Why aren't bees able to fly at night? It seems if they don't get back to their hive before dark, or are unable to find a place to hide (such as one of my roses), I find them dead or dying. Is heat or solar radiation needed to make them fly?

Temperature drop at sundown is one reason bees get stranded. Their flight muscles must be warm enough to work. Another reason is that foraging and homing are predominantly visual tasks, and bees that are active during the day do not see well in dim light.

Day-active insects typically have apposition compound eyes, in which light reaches the photoreceptors—light-detecting cells in the retina—exclusively from the lens located directly above it. In contrast, nocturnal insects, including most moths, typically have superposition compound eyes, in which each photoreceptor receives light from hundreds, sometimes even thousands, of lenses.

The light-gathering power of superposition eyes gives them a sensitivity advantage compared to apposition eyes. Surprisingly, although all bees have apposition eyes, several bee species forage at night or during twilight. One species, the giant Indian carpenter bee, has even been observed foraging on moonless nights.

Bee species that fly between sunset and sunrise generally live in warm desert areas or in forests in tropical or subtropical regions where the flowers of many plants open only at night. Competition for nectar and predation are often reduced during nocturnal foraging.

To overcome the disadvantage of apposition eyes, bees that forage in dim light have various visual adaptations. Some lie within the eye itself; others are located in the neural circuitry that processes visual information. For example, the three simple eyes, or ocelli, that bees have on the top of their heads between their compound eyes are considerably larger in these species. Ocelli are thought to be involved in flight control.

Each lens within the individual eye units that constitute the compound eyes of night-flying bees is larger relative to body size, and night-flying bees typically have more of these eye units. Their photoreceptors are more light sensitive. Not only are the signals from the photoreceptors sent along the usual visual channels to the brain, but these bees also have specialized nerve cells that sum the outputs of neighboring visual channels.

Regarding the mortality you witness among bees that fail to take cover when the light dims and the temperature drops, some bees die from age and injury. Because of the way bee colonies divide tasks, foragers are the hive's oldest workers, and bees don't get to retire.

Working stiff

I frequently walk the beach and see dozens of bees stranded at the waterline. Most are dead and a few are just barely alive. Is this related to worldwide bee health problems? Does it do any good to move the bees to plants on the cliffs or is my intervention more of a problem than a help?

The lifespan of a honeybee is about five to seven weeks. In a healthy colony of around 50,000 bees, an average of 1,000 bees die daily. The bees at the beach are middle aged or elderly. We know this because an age-related division of labor occurs among most social insects. Worker bees nurse the brood and tend to the hive until they are two or three weeks old, and then they begin foraging.

Bees literally work themselves to death. If they do not fall victim to one of the many hazards of being a bee, such as predation or disease, they die after wearing out their wings logging hundreds of miles searching for flowers and lugging nectar and pollen back to the hive.

Compounding the normal bee mortality is an enigmatic disappearance of bees. In October 2006, U.S. beekeepers began reporting large losses of bee colonies. Symptoms exhibited by the affected hives did not match those produced by known bee parasites and diseases. The name Colony Collapse Disorder (CCD) was coined to describe the sudden losses, which have since been documented in many other countries.

Four main symptoms are associated with hives that have been lost to CCD. First, adult bees are absent. Second, few dead worker bees are found within or surrounding the hive. Third, the brood is still present. Fourth, food stores remain and are not scavenged by bees from other colonies or common colony pests.

Of the long list of possible CCD causes, most attention is on three: infectious agents, pesticides, and stresses related to bee-management practices. The strongest evidence to date, from a recent study of 91 colonies in 13 different apiaries in Florida and California, implicates infectious agents but does not rule out other causes.

The study found that CCD colonies had higher levels of viruses and were infected with a greater diversity of viruses than non-CCD colonies. Also, the distribution of CCD colonies was not random. Dead colonies tended to neighbor other dead colonies, suggesting that the condition is contagious. Because bees live in crowded conditions with genetically similar individuals, new diseases and parasites spread quickly.

No single disease distinguished CCD and non-CCD colonies in the study. Other studies have found specific diseases—including *Nosema ceranae,* a fungus that attacks cells in the gut, and Israeli acute paralysis virus—that are more common in collapsing colonies. It is not clear whether the diseases caused the collapse, but one way that bees control spread of disease is to have infected individuals leave the hive.

Many factors can reduce bees' disease resistance. For example, parasitic mites, which feed on bee blood, weaken their hosts and transmit disease. Recently, the mites have been evolving resistance to the most effective chemicals used to control them.

In addition, foraging bees are exposed to myriad pesticides intended for other insects. France banned one insecticide thought to be particularly harmful to bees, but colony losses have continued. Beehives are also being trucked greater distances than in the past, typically to less diverse food sources. Bees are often fed pollen substitutes and corn syrup in the winter, which may harm their health. The general consensus is that CCD is the result of this perfect storm of factors working in combination.

Although most of the workers you observe dying away from the hive are likely the result of normal population turnover, because of the sheer number of bees that involves, some may be from collapsing hives. For example, one of the symptoms of infection with Israeli acute paralysis virus is disorientation. Likewise, certain pesticides have been found to cause learning and memory problems in bees. Disorientation and memory problems could leave bees stranded on the beach.

Sea spray is another hazard for bees, especially on cold days. Evaporative cooling chills the bees, and bees need to keep their flight muscles warm to fly. Bees quickly rescued from our swimming pool usually fly off after drying in the sun and shivering to warm their flight muscles. But the rescue attempt fails if the bee is disoriented or injured, or stings its potential rescuer.

Beekeepers have long had to contend with “disappearing diseases,” especially after harsh winters. Nonetheless, CCD has created quite a buzz because bee pollination is so important in agriculture, adding an estimated $15 billion in improved quality and yield of U.S. crops annually. The recent declines exacerbate a beekeeping trend that has more than halved the number of U.S. hives to 2.4 million during the past half-century.

The bees and the birds

A bottlebrush in my backyard and an agave plant in the canyon have attracted numerous bees and birds. Do the bees ever sting the birds because they are both going after the nectar?

The barb of a stinger needs to lodge in an elastic material to pull away from a bee’s bottom and deliver venom. Thick skin and feathers provide birds with protection, but they can still get stung. Honeyguides—small birds in Africa and Asia that feed on beeswax from honeybees—have been found dead under beehives with hundreds of stings.

Bees are most likely to sting when they are protecting the hive, but some species vigorously defend nectar sources. Quarrels over flowers are most likely to arise when resources are limited. During these disputes, the bully and the bullied have been observed to reverse places. At times, hummingbirds chase bees away from flowers, but at other times, the bees turn around and chase the bird instead of fleeing.

One study in the Sierra Nevada discovered that in a meadow where bees were abundant, hummingbirds foraged mainly in the morning and evening, when it was cooler and bees were less active. In a meadow that was devoid of bees, hummingbirds collected nectar all day. Hummingbirds did not show hawkmoths the same respect—the birds chased them away from flowers.

The birds and the bees are not all about conflict. More than 100 species of birds, especially in the tropics, have been reported to build their nests close (less than 5 feet) to the nests of bees, wasps, and ants. The birds take advantage of the biting and stinging insects' defensiveness of their own broods.

Predation is the greatest risk to birds' eggs and nestlings. Building nests in places that are inconspicuous or inaccessible does not always work, especially in regions where terrific climbers are prevalent. So neighboring nests of bees, wasps, and ants help birds up the ante against potential predators.

A study in Costa Rica in which wasp nests were relocated close to the nests of wrens showed that the young of wrens nested near wasp nests were more likely to survive than the young of wrens without wasp nests in proximity. The researchers observed the birds' main predators, monkeys, beating a hasty retreat from attempts to rob the birds' nests when confronted by the birds' aggressive insect neighbors. The birds avoided the wasps and were not usually disturbed by them.

Twinkle, twinkle, little bug

Why doesn't California have fireflies as the Midwest does?

In many parts of the country on warm summer evenings, the sky twinkles with what appear to be flying, flashing light-emitting diodes (LEDs). The little lights are fireflies, or lightning bugs, using an interactive visual Morse code to find that special someone for a brief summer romance.

Fireflies are a large family of beetles known as *Lampyridae,* or lampyrids. More than 2,000 species of fireflies have been identified worldwide, but by some estimates, this is just a quarter of the total number of firefly species. All fireflies produce light at some stage during their life cycle, but not all species put on a nightly light show in search of a mate.

In addition to the "lightning bug" fireflies in which both males and females use species-specific light signals to communicate, there are "glowworm" fireflies and "dark" fireflies. Glowworm fireflies have grublike females that emerge from burrows at night and emit a continuous glow. Males seek out the glow but do not signal. Dark fireflies are generally active during the day. Instead of light signals, they use chemicals called pheromones to attract a mate.

In California, 18 species of fireflies have been identified, but the Golden State lacks lightning bug fireflies. Why Californians got the short end of the firefly stick is not clear. Predation could have played a role. The modes of communication different species of fireflies use have different advantages and disadvantages. Would-be paramours can more easily localize the source of a light signal than the source of pheromones. But light signals are more vulnerable to espionage by would-be predators because a predator must possess a chemical receptor—detector—for a specific pheromone.

Researchers have proposed that in an ancestor of fireflies, bioluminescence—light production—was used solely to deter predators and only later evolved in some species as a tool for finding a mate. The light-producing substance, luciferin, is bitter. Fireflies produce other chemicals that are distasteful and even toxic to some predators. However, other predators have no qualms about snacking on fireflies, so the types of predators in a region should influence what firefly signaling modes (and, hence, what species) are present.

Climate also influences the distribution of firefly species. The southeastern United States, with its hot, muggy summer nights, has the highest concentration of lightning bug fireflies. In California, typically cool summer nights would be disadvantageous for all but dark fireflies that are active during the day.

Body tunes

Why do crickets chirp?

Those chirps you hear are usually gentlemen crickets serenading the lady crickets. Males use a loud, monotonous sound to attract a female, and a quick, quieter chirp to court a female nearby. Male crickets also chirp to defend their territory against other male crickets.

Crickets make sound through stridulation, rubbing one body part against another. They rub a sharp-edged ridge (the scraper) on the outer edge of one wing against a series of sawlike teeth (the file) on the other wing. As when a bow is pulled across the strings of a violin, the scraper dragging across the file sets up a vibration. The vibration is amplified as it resonates on the wing membrane.

Each species of cricket has its own song, but the song also varies within a population. A male's song is revealing. Larger males have a song with a lower carrier frequency, or pitch. Females seem to be able to determine the relative size of a male cricket from his song because they find lower pitch songs more attractive.

Temperature affects crickets' chirp rates. The *Old Farmer's Almanac* provides a formula to convert the chirp rate to temperature. To get the temperature in Fahrenheit, count the number of chirps in 14 seconds and add 40. It may not be as accurate as a thermometer, but if the crickets stop chirping, grab a jacket.

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