

## CONTENTS

1.	Birds, Bees, and Butterflies	1
2.	Chimp Chausiku	13
3.	Parasites and Pathogens	30
4.	Beetles and Bulldogs	42
5.	Birds and Butts	53
6.	Ants and Aliens	67
7.	Poisons and Proteins	79
8.	Living and Learning	95
9.	Woolly Wisdom	116
10.	Sticky Bee Business	134
11.	Dogs Are Dogs	154
12.	Elephant Educators	171
13.	Cats and Catnip	180
14.	Plants and Pollinators	195

*Acknowledgments* 205

*Notes* 211

*Index* 239

# 1

## Birds, Bees, and Butterflies

“Did you know that monarch butterflies use drugs?” I ask.

It is October 2022, and I am sitting at an outdoor table at the St. Marks National Wildlife Refuge located on the southern side of Florida’s Big Bend, right on the water of the Gulf of Mexico. Behind me is a white lighthouse. To my left I can look out over Goose Creek Bay, where I saw dolphins earlier. In front of me is a lagoon with alligators. Standing around the table are twenty people, varying in age from about three years old to seventy years old. We are at the St. Marks Monarch Butterfly Festival, held every year on the fourth Saturday of October. It is one of my favorite weekends of the year. For more than a decade, my students and I have made the six-hour drive from Emory University in Atlanta, where I am a professor, to attend the celebration of monarch butterflies. We come here to tell people about monarchs, and the research we do on them.

“Just like us, monarchs get germs,” I say to a little girl wearing a tutu and dress-up butterfly wings. Holding the butterfly for her to see, I explain that these germs make the monarchs very

sick. “They cannot go to the doctor like you or me, but luckily they can find medicines in the plants they eat.”

Most people who know about monarchs are aware of their amazing migration.<sup>1</sup> As temperatures drop and the days get shorter, monarch butterflies from the United States and Canada embark on an amazing autumn journey. Flying as many as forty-five hundred kilometers, they travel to oyamel fir forests in the Transverse Neovolcanic Belt in Central Mexico. From late October to late November, and coinciding with the Mexican celebration of Day of the Dead, hundreds of millions of monarchs make their way into the high-altitude forests. They form clusters on the trees. Although each monarch weighs about as little as a medium-sized paperclip, some branches break under the weight of the thousands of monarchs that huddle together. Monarchs overwinter at these sites until February and March, when they mate and fly back north. On their way south, many monarchs follow the coast of the Gulf of Mexico to reach their overwintering sites. And lots of these monarchs stop in the refuge at St. Marks. On a good day, we see thousands flying through the refuge, feasting on the nectar of the abundant salt bushes and other flowering plants.

Amazing as monarch migration is, though, it is not the reason I started studying monarchs. I like to tell people that I study monarchs because they get sick. This takes many people by surprise. Accustomed as we are to becoming sick ourselves, and taking our pets to the vet, few of us think of wild animals becoming ill. But they do. Just as humans encounter a whole collection of disease-causing viruses, bacteria, worms, and protozoans throughout our lifetime, so do birds, bees, and butterflies. The most common disease in monarchs is caused by a one-celled parasite called *Ophryocystis elektroscirrha*.<sup>2</sup> Because its name is difficult to pronounce, many people refer to the parasite simply

as “OE.” This parasite is somewhat related to the parasites that cause malaria in humans, and it is no joke for monarchs. The parasite forms millions of spores on the skin of the monarch and pokes little holes in the monarch body. If the parasite does not kill the monarch, it causes dehydration and weight loss. Infected monarchs cannot fly well. So, instead of completing their journey to the overwintering sites in Mexico, they die along the way.<sup>3</sup>

Sitting at the table in St. Marks, I show people how we figure out whether monarchs are infected. My students and I like to call it the monarch health check. Like nurses and doctors, we wear examination gloves as we stick a clear plastic sticker to the abdomen of the butterfly (it does not hurt them), then place the sticker on a paper index card. We use a microscope and check for little black parasite spores. I show the festival visitors the parasites when we find them.

Then I tell them something truly remarkable. *Monarch butterflies are expert doctors*. Just as humans use drugs to treat parasitic infections, so do monarchs. As it turns out, I tell my audience, when faced by this horrendous OE parasite, monarchs are not helpless. They can seek out medicinal plants that reduce infection and relieve disease symptoms.

## POISONOUS PLANTS

I started studying the parasites of monarchs in 2005 when I moved to the United States for a research position. While I was initially interested in studying the basic biology of these parasites, I quickly became interested in the interactions between the parasites, the monarchs, and the caterpillars’ sole food source, milkweeds. Like many other butterflies, monarchs are specialist herbivores, meaning they eat only specific plants as

caterpillars. For monarchs, their specialized diet consists only of milkweeds. There are actually many kinds of milkweed, in many forms and sizes, but most are in the same genus, *Asclepias*. When we rip off their leaves, they ooze white latex that looks like milk—hence the name.

In addition to producing latex, milkweeds produce a class of chemicals known as cardenolides. These steroid chemicals are toxic to most animals, and the plants use them to deter herbivores.<sup>4</sup> Monarchs can tolerate them, though. What's more, the caterpillars, while feeding on the plants, store the toxic chemicals in their own tissues.<sup>5</sup> This is what makes monarchs poisonous to their predators. Monarchs have bright orange wings, lined with black lines and white spots, which they use to tell birds and other predators they taste bad.<sup>6</sup>

When I started studying monarchs, it was a well-known fact that monarchs use cardenolides to protect themselves against predators. But with my interest in parasites, a question soon started forming in my brain. I knew of studies that had shown that other types of toxic chemicals, found in other plants, can kill disease-causing viruses of insects.<sup>7</sup> And that made my colleagues and me wonder: Could the cardenolides found in milkweeds be toxic to OE parasites? Were the monarchs using plants not just as food, but as medicine?

To answer that question, I set up an experiment with two groups of monarch caterpillars—one group fed on only tropical milkweed and the other fed on only swamp milkweed. All caterpillars (a total of 240) were exposed to OE by feeding them milkweed with parasite spores. I knew from published studies that tropical milkweed (*Asclepias curassavica*) has more cardenolides than swamp milkweed (*Asclepias incarnata*). After the caterpillars became butterflies, we tested how many of the monarchs had become infected and how sick they were. If

cardenolides could protect against parasites, we would expect the monarchs who had fed on tropical milkweed as caterpillars to experience less illness. The result was exciting: in the group of monarchs that had fed on tropical milkweed as caterpillars, 20 percent fewer monarchs became infected than those that had fed on swamp milkweed. And the tropical milkweed–fed caterpillars that did become infected had less than half the number of parasites and were a lot less sick, living up to twice as long.<sup>8</sup> All in all, our experiment suggested that highly toxic milkweed not only wards off predators but also acts as a potent antiparasitic drug.

The next question was as logical as it was unlikely. Was it possible that monarchs could intentionally take advantage of these medicinal milkweeds? Would sick monarchs be able to specifically use highly toxic milkweeds as a form of medicine? In 2008, I had taken a position as assistant professor at Emory University. There, my team and I carried out a series of experiments in which we offered infected and uninfected female butterflies medicinal tropical milkweed and nonmedicinal swamp milkweed in big flight cages. We counted the numbers of eggs that these females laid on each species. What we found is that infected butterflies laid way more eggs on medicinal plants than on nonmedicinal plants.<sup>9</sup> Uninfected butterflies did not. In other words: when monarch mothers are infected, they prefer to lay their eggs on medicinal milkweed.

That infected monarchs prefer to lay their eggs on medicinal plants is remarkable. It is even more remarkable when we think about who they are actually protecting. Diseased monarchs do not benefit from the medicinal plants themselves. They are already infected and have suffered the consequences. They cannot cure themselves. What they also cannot do is avoid the spread of parasites to their offspring. The parasites form



FIGURE 1.1. A female monarch butterfly lays eggs on a medicinal milkweed, which will reduce infection and disease symptoms in her offspring caterpillars. Photo by Jaap de Roode.

millions of spores on the butterflies' abdomens, and every time the butterfly lays an egg on a milkweed plant, some of these will inevitably get stuck to her eggs and the milkweed leaves.<sup>10</sup> But what the mother butterfly *can* do is choose to lay her eggs on medicinal plants. When her babies hatch from their eggs, they will ingest the parasites. But they will also ingest the medicinal milkweed. And this reduces the chance that the parasites take hold. Should the caterpillar still become infected, the plant reduces the growth of the parasites, and thereby relieves disease symptoms. Thus, rather than medicating herself, a monarch mother medicates her offspring—and she does so even before those offspring are born. A wonderful case of “mother knows best.”

## TEENY-TINY BRAINS

As I was studying monarch medication, I realized that many other animals use drugs as protection against disease. (I fully realize that humans are animals. But for the sake of simplicity, I will use the term “animals” specifically for nonhuman animals throughout this book). In the 1980s, primatologists had discovered that chimpanzees can use the toxins and hairy leaves of plants to treat intestinal worm infections. I found other studies that showed that goats and sheep are their own medical doctors too. And while many scientists traditionally believed that animals needed big brains to be able to medicate themselves—a bias mostly driven by the fact that chimpanzees are our closest living relatives—this idea did not jibe with the data.

I learned that woolly bear caterpillars and wood ants can use medicine too. Thus, animals with brains smaller than a pinhead can be just as good at medicating as those with brains like our own. What this suggested to me is that animal medication is

common across the animal kingdom. I became fascinated with this idea, and that fascination eventually grew into this book. In the coming chapters, we'll explore all of these examples, and more.

Over the last four decades, scientists have discovered that animals do in fact seem to seek out medication (though, as we'll see, defining exactly what this means is a tricky task): animals of all shapes and sizes use a vast array of plants, fungi, toxic animals, chemicals, and other natural products to fight infections and alleviate disease. And they can do so in four different ways. First, animals can use "prophylaxis," which is when healthy animals choose to eat foods and antiparasitic compounds *before* they get sick to stay healthy and prevent disease. Japanese monkeys that live in areas with more parasites eat more antiparasitic plants than monkeys that live in areas with fewer parasites.<sup>11</sup> In Ethiopia, baboons that are at greater risk of schistosome infection increase their worm resistance by eating more toxic berries.<sup>12</sup> Second, animals may use "therapeutic medication." This is the use of medicinal compounds when the animal is already infected: chimpanzees suck the toxic juice out of bitter plants when sick with parasitic worms, and woolly bear caterpillars use toxic alkaloids to kill parasitic fly maggots. A third form of medication is "body anointing," where animals as diverse as lemurs, cats, and coatis rub antiparasitic substances into their fur to deter parasites such as mites, lice, and mosquitoes. Finally, animals may use "fumigation," by which they add antiparasitic substances to their living or sleeping quarters. Fumigation is used widely by birds, who line their nests with aromatic plants that kill mites, ticks, and lice. It is also used by ants and bees, which fill their nests with antimicrobial tree secretions to prevent disease.

Some scientists have described all these different behaviors with the word "zoopharmacognosy."<sup>13</sup> The term derives from

the root words “zoo” (animal), “pharma” (drug), and “gnosy” (knowing). Other scientists prefer to describe the different behaviors as “animal self-medication.” I do not particularly like either term. To me, the word “zoopharmacognosy” suggests that animals know that they are medicating themselves (they may not: the behaviors they display could be fully innate, as we will see in chapter 8). And the term “animal self-medication” suggests that animals exclusively medicate themselves (they do not—as we already saw, monarch butterflies medicate their offspring). I believe a more inclusive term to describe all these different behaviors is “animal medication,” and that is what I will use throughout this book.

Demonstrating that animals use medication is difficult. I will discuss this in the next few chapters, highlighting the use of observational studies and experiments. For now, I want to make two important points. First, I will spend most of this book discussing behaviors that allow animals to fight against infection—that is, dealing with parasites and pathogens that make them sick. The reason for this focus is not only because parasites and pathogens are extremely important for animal evolution but also because most of the well-described examples of animal medication involve defenses against infections. That said, infectious diseases are not the only reason animals use medication. As this research continues, we are learning that animals may use medicine to treat wounds or relieve sore joints.<sup>14</sup> Orangutans, for example, mix specific plants with saliva and rub the mixture either into wounds,<sup>15</sup> or onto different body parts, which reduces inflammation.<sup>16</sup> Scientists have also suggested that pregnant animals may use particular plants to induce labor. Pregnant and lactating si-faka females increase consumption of tannin-rich plants, which is associated with increased body weight and stimulation of milk secretion.<sup>17</sup>

There are also reports of animals using drugs for recreational use. The concept of drunken monkeys is quite popular indeed. And reports of drunken elephants ransacking buildings can count on a wide readership. After a herd of 50 elephants raided a shop that sold a fermented drink in 2012, local police spokesman Asish Samanat commented in an online news outlet: “They were like any other drunk—aggressive and unreasonable but much, much bigger.”<sup>18</sup> (Although it is entertaining to assume that animals consume alcohol to get drunk, a recent analysis suggests that primates actually eat fermented fruits because the fermentation process breaks down toxic chemicals that would otherwise make the fruits inedible, and because it provides a food source during times when fresh fruit is unavailable.<sup>19</sup>) Wound treatments, pregnancy care, and alcohol use fall outside the scope of this book, but if you are interested in learning more about these fascinating behaviors, I recommend the excellent book *Wild Health* by Cindy Engel.<sup>20</sup>

The second point I want to make is that it is not always obvious that a specific animal behavior is a form of medication. As I will discuss in the next few chapters, the most important criterion for animal medication is that the behavior helps the animal: either by reducing or avoiding infection, or by alleviating disease. But infection can also change behaviors in ways that are not beneficial to animals. On the contrary: it turns out that parasites and pathogens are masters at manipulating animal behaviors for their own benefit.<sup>21</sup> This means that when we see an infected animal change its behavior, we cannot simply assume it is medicating. Instead, it may be the parasites and pathogens doing the talking.

That animals can use medicine is now supported by many studies, and I chose to write this book to share the many fascinating stories of how animals use medication to protect themselves

against parasites and pathogens. I also wanted to introduce the people who have provided us with these stories, showcasing how scientists from many different backgrounds, and in different continents, have been driven by an innate interest in understanding the natural world. As we will see, those scientists share a common belief: the study of animals is not only interesting in itself but can also teach us about how we can tackle the many parasites and pathogens that continue to inflict death and suffering on humans, domesticated animals, and pets.

The goal of this book is therefore twofold. First, I want to make the case that animals are highly evolved experts at medicine. They may not speak Latin, be trained in bedside manners, or write prescriptions, but they have evolved a plethora of ways to keep infectious diseases at bay through rather sophisticated medicine.

The second goal of this book is to show that we can benefit from studying animal doctors. Yes, most researchers studying animal medication are driven by a basic curiosity to understand the natural world. But as we will see, we can use insights into the medication behaviors of goats and sheep to increase animal health and reduce antibiotic resistance at farms and in the livestock industry. We can apply the antiparasitic behaviors of bees to improve beekeeping. And work is underway to develop bug repellents from compounds discovered by cats. Many scientists studying animal medication believe that their research may ultimately lead to the discovery of drugs that we can use to treat our own diseases.

Some would argue that our modern chemistry and technology equip us well enough to come up with new drugs from scratch.<sup>22</sup> But consider this: over the last forty years, more than half of the new antibacterial drugs and 45 percent of the antiparasitic drugs that hit the market for human use were derived

from natural products. These include compounds from plants, bacteria, and fungi.<sup>23</sup> With the ongoing threat of infectious disease, and the ever-growing number of pathogens that evolve resistance to the drugs we rely on, it is more important than ever to study animal medication—and to apply the medical knowledge of animals to the health of humans and domesticated animals.

We'll explore all these ideas in future chapters. But before we get to those exciting applications, let's start by asking how a sick chimpanzee sparked the birth of a new scientific field.

## INDEX

A page number in *italics* refers to a figure.

- acidosis, in sheep, 121–22, 123, 126
- addiction to drugs, 84
- agriculture, 138. *See also* livestock; pollinators
- AIDS, substitute antibiotic in, 26
- alkaloids, 89; antiparasitoid, 74, 75–78, 95–97
- allergies, and microbiome, 158
- Altizer, Sonia, 43
- American foulbrood, 144–45, 147
- Anderson, Kirk, 147
- animal medication: applied to human issues, 11–12; as common phenomenon, 7–8; conditions to conclude use of, 47–49, 55; costly or harmful to healthy animals, 73, 77, 78; different definitions of, 91–92; drug discovery based on, 183–85; field studies of, 46–52; first scientific examples of, 25, 29; food used as, 47–48, 91–94; four different types of, 8, 38, 48; habitat loss and, 198; incentives for preservation of, 199; inconclusive studies of, 49–52; most important criterion for, 10; not only for infections, 9–10; parasite manipulation mistaken for, 41; as preferred term, 9; side effects of, 48–49, 77, 124; skepticism about, 45, 97–98, 169. *See also* behaviors of animal medication
- animal populations, declining, 196, 197
- animal self-medication, 9
- anthelmintics, 124, 128
- anthropomorphism, 19
- antibiotic activity: of mulengelele, 26; of propolis, 153; in propolis-rich bee colonies, 147; of thiarubrine A, 27
- antibiotic resistance, 11, 117, 128, 148
- antibiotics: bitter-tasting tetracycline, 108; causing *C. diff* infection, 159; from fungi and animals, 84, 90; given to livestock, 128; for infections in AIDS, 26
- antimalarial drugs, 82, 84, 89–90, 103, 181; evolution of resistance to, 172
- antimalarial plant compounds: bonobos as source of, 184; chimpanzees as source of, 183–84
- antioxidants: alkaloids with activity of, 89; consumed by worm-infected sheep, 126; inducing tolerance in sheep, 47; in plants for livestock, 130–31

- ants: behavioral defenses of, 37; food used as medicine by, 72; fumigating their nests, 8; fungal parasites of, 72. *See also* wood ants (*Formica paralugubris*)
- aphids, harboring protective bacteria, 36
- Aristotle, 156, 159–60
- artemisinin, 82, 84, 89–90
- Asclepias*, 4. *See also* milkweeds
- Aspilota* leaves, swallowed, 27
- aspirin, 16–17, 83, 90, 173, 181–82
- associative learning, 104–8; with gap of many hours, 107–8; reinforced in social group, 114; of sheep and lambs, 121
- astringent plants, 103, 106; tannin-rich, 120
- atropine, killing parasitoid wasp larvae, 71–72
- Attenborough, David, 68
- Ayurvedic medicine, 93, 166, 171
- baboons, increasing worm resistance, 8
- bacteria, beneficial: helping against infections, 36. *See also* microbiome
- bacterial infections: development of drugs acting on, 184; of honey bees, 138, 139, 144–46, 147; quorum sensing in, 183; with *Staphylococcus aureus*, 182–83
- barber's pole worm (*Haemonchus contortus*), 124, 125, 126
- Bastock, Margaret, 99
- bearberry (kinnikinnick), 16
- bear root, 16
- bears: consuming grass, 164; knowledge from, 14–17, 173; shamanism and, 14–15, 17
- Becker, Karen, 155, 166
- beef calves, assembling their own diet, 127–28
- beekeeping businesses: antibiotics used by, 148; dislike for propolis in, 143, 199; increasing the likelihood of disease, 149; losses in, 136; migratory, 136; new hive boxes for, 65, 150–52; pesticides used by, 148; reintroducing propolis to, 150–53; size and density of, 138; smooth rectangular hive boxes of, 149–50; unhealthy environment for bees in, 149
- bees: fumigating their nests, 8. *See also* bumblebees; honey bees
- behavior of animals: in courtship and mating, 99–102; function vs. motivation in, 114; genetic component of, 98–103; to protect against parasites and pathogens, 36–37. *See also* innate behavior of animals
- behaviors of animal medication: aversion for familiar foods and, 106–7; aversion for new foods and, 107, 108, 109, 113, 129; bitterness and, 102–3, 108, 112; combining innateness, association, and social learning, 114–15; discouraged by humans, 198–99; function vs. motivation in, 114–15; needing choices, 203; simple rules of thumb and, 102–3, 106; social rather than for self, 146. *See also* innate behavior of animals; learning
- Berberis* plants in Pakistan, 175
- Bernays, Elizabeth, 73, 96
- biodiversity crisis, 198, 199; planting gardens and, 202–4
- biofilms, 169, 183
- birds: avoiding nest boxes with fleas, 37; controlled experiments with, 53, 60, 62–63, 66; defenses against

- parasites and pathogens, 37; eating blister beetles, 51, 51–52; food choices of chickens, 110–11; language of, 13–14; *Mycoplasma* infection of, 32; urban adaptability of, 58, 65. *See also* fumigation of bird nests
- bitter leaf (*Vernonia amygdalina*), 103; analyzing chemicals in, 21–22, 23; anti-tumor compound in, 184; highly toxic, 48, 124
- bitter pith sucking, 20–21, 23, 24, 28–29, 48–49; copied by an infant, 111–12
- bitter-tasting antibiotic, 108
- bitter-tasting plants, 102–3; overcoming aversion to, 108; social conformity and, 112
- blackberry extract, and biofilms, 183
- blister beetles, eaten by great bustards, 51, 51–52
- body anointing, 8, 38, 48, 50–51
- Bombella apis*, 147–48
- bonobos: bitter pith chewing and leaf swallowing in, 27, 28–29, 112, 113, 163; eating plants active against malaria and bacteria, 184
- Bowers, Kathryn, 200
- breast cancer, and plant compound, 184
- Buddhism, 19
- bumblebees: medicinal nectar and, 192, 201; with trypanosome parasites, 72
- Buruli ulcer, green clay for, 168
- bush pigs, learning from, 26
- butterflies: declining populations of, 197. *See also* cabbage white butterflies; monarch butterflies
- cabbage white butterflies, 90, 102
- caffeine, 89, 94, 173, 201
- cancer treatments: potential of vernaldin for, 184; taste aversions associated with, 106
- cantharidin, 51–52
- capsaicin, 89
- capuchin monkeys, using toxic millipedes, 48, 50–51, 90
- carbohydrates, dietary, 92
- carbon emissions, 200, 201
- cardenolides, 4–5, 44–45, 46, 48–49, 78
- Carroll, Lewis, 38
- Carter, Rosalynn, 202–3
- caterpillars: high-protein diets and, 92–93; of monarch butterflies, 3–5, 7, 49, 76, 85; nuclear polyhedrosis virus infection of, 32; plant chemicals aiding survival of, 73; plant defenses against, 85–86; taste cells of, 95–97; viral infectivity of corn earworm, 73. *See also* woolly bear caterpillars
- catnip, as human insect repellent, 186, 192–93, 202
- catnip response, 185–94, 187; of big cats in zoos, 189; with biting and licking of leaves, 186, 191–92; driven by a single gene, 192; endorphins and, 188–89; as innate behavior, 192; known for hundreds of years, 186; as mosquito protection, 189–93; nepetalactol and, 188–92
- Caton, Judith, 28
- cats: body anointing by, 8; consuming grass, 164, 165; diverse gardens and, 202, 204; wild, 164. *See also* catnip response
- cattle, 37, 127–28, 129, 198
- C. diff* (*Clostridioides difficile*), 158–59
- chalkbrood fungus, 146

- chamomile (*Matricaria chamomilla*), 80
- Chapuisat, Michel, 70–71, 145
- Chausiku, 19–21, 22, 23, 25, 29, 48, 111–12, 179, 184
- chestnut leaves, and skin conditions, 182–83
- chickens, learning what to eat, 110–11
- chimpanzees: bitterness as marker for medicine in, 103; bitter pith sucking by, 20–21, 23, 24, 28–29, 48–49, 111–12; geophagy in, 157; ironwood in night beds of, 54; leaf swallowing among, 26–29, 47, 49, 112–15; social learning in, 109, 111–15; treating parasitic worm infections, 7, 8, 20–25, 24, 26, 28
- Chinese medicine, 82, 93, 166, 171, 174
- chlorogenic acid, from tomato plants, 72–73
- chloroquine: bitter-tasting, 103; evolution of resistance to, 172
- cholera in humans, 47
- Chopin, 20, 21, 112
- Christe, Philippe, 69–71, 145
- Christianity, 14, 18, 19
- chytrid fungus, inhibited by bacteria, 36
- cigarette butts: as bird medication, 56–64, 61, 65–66; as environmental problem, 64–65
- Cinchona tree, 82, 181
- Clark, Larry, 54–55
- clay as medication, 167–68; neutralizing toxins, 156–57; for primates, 67
- clay eating: by animals, 156; by humans, 156
- climate change: actions to alleviate, 199–200; decreasing populations of species, 196; livestock industry and, 130, 132
- Clostridioides difficile* (*C. diff*), 158–59
- clove essential oils, 168–69
- clown fish with parasite, 30, 31
- cocaine, 83, 89, 173
- coevolutionary arms race: of fungi and animals with chemicals, 90; of hosts with parasites and pathogens, 38, 41; of plants with insects, 88–90
- companion animals, 175, 198. *See also* pets
- conformism, 109–10. *See also* social learning
- conservation, 199, 200
- controlled experiments: in applied zoopharmacognosy, 170; with birds, 53, 60, 62–63, 66; suitability of insects for, 67–68
- corals and sponges: antimicrobial compounds from, 90; dolphins rubbing against, 49–50
- Cotter, Sheena, 92–93
- COVID-19 pandemic, 37, 58, 137, 151, 156; vaccines in, 142
- crickets: hairworm parasites of, 45; parasitic flies and, 101–2
- culture in animals, 14; in chimpanzees, 113
- Curtis, George DeClyver, 142
- Cymothoa exigua*, 30, 31
- dairy cows, 130, 134
- Darwin, Charles, 33–35, 87–88; on domestication, 116–18
- Dawkins, Richard, 99
- defaunation, 197
- defenses against parasites and pathogens, 9, 36–38; behavioral, 36–37; evolution of, 32, 35–36; strategies against, 38–41. *See also* parasites and pathogens
- deforestation, 197, 198, 199

- de Réaumur, René Antoine Ferchault, 68
- de Waal, Frans, 114
- diabetes type 2, venom-derived drug for, 84
- diarrhea: fecal concoction for, 175; Mohamedi's new treatment for, 26
- digoxin, 83, 181
- dirt eating: by dogs, 156, 159, 199; gut microbiome and, 158–59; by many different species, 156; by many people, 156
- Dobzhansky, Theodosius, 35
- dogs: diverse gardens and, 202, 204; eating dirt, 156, 159, 199; eating grass, 159–66, 160, 162, 199; unable to access medicinal plants, 198
- dolphins, rubbing against corals and sponges, 49–50
- domesticated animals: animal-derived treatments for, 175–76; Darwin vs. Wallace on, 116–18; in habitats lacking medicinal plants, 198; herbal medicines for, 166–67; medicating themselves, 117–18; negative consequences of domestication, 65; regulating their own diet, 118–22; reintroducing medication for, 65. *See also* honey bees; livestock; pets
- Drosophila suzukii*, and atropine, 71–72
- drug resistance, 172; to antibiotics, 11, 117, 128, 148; in domesticated animals, 65
- drugs: boundaries between poisons and, 94; defined, 81; recreational use of, 10
- drugs in human medicine, 81–84; addiction and, 81, 84; ancient sources of, 171–72; animals as potential source of, 183–85; developed by pharmaceutical industry, 11–12, 81–82, 180–82; majority from natural sources, 82, 171–72; from plants, 82–84
- Egyptian medicine, ancient, 168, 181
- Ehrlich, Paul, 88
- elephants: clay eaten by, 156–57; drunken, 10; green clay for wounds of, 168; learning about treatments from, 26, 174, 176–78; learning what to eat, 110; mahouts' care for, 176–78, 177
- endorphins, and catnip response, 188–89
- Entomophthora muscae*, infecting houseflies, 39
- essential oils, 168–69
- European foulbrood, 144, 148
- evolution, 33–36; of animal behaviors, 98–99; of catnip response, 192; of defenses against parasites and pathogens, 32, 35–36; humans as supposed pinnacle of, 200; of strategies against host defenses, 38–41, 40. *See also* coevolutionary arms race
- exenatide, from venom, 84
- extinctions: current rates of, 196; mass historical events, 195–96
- Farid, Arian, 164–65
- fats, dietary, 92
- Fatuma, 22–23
- fecal concoction, for diarrhea, 175
- fecal transplant therapy, 159, 175
- feces, avoided by animals, 37
- fermented fruits, eaten by primates, 10
- fitness: defined, 35; improved by animal medication, 47; of manipulating parasites, 45

- FitzRoy, Robert, 33
- flies: crickets parasitized by, 101–2;  
fungal infection of houseflies, 39,  
40. *See also* fruit flies
- food, as animal medication, 47–48,  
91–94
- foodscapes, for livestock, 131, 166
- fossil fuels, 200
- foulbrood, 144–45, 147, 148
- Fraenkel, Gottfried, 87–88
- Franck, Alan, 164–65
- fruit flies: atropine-containing plants  
and, 71–72; genetics of courtship  
behavior in, 99
- fumigation, 8, 48; human uses of, 53;  
by many different animals, 53–54
- fumigation of bird nests, 8, 38, 52, 53,  
54–55; with cigarette butts, 56–66, 61
- fungal infections, 31; of ants, 37, 72; of  
flies, 39, 40; of honey bees, 137, 146,  
148; of salamanders, 36; of wood  
ants, 70, 71
- fungi: with antibiotic and laxative  
effects, 80; reactive oxygen mol-  
ecules and, 72; as source of drugs,  
84, 90
- Garcia, John, 104
- gardens: creating diversity in, 202–4;  
of medicinal plants, 202–3, 203;  
sensory, 166–67, 170
- garlic, 168–69
- Gekker, Genya, 142–43
- geophagy, 156–59
- gibbons, leaf swallowing by, 29, 112, 163
- gila monsters, drug derived from, 84
- glucosides, 87; steroid, 22, 78
- goats: associative learning in, 118–22;  
physiological associations in,  
104–5; social learning in, 129–30;  
tannin-rich plants consumed by, 125;  
wood rat houses eaten by, 129–30.  
*See also* livestock
- Goodall, Jane, 27, 108, 197
- gorillas: bitter pith chewing and leaf  
swallowing in, 27, 28–29, 112, 113,  
163; geophagy in, 157; plants used  
by, 184; social interactions of, 109;  
in zoos, 198
- grass consumption: by dogs, 159–66,  
160, 162, 199; by domesticated cats,  
165; by many carnivores, 164–65;  
pesticides and parasites obtained  
from, 165–66; vomiting and, 160–62,  
165; by wild cats, 164; by wolves,  
163, 165
- grasses: hardened with silica, 85, 164;  
of lawns, 201–2
- great bustards, 50, 51–52
- Greek medicine, ancient, 68, 82, 168,  
181–82
- green clay, 168
- greenhouse gases, and livestock, 130
- green tea, 93
- gut microbiome, 158–59
- Habib, Rodney, 155, 166
- habitat destruction, 196, 198
- Hardy, Karen, 80
- Hart, Benjamin, 102–3
- Helianthus tuberosus*, 112–13
- herbs for healing, 166–67; evaluating  
efficacy and safety of, 172–73; me-  
dicinal gardens and, 166–67, 170;  
in Native American cultures, 15;  
in traditional medicine, 166
- Hillier, Carly, 169–70
- Hippocratic medicine, 93–94,  
181–82
- HIV, propolis activity against, 142

- honey: antimicrobial chemicals in, 72;  
bees choosing different types of, 72;  
beneficial *Bombella apis* in, 147–48;  
increased by increasing propolis,  
150; not decreased in new hive  
boxes, 151–52
- honey bees: Africanized, 150; agricul-  
tural monocultures and, 138,  
198; antiparasitic behaviors of, 11;  
attacked by mites, 37, 137–38, 146–47;  
food requiring pollination by, 134,  
135, 136; in hollow trees, 138, 143,  
148–49; hygienic behavior in, 98–99,  
100, 139, 142; immune responses of,  
137, 138–39, 145–46, 148; infectious  
diseases in, 136, 137–38; learning in,  
103–4; oral microbiomes of, 147–48,  
158; organized society of, 140; para-  
sites and pathogens of, 137–39, 147;  
planting gardens and, 202; provid-  
ing micronutrients for humans,  
136; recent declines in, 138; as social  
animals, 136–37, 138–39; social dis-  
tancing in mite-infested hives, 37;  
specialized workers for collecting  
resin, 140–41, 141, 146; wild colonies  
of, 138, 143, 148–49. *See also* beekeep-  
ing businesses; honey; propolis
- Hooker, Joseph, 34
- horny goat weed, 173–74
- horses, 37, 169–70
- house finches (*Carpodacus mexicanus*):  
bacterial infection of, 32; using  
cigarette butts, 56
- houseflies, fungal infection of, 39, 40
- house sparrows (*Passer domesticus*), 56
- Hoyt, Murray, 143
- Huffman, Michael A.: Japanese prima-  
tology and, 18–19, 111; on learning  
from nature, 201; on learning  
treatments from animals, 178, 179;  
livestock research learning from,  
123; on methods of leaf swallowing,  
112–14; preparing dictionary for  
WaTongwe, 198; studying chimpan-  
zees, 19–29, 49, 54, 111
- human beings: claimed uniqueness  
of, 13–14, 200; losing health when  
losing honey bees, 136; as member  
of animal family, 200
- human medicine: Ötzi as early evidence  
of, 80; propolis in, 142–43. *See also*  
drugs in human medicine; tradi-  
tional human medicine
- Hunter, Mark, 44–45
- Hurst, Jane, 189
- hyenas, social conformity of, 110
- icariin, 174
- immune responses: diet of insects and,  
92–93; gut microbiome and, 158; of  
honey bees, 137, 138–39, 145–46, 148;  
of infected lambs on high-protein  
diet, 126; of insects, 73; intestinal,  
boosted by tannins, 123; of inverte-  
brates, 36; of livestock, 131; mam-  
malian system of, 36; not defined as  
animal medication, 47; of plants, 36;  
subverted by parasites and patho-  
gens, 38–39; of woolly bear caterpil-  
lars, 78
- impotence, horny goat weed for,  
173–74
- Indigenous people. *See* traditional  
human medicine
- infectious diseases: animal medication  
and, 9; bear medicine for, 16; micro-  
biomes protecting against, 158–59.  
*See also* bacterial infections; fungal  
infections; viral infections

- inflammation: treated with resin by humans, 68; unhealthy lifestyles of pets and, 155; willow bark and, 181; of wounds, 9
- Ingraham, Caroline, 167–69
- innate behavior of animals, 98–103; animal medication and, 95–97, 113, 114, 115, 192; in courtship and mating, 99–102
- insecticides: humans fumigating with, 53; in propolis, 153
- insects: countermeasures to plant defenses, 87–88; declining populations of, 197; immune responses of, 36; as most diverse group of animals, 67; plant defenses against, 85–86, 87; planting gardens and, 202–3; suitability for medication research, 67–68, 72; value to humans and agriculture, 197. *See also* bees; butterflies; caterpillars; pollinators
- invasive species and diseases, 196
- iridoid chemicals, 186–87, 189, 191–92, 193. *See also* nepetalactol
- Japanese monkeys: cultural behavior of, 14; eating antiparasitic plants, 8
- Japanese tit, language of, 13–14
- Jeffreys, Diarmuid, 16–17
- jellyfish, learning in, 104
- Jilba, 24
- Jura Mountains, 68, 69
- Kalunde, Babu, 174
- Kalunde, Mohamedi Seifu, 19–21, 22, 25–26, 29, 49, 111, 174
- kaolinic clay, 157
- kinnikinnick (bearberry), 16
- Knezevich, Mary, 157
- Koshimizu, Koichi, 21, 23
- Kyoto University, 18, 21
- lactating animals, plants used by, 9
- Lactobacillus kunkeei*, in bees' mouths, 148
- lambs. *See* sheep and lambs
- Lame Deer, 15
- languages: of animals, 13–14; of Indigenous peoples, 198
- lawns, 201–2
- leaf swallowing, 26–29, 47, 49; by chimpanzees in captivity, 112, 113; social learning of methods, 112–15
- learning, 103–6; animal medication without use of, 115; associative, 104–8, 114, 121; social, 109–15
- Lefèvre, Thierry, 45
- lemurs: body anointing by, 8; geophagy in, 157; sifaka, pregnant and lactating, 9; toxic millipedes used by, 50–51, 90, 91
- livestock: antibiotic resistance and, 11; antiparasitic drug resistance in, 122–23; diverse pastures for, 130–31, 131; foodscapes for, 131, 166; given drugs for parasites and pathogens, 127, 128, 132; human health linked with diets of, 132–33; learning specific medicines for specific ailments, 126; need to assemble their own diets, 128–30; need to live in social groups, 128–30; reintroducing self-medication to, 65, 130–32; today's uses of medicinal plants in, 125–26; total mixed rations given to, 127, 132. *See also* cattle; dairy cows; goats; horses; sheep and lambs

- Lyell, Charles, 34  
Lyme disease, 169
- Macías García, Constantino, 58–59, 60, 63–66  
magical cone (*Conus magus*), 84  
Mahale Mountains National Park, Tanzania, 19, 22–23, 24, 27, 28, 114  
mahouts, 176–78, 177  
malaria: caused by protozoan, 31; host immunity and, 39, 43. *See also* anti-malarial drugs; mosquitoes  
Maldonado Hernández, Helena, 56, 62  
Maloueki, Ulrich, 184–85  
Mason, J. Russell, 54–55  
mass extinctions, 195–96  
medicinal plants. *See* animal medication; drugs in human medicine; plants  
meerkats, social learning in, 110  
*Metarhizium brunneum*, 70, 71  
mhefu (*Trema orientalis*), 26  
microbiome: of gut, 158–59; in honey bees, 139, 147, 158  
milkweeds: as antiparasitic drug, 4–5, 7, 44–45; bitter taste of, 103; gluing mouthparts of monarch caterpillars, 85; monarch butterflies laying eggs on, 6, 7, 46, 115; as monarchs' specialized diet, 3–4, 43–44, 74; planting in gardens, 203; toxic chemicals in, 4 (*see also* cardenolides). *See also* monarch butterflies  
millipedes, toxic, 50–51, 67, 90, 91  
mites: attacking honey bees, 37, 137–38, 146–47; avoiding smoked cigarette butts, 59; fumigation of bird nests and, 8, 38  
Miyazaki, Masao, 185–94  
mjonso, 20–22, 24. *See also* bitter leaf (*Vernonia amygdalina*)  
Mohamedi. *See* Kalunde, Mohamedi Seifu  
monarch butterflies: caterpillars consumed by fly maggots, 76; caterpillars of, 3–5, 7, 49, 85; experiments on medication by, 42, 45–46; heritable medicating behavior of, 95, 102; innate medicating behavior of, 115; migration of, 2, 3; parasites of, 2–7; reducing likelihood of infection, 47; skeptical peer review and, 45, 97; toxic to predators, 4. *See also* milkweeds  
monkeys: capuchins using toxic millipedes, 48, 50–51, 90; drunken, 10; Japanese, eating antiparasitic plants, 8; macaques eating kaolinic clay, 157  
morphine, 82, 86, 89  
mosquitoes: catnip response and, 189–93; diseases transmitted by, 185; insecticides used against, 53. *See also* malaria  
mosquito-repellent millipedes, 48, 50, 90  
Muganza, Désiré Musuyyu, 184  
mulengelele (*Aeschnomene* sp.), 26  
*Mycobacterium ulcerans*, 168  
*Mycoplasma gallisepticum*, 32
- Native American cultures: bears and, 15–16; herbal medicine in, 166; spiritual connection to animals in, 179  
Natterson-Horowitz, Barbara, 200  
natural selection, 33–36; domestication and, 116–17  
nature, Western loss of connection to, 14, 19

- nausea, associations of, 104, 105–6, 108, 110; of tannins in goats, 120–21; of tannins in sheep, 124–25
- Neanderthals: chemicals on calculus of, 80–81; treating wounds with clay, 168
- neophobia, 107, 108; social learning and, 109, 113, 129
- nepetalactol, 188–93
- nepetalactone, 187, 192
- nicotine, 64, 78, 89
- Nishida, Toshisada, 27
- Nishikawa, Toshio, 187–88
- nitrogen fertilizers, 201–2
- Nosema bombi*, 201
- Nosema ceranae*, 137, 148
- nuclear polyhedrosis virus, 32
- obesity epidemic, 128
- Oesophagostomum stephanostomum*, 23–24, 28
- Ohigashi, Hajime, 21, 23
- Oliver, Lindsay, 45–46
- Ophryocystis elektroscirrha* (OE), 2–5, 7, 44
- opium poppy, 82, 83, 84, 86, 89
- orangutans: massive loss of, 197; social interactions of, 109; treating wounds or body parts, 9
- Origin of Species* (Darwin), 35, 116–17
- Oshá (*Ligusticum porteri*), 16
- Osler, William, 13, 14
- Ötzi the Iceman, 79–80, 84, 90, 171
- oxalic acid, 126
- pain: chemicals alleviating, 82, 84, 89.  
See also opium poppy
- pandemics, 35, 37
- Paracelsus, 94
- parasites and pathogens: in coevolutionary arms race, 38, 41; definitions of, 30–31; Greek word origins for, 30–31; of humans, domesticated animals, and pets, 11; manipulating animal behavior, 10, 39–41, 40, 42, 45, 47; outnumbering free-living organisms, 32. See also defenses against parasites and pathogens
- parasitic worm infections: with barber's pole worm, 124, 125, 126; chimpanzees' treatment of, 7, 8, 20–25, 24, 26, 28; diet of sheep and lambs and, 92, 108, 123–26, 125; with hairworm in crickets, 45; macaques eating kaolinic clay and, 157; with schistosome worms, 8, 32; tannins and, 123–26; with tapeworms, 28, 163; with whipworms in Ötzi the Iceman, 79–80. See also bitter pith sucking; leaf swallowing
- parasitoid flies. See tachinid fly maggots
- parasitoid wasps, of fruit flies, 71–72, 73
- pathogens, 30–31. See also parasites and pathogens
- penicillin, 84, 90
- peroxidases in cotton leaves, 73
- pets: deprived of choices, 154, 155; diverse gardens for, 203–4; giving choices to, 167, 170; herbal medicines for, 166–67; providing medicinal plants for, 202; reintroducing self-medication in, 65–66; retaining ability to medicate themselves, 154; sensory gardens for, 170; unhealthy lifestyles of, 154–55. See also cats; dogs
- pharmaceutical industry: animal-discovered chemicals and, 193–94; drug development by, 11–12, 81–82, 180–82
- Pim, 22

- Piria, Raffaele, 182
- plants: as basic food for organisms, 85; as basis for most drugs, 172; with chemicals affecting parasites and pathogens, 72–73; defenses of, 85–88; evolution of drugs in, 84; immune responses of, 36; loss of medicinal species, 197–98; outnumbered by insect species, 85; recreating diversity of, 201
- Plasmodium*, 31
- pollinator gardens, 199–204
- pollinators: declining populations of, 197; needed for our food, 134, 136; planting gardens and, 202–3; programs to support, 201. *See also* insects
- polyethylene glycol (PEG), 121, 126, 128–29
- polyphenols, 126
- polypore mushrooms, 80, 90, 171
- porcupines, learning from, 25–26
- predators: bird calls warning of, 13–14; toxic chemicals in plants and, 75; toxins as protection from, 90
- pregnant animals, plants used by, 9, 10
- primary chemicals, 86, 92, 119–20, 127
- primates: fermented fruits eaten by, 10; geophagy in, 157; medication used by many species of, 67; plants used by, 184; social conformity and learning in, 109, 111. *See also* bonobos; chimpanzees; gibbons; gorillas; lemurs; monkeys; orangutans
- primatology: in Japan, 18–19; in United States and Europe, 18–19
- programmed cell death, 36
- prophylaxis, 8, 38; demonstrating in animals, 48; malaria in chimpanzees and, 183–84; wood ants using resin as, 145
- propolis: antibacterial properties of, 145; bees collecting resin for, 140–41, 141; as building material, 143, 145; filling tree hollows of wild bees, 148–49; Greek word origin of, 143; harmful idea of feeding it to bees, 153; in human medicine, 142–43, 145; hundreds of plant chemicals in, 148; increased in new hive boxes, 151–52; medical properties of, 143, 145, 153; medicinal for honey bees, 143–48, 152; mixing resins with wax, 139, 140; reintroduced to beekeeping, 150–53; selection for greater production of, 150. *See also* resin
- propolis envelope, 149, 150
- protein, dietary, 92–93; innate responses to, 97; worm infection in lambs and, 125–26
- Provenza, Fred, 118–24, 126–29, 131
- Provenza, Sue, 118
- Pseudomonas fluorescens*, 70
- Pseudomonas luteola*, 70
- pyrrolizidine alkaloids, antiparasitoid, 74, 75–78, 95–97
- Quave, Cassandra, 182–83
- Quechua people, 82, 181
- quinine, 82, 89, 172, 181
- rabies virus, 39
- rats: social conformity of, 109–10; solving infestations of, 107
- Raven, Peter, 88
- reactive oxygen molecules, 72, 89
- Read, Andrew, 43
- Red Queen, 38
- religious rites, plants used for, 175

- resin, 68; fossilized as amber, 139–40; human uses of, 68; medicinal, 139, 149; plants used by bees for collection of, 140–41; reduced amount in commercial colonies, 150; wood ants' use of, 68–71, 69, 72, 145; worker bees specialized in collection of, 140–41, 141, 146. *See also* propolis
- Reyes, Miguel, 56
- rhesus macaques, eating kaolinic clay, 157
- Rodriguez, Eloy, 27
- role models. *See* social learning
- Rosalynn Carter Butterfly Trail, 202–3
- Rothenhuhler, Walter, 98–99
- Rozin, Paul, 106
- sainfoin (*Onobrychis viciifolia*), 201
- salamanders, harboring protective bacteria, 36
- salicylic acid, 16–17, 90, 173, 182
- salt: animals' specific hunger for, 106; mammalian taste of, 102
- Samanat, Asish, 10
- schistosome worms: baboons increasing their resistance to, 8; life cycle of, 32
- Schwartz, Stefanie, 166
- sea slugs, purging parasites, 36
- secondary chemicals of plants, 86–88; benefits for humans and other animals, 88–90; missing from rations for livestock, 127; overcoming aversion to, 108; plants' uses of, 88, 119–20; sometimes killing part of plant, 90
- sensory gardens, 166–67, 170
- Sertüner, Friedrich Wilhelm, 86
- sesquiterpene lactones, 21–22
- shamanism, 14–15, 17
- sheep and lambs: acidosis in, 121–22, 123, 126; antioxidants inducing tolerance in, 47; associative learning in, 121; choosing medicine for specific malady, 126; diet and worm infection in, 92, 108, 123–26, 125; feces avoided when grazing, 37; physiological associations in, 104–5; as social animals, 109, 129; tannin-rich plants consumed by, 123–26, 128–29
- Shinto, 19
- side effects of medicine, 48–49, 77; of tannins and *Vernonia*, 124
- sifaka lemurs, pregnant and lactating, 9
- silver vine, 185–92
- Simone-Finstrom, Mike, 144–47, 150–53
- Singer, Michael, 73–78, 95–96
- Sinya, 167–68
- Siyaka, 15
- skin: as barrier against infection, 36, 38, 47; dark near the equator, 35; staph infections of, 182–83; traditional treatments of, 182–83
- social bonding, in body anointing, 51
- social distancing, 37
- social immunity, 139
- social learning, 109–15
- Spivak, Marla, 138, 141–43, 144, 145–47, 150, 152
- spotted cucumber beetles, 100–101
- squalamine, 90
- Stahl, Christian Ernst, 87–88
- Staphylococcus aureus*, 182–83
- starlings, fumigating nests, 69
- steroid glucosides, 22, 78
- St. Marks National Wildlife Refuge, 1–2, 3
- Stone, Edward, 182
- Suárez Rodríguez, Monserrat, 56–66, 61
- symptoms, and tolerance, 47

- tachinid fly maggots, 75–78, 76
- tannin-rich plants: consumed by  
livestock, 123; consumed by sheep  
and lambs, 123–26, 128–29;  
consumed by sifaka females, 9
- tannins: bound by polyethylene glycol  
(PEG), 121, 126, 128–29; goats’  
aversion to, 120–21; harmful side  
effects of, 123–24
- tapeworm infections, 28, 163
- taste receptors, 96, 106
- taste sensations: animals choosing  
medicinal foods based on, 102–3;  
negative or positive associations of,  
104–5; of woolly bear caterpillars,  
95–97
- Taxol, 82–83, 89–90
- tears of Chios, 68
- teeth, calculus on, 80
- terpenes, 89–90, 126
- tetracycline, 108
- therapeutic medication, 8, 37–38, 48,  
54, 78
- thiamine deficiency, 106–7
- thiarubrine A, 27
- ticks, in bird nests, 8, 63, 66
- Tinbergen, Niko, 99
- tolerance, 47
- tools, made by animals, 13
- toxins: in many forms of animal medi-  
cation, 47, 78; of millipedes, 50–51,  
67, 90, 91; neutralized by clay,  
156–57; as protection from natural  
enemies, 90; of staph, disrupted by  
chestnut chemical, 183
- traditional human medicine: animals  
as source of, 173–78; *Aspilia* used  
in, 27; bears as source of, 15–16, 173;  
catnip in, 186; Chinese, 82, 93, 166,  
171, 174; discovering new drugs based  
on, 182; elephants as source of,  
176–77; food in, 93; healthy diet in,  
48; herbs in, 166; loss of medicinal  
plants for, 197–98; passed orally in  
dying languages, 198; rediscoveries  
of, 18, 25; sacred secrets in, 178–79;  
shamanism and, 14–15; used by  
most people in the world, 172; used  
by pharmaceutical industry, 181–82
- Trichilia rubescens*, 184
- triterpenes, 90
- Uenoyama, Reiko, 185, 188–94
- UNAM (Universidad Nacional  
Autónoma de México), 56–58, 65
- Vackova, Kristina, 30
- Varroa destructor*, 137, 146–47
- venoms, as drug sources, 84
- vernodalinalin, 184
- Vernonia*. See bitter leaf (*Vernonia  
amygdalina*)
- vernonioside B1, 23
- veterinary care: herbal, 166, 175; human  
health relating to, 200; learned from  
observing animals, 175–76, 177
- Villalba, Juan, 123–24, 125, 126, 128–32,  
131, 166
- viral infections: of caterpillars, 32, 73;  
of elephants, 176; of honey bees, 137,  
147; of insects, 4; jumping from  
other species, 35; plants using sali-  
cyclic acid against, 90; with rabies, 39
- Wallace, Alfred Russel, 33–35, 87–88;  
on domestication, 116–18, 122
- WaTongwe healers, 20, 21, 23, 25–26,  
174; Huffman’s dictionary for, 198
- whipworm (*Trichuris trichiura*),  
79–80

- Whiteman, Noah, 84
- Whole Foods Market, 134, 135
- willow bark, 173, 181–82
- wolves: grass consumption by, 163, 165; in Yellowstone, parasites and pathogens of, 32
- wood ants (*Formica paralugubris*): adding formic acid to resin, 72, 192; resins used by, 68–71, 69, 72, 145; small brains of, 7
- wood rat houses, eaten by goats, 129–30
- woolly bear caterpillars: antiparasitoid alkaloids and, 74, 75–78, 95–97; diverse plants eaten by, 73–74; innately medicating without learning, 115; innate taste sensations of, 95–97; killing parasitic fly maggots, 8, 78; small brains of, 7
- worms. *See* parasitic worm infections
- wounds: of baby elephant, 167–68; orangutans using plants for, 9; primates rubbing insects into, 67; treated with clay, 168
- Wrangham, Richard, 27, 28, 29, 113
- Xerces Society, 134
- yarrow (*Achillea millefolium*): as an astringent, 80; tea made from, 16
- zoopharmacognosy, 8–9; applied, 166–67, 169–70
- Zuk, Marlene, 98, 101–2