As Charles Darwin had suspected, earthworms that flee from ground vibrations do so to escape hungry moles—even though sometimes it is humans chasing them.

If you happen to be hiking in the right part of Florida at dawn, you might catch the sound of a predator hidden in the vegetation. Surely an alligator must be the source of these calls, you say to yourself. But the sound does not come from an alligator, or a mother bear, or some newly introduced predator from the Amazon. It comes from a human predator—a “worm grumer.”

Worm grunners have mastered the art of charming worms out of their burrows so they can be collected and sold as bait. First, the hunters pound a stoh, or wooden stake, into the soil, and then they rub the stake with a flat piece of metal called a rooping iron. The vibrations resonate through the ground. In response, hundreds of large earthworms emerge, some as far as 12 meters from the baiter.

Why would earthworms emerge in daylight and expose themselves to a host of potential predators, including baiters? It seems that it would make more sense for earthworms—a top item on the menu of many animals—to go deeper into the ground when they sense vibrations. Until recently, a common explanation among bait collectors held that earthworms interpret vibrations as rain and make haste for the surface to avoid drowning in saturated soil. After all, most of us have seen worms crawl on the pavement after a heavy rain. But I suspected something else was at work.

In the 1800s Charles Darwin heard similar stories in Europe of vibrations driving local earthworms from the ground, and he, too, wondered why the worms emerged. Some observers suggested the worms interpreted vibrations as a sign that hungry moles were after them and that immediate escape was imperative. My own recent studies and experiments put the question to rest and demonstrated in 2008 that the worms’ behavior is indeed a response to moles.

Into the Forest
Darwin thought the mole explanation made sense, as he noted in 1881 in his last book, *The Formation of Vegetable Mould through the Action of Worms with Observation of Their Habits*. But when he tried to coax earthworms from the ground with vibrations, he had little success and thus did not get far investigating this strange behavior. But then, Darwin never met Gary and Audrey Reveil.

The Reveils are among the few professional bait collectors who still make their living by selling worms. Once a year, in April, you can find the couple at the annual worm-grunting festival in Sopchoppy, in Florida’s panhandle. The festival celebrates local history and includes live music, food vendors, worm-grunting T-shirts, and the crowning of a worm-grunting queen.

Worm grunting has been handed down for generations in the southeastern U.S. but seems to have reached its peak in the Apalachicola National Forest—just outside Sopchoppy—in the 1960s and 1970s. When the practice began to attract media attention, the National Forest Service became concerned about possible overharvesting of the large earthworms in the area (*Diplocardia mississippiensis*), and it now requires a yearly permit for worm.
grunting within the forest’s boundaries.

The Apalachicola National Forest was the perfect place to test the “mole hypothesis.” The area’s *Diplocardia* are legendary for their responses to vibrations. Also, many worms found in North America technically are invasive species—introduced from Europe—but *Diplocardia* earthworms are native to the region. This feature means they have coevolved with the local predators, and so their behavior reflects adaptations to their current environment.

I enlisted the Revells’ help to observe the worms’ response to grunting. As Gary worked the stob and iron and as Audrey collected worms, I carefully marked where each worm emerged with a flag. When the last worm was collected, we were astonished to look back and see the number of markers spread out around Gary. Worms had emerged more than 12 meters from Gary’s location.

I also observed the worms after they emerged, and I used geophones (devices for recording ground vibrations) to determine the frequency and magnitude of the vibrations generated by worm grunting at different locations.

The worms came out of the ground fast; if a worm could ever be described as running, I would say this was the time. The rapid early movement was consistent with an escape from an underground danger, followed by a more leisurely pace as they searched for a new place to burrow into the ground several meters away.

After about 10 minutes of crawling, the
worms began the laborious task of burrowing back into the soil, an endeavor that could take anywhere from 10 minutes to more than an hour. The vast majority made it back unharmed. But some were attacked by ants, some were eaten by snakes, lizards or carnivorous beetles, and a few that emerged in hot, dry weather simply died from desiccation. It was clear that surfacing exacts a cost from the animals and, therefore, that they presumably have a compelling reason to do so.

To test the worm-mole connection more directly, I needed first of all to check that the worms actually are at risk of running into a mole—in this case, an eastern American mole (Scalopus aquaticus), the only one that lives in the Florida panhandle. The answer was clear as soon as I arrived at the Apalachicola National Forest: I had not set foot out of my car before I saw the signs of mole tunnels—raised ridges of dirt—crossing the forest’s unpaved roads. After driving around for a few days, I marked 39 such road crossings by moles and caught several by waiting for them to make repairs where cars had crushed their tunnels flat. Many of these roads had daily traffic and hard-packed soil, where digging takes considerable effort. But the moles will do all they can to avoid coming out and exposing themselves to danger. Thus, an earthworm that has exited to the soil surface is safe from a nearby foraging mole.

**Undercover Predator**

I now needed a more quantitative way to measure the overlap between mole and worm habitat. Gary Revell and I turned out that bait collectors leave stub holes behind throughout the forest. By locating these holes and measuring the distance to the nearest mole tunnels, I could get a good idea of mole-earthworm interactions—and thus of mole-earthworm overlap. I checked eight different earthworm-grunting sites and found mole tunnels at every one. The average distance from a stub hole to a mole tunnel was only 20 meters, much shorter than I expected. It turns out the Apalachicola National Forest is full of moles.

How many worms might these moles eat? A single mole I captured in the Apalachicola National Forest ate the equivalent of its body weight in Diplocardia (40 grams, or about 20 worms) every day for two weeks. Thus, when given a chance, a mole will eat as much as 15 kilograms of worms a year, or perhaps 7,000 full-size worms. Clearly, earthworms have a strong reason to avoid moles at all costs. Things were looking interesting for Darwin’s idea.

If worm grunters are imitating moles, then presumably a digging mole should create soil vibrations similar to a worm grunter’s. I was not lucky enough to happen on an eastern mole actively foraging in the Apalachicola National Forest. But eastern moles are also found near my home, in Tennessee. With some patience,
EASTERN AMERICAN mole (*Scalopus aquaticus*) has forelimbs adapted for efficient digging. As it excavates tunnels, it creates vibrations that alert the *Diplocardia* earthworm to its presence. The worms attempt to escape this predator by coming to the surface. But sometimes it is other predators—including bait collectors but also animals such as wood turtles or herring gulls—that mimic the moles’ vibrations to fool the worms into coming out.

geophones and a laptop computer, I was able to record quite a lot of digging from a number of wild, foraging moles and film them as they wreaked havoc on the soil. The moles’ vibrations—mainly created as their powerful forelimbs broke networks of grass roots—were actually audible as I stood several meters away. The recordings revealed a peak in the strength of the vibrations at frequencies that overlapped substantially with those made by the worm grunter (between 80 and 200 hertz).

**Full Worm Speed**

With all these observations in mind, I built meter-wide soil-filled arenas where I could observe, videotape and quantify the mole-earthworm interactions. But before starting these experiments, the Revells and I performed a simpler test. We happened to have a dirt-filled bucket containing dozens of worms, and I had a recently captured mole. We could not resist putting the two together to see what happened. The mole dug down into the dirt, and within seconds the earthworms came streaming out.

Reactions in the larger, earth-filled arenas were equally dramatic. As the moles dug tunnels in various directions, the worms came spilling out of the soil in an apparent panic. In this much more natural setting, it was clear the worms were escaping from a feared predator as they came out at full (worm) speed. In separate experiments in smaller arenas rigged with speakers, the worms also fled from just the sound of a foraging mole played into the soil. The results made it quite clear: *Diplocardia* earthworms live in fear of moles and flee above ground at their approach. And apparently, to an earthworm in the Apalachicola National Forest, a worm grunter sounds like the mother of all moles.

Could the worms have evolved to escape from the ground when they feel raindrops falling? I tested that alternative explanation with several experiments. The most direct one was to simply wait for thunderstorms with heavy rain and observe the earthworms’ response in outdoor arenas. In these cases, only two or three out of 300 earthworms surfaced after about half an hour. This observation fit well with a few previous studies, which found a slow surfacing response after many hours in saturated soil. Worms do not bolt from their burrows in the first minutes of a storm, as one would expect if the response were cued by the rain’s vibrations and as occurs during worm grunting—and mole foraging!

So it seems that Darwin was right all along. Worm grunters take advantage of what evolutionary biologist Richard Dawkins has termed the “rare enemy effect.” In this scenario, a predator catches its prey by exploiting a response that is usually a good strategy. Because moles are on the hunt day and night, all year long, it makes sense for a worm to flee to the surface when it detects a molelike vibration; the unlucky ones end up on a fishhook—or, sometimes, in the stomach of some other cunning predator. In fact, Dutch biologist and Nobel laureate Nikolaas Tinbergen had previously noted that herring gulls “paddle” the ground to bring up worms. Later, in the mid-1980s, John H. Kaufmann of the University of Florida described how wood turtles stomp on the ground to drive up worms for an easy dinner. Both these investigators concluded that the vibrations were mimicking moles. Kaufmann, a Florida native, even suggested that wood turtles were “grunting” for worms. The idea, though, had never been formally tested, until now.

As I packed up my equipment to leave from my last field trip to Florida, the Revells presented me with a rooping iron that had been in their family for decades. To me, it was a great honor. As I drove out of the forest, I stopped to feed a mole I had collected earlier in the day. I walked into the forest and tried my hand at worm grunting to get the mole some dinner. My new iron worked like a charm, and soon I had more than enough wriggling mole food. I also realized the bitter irony for those unlucky worms. They had fled from my imitation of a mole only to end up as dinner for the real thing.

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