fine details," which are critically important to understanding the materials' true structures, Widom says. "You can know where 90 percent of the atoms are, but still not really know the structure because a minority of the atoms are doing interesting and crucial things. . . . What [Hovmöller and Linus] give us is a good starting point for future structure refinement."

But if someone eventually solves the true structure of the Al-Co-Ni quasicrystal or its approximants, it won't be Linus. "He's refused" to work on the remaining structures, Hovmöller says with a laugh. "He's still a little bit tired" from the last bout of structure solving. —Jef Akst

Home Cookin'

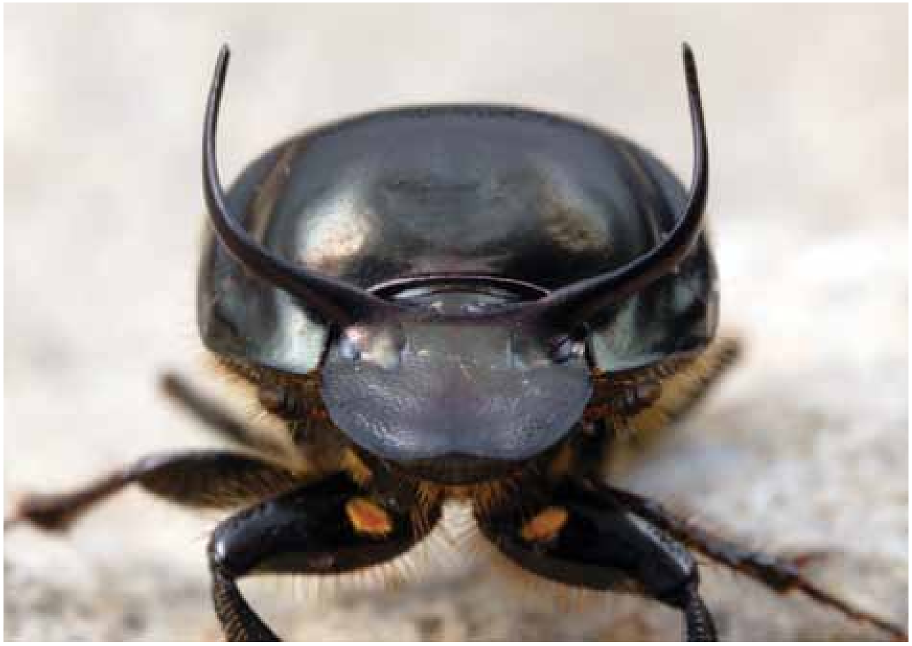
There's more than one way to catch a dung beetle. You can shovel dung pads into buckets with holes in the bottom and wait for the beetles to burrow their way through the fragrant pie, collecting them as they drop through the holes. Or you can simply dig through fresh piles of manure, picking out any beetles going about their business. "We do that with gloves, but it still stinks a lot," says entomologist Bruno Buzatto of the University of Western Australia. "But you learn to ignore that."

The malodorous method yields Buzatto and his colleagues 400 or 500 *Onthophagus taurus* dung beetles a day, plenty for breeding in his lab to study dimorphism: the divergence of male adult beetles into two possible forms. *O. taurus* is the strongest beetle in the world, with some males capable of pulling 1,141 times their own body weight. These brawny males are of two physical varieties, or morphs: "majors," who guard their females by fighting off rival males, and "minors," who secure mates on the sly.

While dung beetles are typically imagined as stocky black bugs rolling their unusual food source—balls of excrement—across the ground, *O. taurus* instead buries dung where it finds it and builds elaborate tunnel systems around it. When a major is threatened in one of his tunnels, he locks horns with the intruding male and they push until one budges. While bigger horns are advantageous in these situations, there is some benefit to avoiding battle altogether and using the sneaky strategy of a minor instead.

O. taurus is native to Europe, but has been introduced to North America and Australia, where the two morphs exist in different proportions. In Australia, where

ONE HORNY BEETLE: This male *Onthophagus taurus* dung beetle is a major, as his impressive horns attest.



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Buzatto collects beetles, populations are much denser than in America, and minors are much more prevalent. But some researchers have suggested that increased population density causes majors to grow larger horns, so that those who do compete have a better chance at succeeding.

To test these hypotheses, Buzatto and colleagues bred generations of *O. taurus* in their lab in varying population densities. They found that increased population pressure does increase average horn size in majors, but doesn't increase the proportion of minors. But the effect didn't seem to hinge on the population density experienced by the adult males. Rather, it was the beetle mothers' responses to differing population conditions that appeared to determine how big their sons' horns would eventually grow.

"Adult insects don't molt anymore, so they can't grow. Once a beetle is an adult, it's going to be that shape, that size, until it dies," says Buzatto. "During the juvenile stage, it's all the time inside a ball of dung under the ground, so it cannot actually perceive the population."

Buzatto's study showed that increases in male horn size are due to so-called "maternal effects." Maternal effects, observed in a few other insect species, involve mothers influencing the phenotype of their offspring beyond genetic inheritance. As a mother beetle senses the conditions her developing offspring will eventually face, she shapes his phenotype, typically by supplying mRNA, proteins, or other resources to the egg. The roughly equal proportion of minors and majors, but longer-horned majors, suggests that mothers focus resources on making stronger sons rather than a greater number of the weaker type.

Buzatto says he isn't sure yet exactly how the mothers exert their influence. Mother dung beetles form "brood masses" of dung, in which they lay one egg. The brood mass has enough dung for the larval beetle to feed on until it reaches maturity as its designated morph. Small brood masses make minors, bigger masses make majors. The beetles in Buzatto's study were given ample dung, so they could essentially choose whether to make majors or more minors.

The mothers with free access to dung didn't change the proportion of majors to minors, nor did they produce brood masses that were any bigger than those of average majors when they spawned majors with longer horns. Something more than dung must be at play, and Buzatto suspects it's one of the other ingredients the mother adds when solidifying the mass, such as the saliva she adds to ward off fungal infection. Proteins or hormones could also be the cause, as could the composition of the actual egg, Buzatto says.

Armin Moczek of Indiana University uses beetles of the genus *Onthophagus* to study phenotypic evolution, and thinks there are a few novel ways the mothers could be transmitting their developmental signals. Within the dung mass, the egg is placed on a pedestal of mom's own excrement, and that is the first thing the hatching larva eats. "That could be a good vehicle in my mind for some information transfer," Moczek says, adding that there is good evidence that beetles get the gut fauna they'll need to digest future dung meals from that pedestal.

The kinds of behaviors and morphological diversity and patterns we see in these dung beetles are not something weird and unusual. They are representative of what we see in a wide range of organisms—insects and beyond.

—Armin Moczek, Indiana University

The discovery of a maternal effect on dung beetle morphology is exciting, and resembles phenomena uncovered elsewhere in biology, says Moczek. "[*O. taurus*] are the size of a coffee bean, with a brain to match, but they behave in ways that are pretty neat," he says. "The kinds of behaviors and morphological diversity and patterns we see in them are not something weird and unusual. They are representative of what we see in a wide range of organisms—insects and beyond."

—Hayley Dunning