More Fun Than Fun: Dung Beetles, the Milky Way and the Marvels of Animal Navigation

30/09/2020

Photo: Arthur Chapman/Flickr, CC BY-NC-SA 2.0.

RAGHAVENDRA GADAGKAR

This article is part of the 'More Fun Than Fun' column by Prof Raghavendra Gadagkar. He will explore interesting research papers or books and, while placing them in context, make them accessible to a wide readership.

Nothing is wasted in nature, not even poop. The faecal matter produced by all the planet's animals put together is an enormous resource that makes life possible for innumerable other creatures. Many species depend entirely on this one resource for their sustenance.

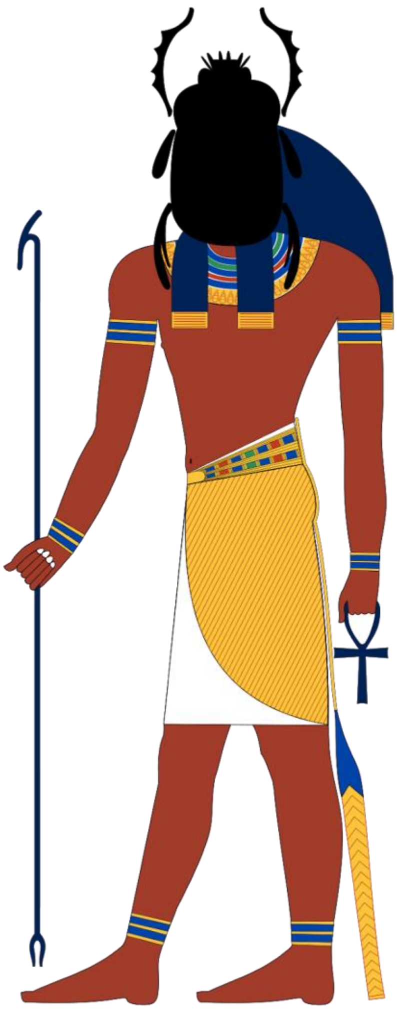
Perhaps the most famous poop lovers are the dung beetles – some 6,000 species. Most dung beetles dig a tunnel from their nest to piles of dung, travel back-and-forth underground, and use the dung as food for themselves and their young. Some of them inhabit dung wherever they find it. Some make impressive round balls of the dung and roll it back to their nests.

It is these ball-rollers that have caught the imagination of people throughout history. Their conspicuous above-ground activity, impressive skills at making dung-balls and even more impressive art of rolling balls larger than themselves across long distances (by beetle standards) probably account for their popularity. I can testify from personal experience that it is impossible not to be spell-bound when watching them work.


A flattened giant dung beetle (Pachylomerus femoralis) rolling a ball of elephant dung. Photo: berniedup/Flickr, CC BY-SA 2.0

Nevertheless, I must confess my amazement that this has been sufficient for so many people to have overcome their innate disgust with poop, in any size, shape, colour or context. People haven’t just admired dung beetles; they have equated them with the gods! Dung beetles inhabit the mythologies, especially the creation myths of many cultures, including the Bushongo people of Congo, the chaca Indians of Columbia, Indian tribes of Bolivia, the Toba of Sumatra, the Taoist texts of China and the Greek world of Zeus and Olympus.

However, it is in Egyptian mythology that dung beetles have pride of place, being associated with the phenomena of birth, death and rebirth, the power of the sun and were worshipped as a deity and prominently placed in tombs and coffins.



Khepri, the Sun god of ancient Egypt. Photo: Jeff Dahl/Wikimedia Commons, CC BY-SA 4.0

Marcus Byrne, a professor in the School of Animal, Plant and Environmental Science at the University of the Witwatersrand, Johannesburg, who has studied dung beetles for many years, recently teamed up with Helen Lunn, who has a PhD in musicology, to write the fascinating book *Dance of the Dung Beetles* (2019). Bruce Beasley, a professor of English, Western Washington University, has rightly called it "a brilliant and funny tour through mythology, evolution and the day-to-day innovations of scientific research". The continuity of our engagement with dung beetles from antiquity to the present day, from mythology to science, is best captured in the book with the following words:

> "The ascendancy of the dung beetle in our collective knowledge mirrors the development of science during the past five centuries: how it moved from being a quest by individuals trying to substantiate the biblical version of creation, to a pastime of well-heeled gentlemen in solitary pursuit of knowledge, to the dazzling but modest brilliance of Charles Darwin, and on to a collective of scientists engaging with increasing volumes of detailed data on animal and entomological development and behaviour…
>
> We have gone from myth, symbols, vague observation and interpretation of a world run by the gods, to a world with one God, and then to a world in which the boundaries of religion no longer act as the limit to knowledge."

Byrne and his colleagues have focused their studies on some dung beetle species of the genera *Scarabaeus* and *Kheper* (the latter is named after the Egyptian sun god, himself named after the dung beetle).

Insects have remarkable abilities to navigate in two- or three-dimensional space. In doing so, they have to solve many perceptual and computational problems. How they accomplish these feats with their tiny brains is a source of infinite wonder. An insect that has at least a semi-permanent home must go out looking for food and return to the point of origin. Often its outbound flight is a meandering path in search of unknown locations of food. But its return path is almost always the shortest straight line from the source of food to the nest.

There is an ongoing debate about whether insects have a cognitive map of their surroundings in their brains. Be that as it may, it is well-known that they can learn and often make special 'learning' flights or walks, to memorise landmark cues – prominent sights and smells in their habitats. Those of us attempting to understand how insects solve problems know that they have many tricks up their sleeves – multiple ways of solving the same problems, multiple backup systems. When denied access to landmark cues, for example, insects can still return home with relative ease.

Their backup system here is even more impressive. They use a method we call 'path integration' and which mariners call 'dead reckoning'. It requires that the insects – incredibly enough – must somehow keep track of every turn they have made and the distance they travelled in a straight line before the next turn. Then, using some equivalent of trigonometry, they must compute the shortest return path. It turns out that rather than wait until the end of the outbound journey, they continuously make these 'computations' so that, at any given time, they have knowledge telling them how to get home in a straight line.

We are hardly in a position to even begin to contemplate how they do trigonometry – but we do have an impressive understanding of how they measure the distances and angles of their motion. They measure distance by measuring optic flow, or image motion, on their eyes, much as Sherlock Holmes used the passage of telegraph poles from the window of his train to compute the speed with which he and Watson were heading toward Exeter, in *Silver Blaze* (1892).

Mandyam Srinivasan and his colleagues at the Australian National University proved this using an elegant experiment. They made honey bees fly inside a narrow tunnel and thereby increased their optic flow. Sure enough, the bees overestimated the distance they had flown. In the absence of visual cues to measure image motion, such as in a visually uniform desert landscape, ants measure distance by counting their steps.

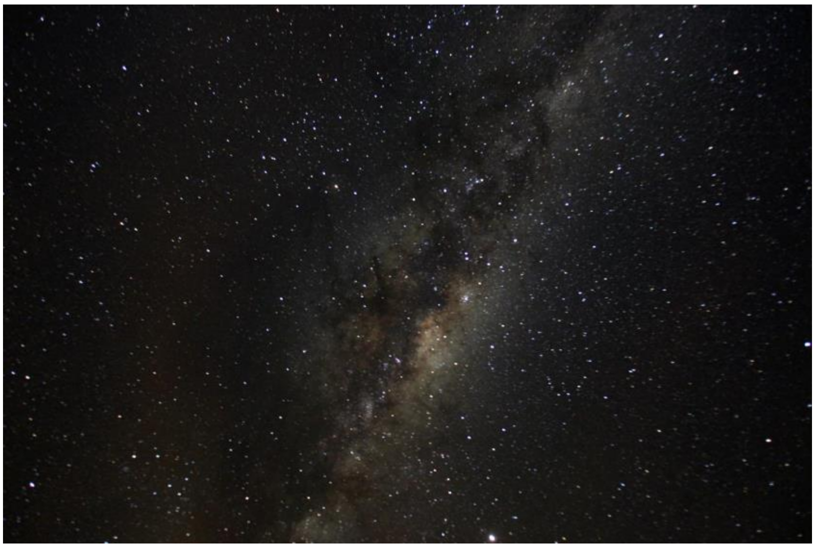
Ruediger Wehner and his colleagues of the University of Zurich proved this using an equally elegant experiment: they made ants walk on stilts or stumps. Just as sure enough, the ants under- or over-estimated the distance they had walked, as expected.

Insects are also known to estimate the angles of their turns by using celestial cues, the Sun or the Moon; if these objects are not visible, they can infer the position of the Sun or the Moon using knowledge of which way light is polarised in the sky.

While it is a remarkable feat, path integration is also prone to errors and doesn't by itself account for the navigational accuracy that insects achieve. Instead, insects have been known to supplement path integration with landmark cues, but can rely solely on either in an emergency.

Experimenting with a nocturnal dung beetle, Byrne and his colleagues found that they used the Moon to orient themselves. The researchers were perplexed, however, to see that the beetles had little difficulty even when the Moon was absent. They could not have resorted to using terrestrial landmarks as bees do on a cloudy day, as it was too dark. So the researchers proposed – and proved – a bold hypothesis: that on a moonless night, their dung beetles used the stars in the sky as their celestial cues. Their experiments were as newsworthy as their result.

First, they put little caps on the heads of the beetles in the field and showed that they were lost when they could not see the sky. They then conducted experiments with dung beetles in the Johannesburg planetarium, controlling their access to different parts of the night sky. Believe it or not, the dung beetles used the Milky Way, no less, as a guide.

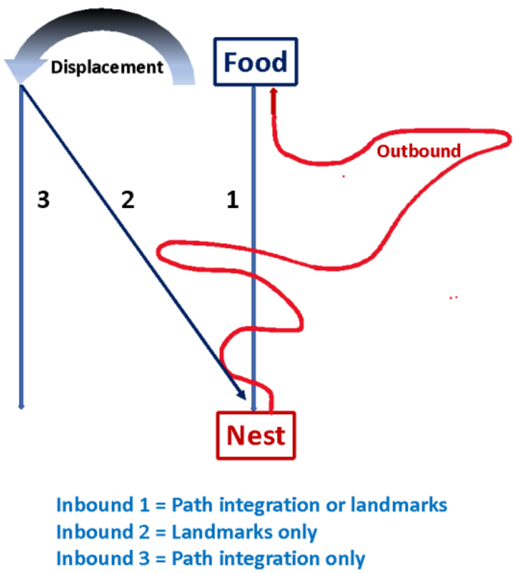


A view of the Milky Way from an area of Puyehue National Park near Osorno City, Chile.
Photo: Reuters/Ivan Alvarado

In another experiment, the group studied a dung beetle that made repeated trips between its nest and a patch of dung, bringing small quantities of dung at a time. This beetle faced a peculiar problem. While some dung beetles walk towards their nest dragging the dung ball with their hind legs, this one walked backwards with its front and middle legs on the ground, and its hind legs pushing the dung ball. This dung beetle therefore had an added difficulty – that it was facing away from the nest both while walking from the nest to the food and while walking from the food to the nest.

Ants sometimes have to walk backwards when transporting large cargo. Rather cleverly, they stop from time to time, turn towards home, take a good look at the landscape, and then resume their backward walk.

Byrne & co. conducted a series of experiments with the dung beetle that walked backwards. They displaced beetles that were ready to return home and found that they always got lost, using path integration to walk to the correct distance but in the direction that would have been correct had they not been displaced. So they relied only on path integration and couldn't use landmark cues. I wonder whether landmark cues would be very confusing if you were looking from the opposite direction.



Schematic representation of the experiment used to distinguish between path integration and use of landmarks. Image: Raghavendra Gadagkar (based on Marcus Byrne's talk)

In their book, Lunn and Byrne write, "In the summer of 2009, one of us, at least, was having fun. He was in the bush with his friends, playing with dung beetles. These friends, a group of scientists from Sweden, Australia, Germany and South Africa, have managed to get together every year since 2003."

With a little stretch, we can perhaps imagine that the dung beetles may also be having fun – rolling balls of dung over the uneven African terrain. The beauty of the experiments we have been discussing is that they can be performed by almost anybody armed with curiosity and a craving for adventure. That is what makes science more fun than fun. But in order to continue to have fun, we must learn to co-exist with dung beetles – and other creatures with which we share the planet.

Raghavendra Gadagkar is a Department of Science and Technology (DST) Year of Science Chair Professor at the Centre for Ecological Sciences at the Indian Institute of Science, Bengaluru.

Gadagkar, R., 2020. More Fun Than Fun: Dung Beetles, the Milky Way and the Marvels of Animal Navigation. The Wire Science. URL https://science.thewire.in/the-sciences/dung-beetles-path-integration-milky-way-animal-navigation/