Outsmarted by ants

An elegant orientation solution that is used by ants to get back to their nest eluded even Richard Feynman, suggesting that social insects could help to solve many of our engineering problems.

Francis Ratnieks

Richard Feynman, the Nobel prizewinning physicist who died in 1988, was smart. *Omni* magazine once declared him "The smartest man in the world". But clever as he was, Feynman was outwitted by an ant, or rather by a colony of ants.

How could ants outsmart one of the twentieth century's leading theoretical physicists? When the physicist plays ants at their own game — trying to understand a problem fundamental to colony survival that ants have been working on, by means of natural selection, for millions of years — ants can come out ahead.

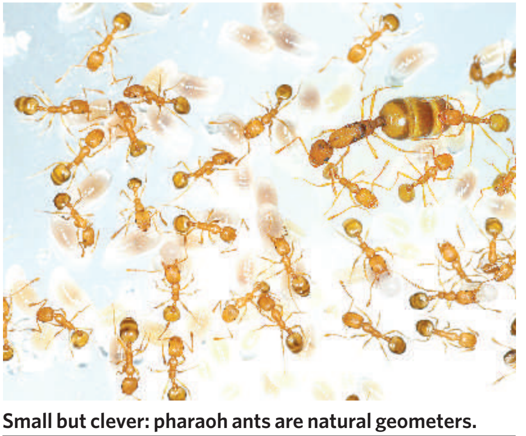
Feynman was well known for his curiosity and practical approach. During the space shuttle Challenger enquiry he famously dunked pieces of rubber o-ring from the shuttle's booster rockets into iced water to demonstrate that the material lost its elasticity at low temperatures, and so failed during a cold-weather launch. Many years before this, while a PhD student at Princeton University, the same qualities had led him to think about ants — ants which had entered his imagination by inviting themselves into his room and even raiding his larder.

At Princeton, Feynman "got curious as to how they [ants] found things. How do they know where to go? Can they tell each other where food is, like bees can? Do they have any sense of geometry?"

All these questions are at the heart of ant foraging biology. Natural selection will make foragers good at going to where the food is. It will also favour ants that help nestmates forage more effectively, for example, by laying chemical trails to guide each other to the food. And a sense of geometry will be favoured, provided there is some workable mechanism, if it boosts foraging efficiency.

Feynman's experiments with sugar baits, which involved ferrying individual ants from place to place on small pieces of paper, told him that ants help each other and that they can learn where to go to get food. But his studies on geometry gave conflicting results. He found that the Princeton ants apparently could not tell whether they were walking the wrong way along a trail, but he later found that Brazilian leafcutter ants could. He suggested that Brazilian ants did this using a series of chemicals that polarized the trail. Thus, a trail marked A-B-space-A-B-space is polarized because it reads differently backwards. But a trail with a single chemical A-space-A-space reads the same in both directions. Further experiments at his home in California left the geometry question unresolved: "The ants look as if they have a good sense of geometry. Yet the experiments that I did to try to demonstrate their sense of geometry didn't work".

There are probably 20,000 ant species and they do not all use the same navigational methods or have equal navigational abilities. Many can reorient on trails by using external cues, including landmarks and the position of the sun. Leafcutter ants are even thought to use the Earth's magnetic field. But recent research has shown that one common ant, the pharaoh's ant, *Monomorium pharaonis*, does have a sense of geometry, and other species probably do as well.



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Small but clever: pharaoh ants are natural geometers.

A pharaoh's ant colony forms a foraging-trail network leading from the nest entrance into the surrounding environment. These trails form Y-shaped branches with an internal angle of approximately 60 degrees as they lead away from the entrance. Ants walking the wrong way along a trail are unable to reorient at a trail bifurcation if the angle is 120 degrees. But if the angle is less, then they can. Angles less than 120 degrees give the 'Y' bifurcation a nest–environment polarity, whereas at 120 degrees there is only symmetry. The ability to reorient is maximized at the natural bifurcation angle of 60 degrees.

It is not surprising that Feynman's hypothesized A-B-space polarity mechanism is not used: it is impractical. With hundreds or thousands of ants walking along a trail it would be virtually impossible not to blur the all-important positions of the two different chemical markers and the space marker as ants reinforced the trail by applying more pheromone. What is perhaps more surprising is the unexpected and elegant solution that pharaoh's ants actually use.

Are there any general lessons to take from this? One is that Feynman's research strategy of using whatever ants were around was not ideal for doing biology. But then biologists are probably more used to diversity than are physicists.

The main lesson, however, is one that we have yet to grasp: that we can learn from ants. Natural selection has made insect societies good at solving a problem that is simple to state but hard to solve — to send foragers to where the food is. Because social insects have been solving this complex dynamic problem for millions of years, they have probably evolved some simple and elegant solutions. We should care about these solutions because human life depends more and more on engineering systems that must solve similar problems to function efficiently — electronic messaging, grid computing, transmitting electricity and traffic regulation to name a few. One obvious lesson we might learn is how to make our systems more reliable and robust. If there is one thing that natural selection should be good at, it is eliminating solutions that are not robust. The colony or organism that 'crashes' will soon be a dead one.

If Feynman were alive today he would surely be smart enough to realize that it is no disgrace to be outsmarted by ants. But are we smart enough to learn from them? ■

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FURTHER READING

Feynman, R. P. *Don't You Have Time To Think?* (ed. Feynman, M.) (Allen Lane, 2005).
Feynman, R. P. *Surely you're joking, Mr. Feynman!* (Norton, New York, 1985).
Jackson, D. E., Holcombe, M., Ratnieks, F. L. W. *Nature* **432,** 907–909 (2004).

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