Wings make room for muscle

The worker ant has evolved to become the weightlifting champion of the natural world

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The flightless ant is a unique evolutionary adaptation of giving up one faculty to enable another one.

The ant belongs to the insect order, *Hymenoptera*, a word built of the Greek *hymen* or membrane, and *pteron* or wing. And indeed, most of the members of the order, bees and wasps, have translucent wings. Honey bees, some wasps, and ants, which evolved from a line of wasps, are *eusocial* insects, or insects that collect food at a central place, with a large number of female workers acting in collaboration, for the benefit of the swarm, and the queen and male members.

The ant, however, stands out, in that the female ant has no wings. But then, the female ant has phenomenal strength to lift and carry food or prey over a distance, or to scamper for cover if there is danger. Christian Peeters, Roberto A Keller, Adam Khalife, Georg Fischer, Julian Katzke, Alexander Blanke and Evan P Economo, from Sorbonne, Universities of Lisbon and Cologne and the Okinawa Institute of Science and Technology, Japan, write in the journal, *Frontiers in Zoology*, a study of how the worker ant is different from the queen and males, who stay in the nest. They document how the body structure of the worker has evolved, to use the space that is freed by not having wings, to accommodate powerful muscles for other purposes.

The differentiating feature of *Hymenoptera* is the method of reproduction. Among ants, it is the queen that lays eggs, and the eggs may be fertilised or unfertilised. The fertilised eggs, which have two chromosomes, develop into the female, worker ants. The unfertilised eggs, with a single chromosome, turn into males. It would appear odd that the females yield their interest of propagating themselves to the queen to do all the reproducing. But it turns out that as females are borne of a union where the mother makes twice the genetic contribution that the father makes, the sisters share three-quarters of the genes, in place of only half that would be carried forward if they mated in the normal way.

The way of cooperative reproduction thus seems to mirror the legendary cooperation that ants show in the way they work for the colony and nest. We see that evolution, which functions not at the level of the workers, but of the queen, has acted not on the queens, but on worker ants to make them more efficient. This showcases how natural selection can bring about genetic modification by affecting the fitness, not of the one that procreates, but of the genetically passive collaborator.

Peeters and his colleagues write that the success of ants as one of the most abundant animal groups, is generally explained as the result of how ants share the load and act in cohesion while foraging and within the nest. "However, the principal innovation of ants relative to their wasp ancestors was the evolution of a new physical form – a wingless worker caste optimised for ground labour," they say in the paper. "Ant reproductives (queens and males) need to fly when they are young, but workers are freed from the need to find mates and disperse. Instead, ant workers are famous for their abilities to lift and carry objects, suggesting adaptations for enhanced foraging on six legs," the paper says.

In the body of the winged ants, the queen and drones, the paper says, the thorax, or the portion between the neck and abdomen, bears the wings and the legs, and supports the head and abdomen. The thorax is thus subject to conflicting forces. In the case of the wingless worker ant, the load of the wings is no longer carried. There is hence a change in the sizes of the back and front of the thorax -- the flight muscles are eliminated, and the neck muscles become bulkier. These features have been studied since over a century but what effect elimination of the wings has had on the shape and structure of the ant frame has not been investigated, the paper says.

The current study considered two species of ants, one where the workers are not widely separated from the queens, and likely to represent the ancestral condition, and the other, where there is pronounced difference. Unlike past studies, the current work had a sensitive apparatus and micro-CT scans were carried out using a 3D X-ray microscope.

The results of the study identified five major changes in the worker thorax, involving the skeleton, muscles of the neck, legs and connection to the abdomen. Taken together, these changes "represent the evolution of an enhanced power core for more effective foraging on six legs," the paper says.

"The thorax of a winged insect is essentially a flying engine with powerful wing muscles," which occupy 41 and 52 per cent of the thorax, in the two species studied, the paper says. In worker ants, there are no wings. Bony supports for wings can hence fuse into a rigid structure. The thoracic cavity has depressions to connect muscles that move the legs – a feature that is markedly different from what is there in the queen ant.

The paper then describes several other areas where the worker ant has evolved for strong and rapid muscle movement on the ground. "The queens and workers in two distant sub-families reveals that the evolutionary loss of the flying engine typical of insects allowed for a remodelling of the thoracic skeleton and associated muscles to power earthbound activities," the paper says, "All worker castes in *Hymenoptera* evolved specialisations for tasks complementary to the queen caste, but the chasm is much less dramatic in social bees and wasps, because the workers need to fly. Our insights in the adaptations of a thorax rearranged for strength on six legs reveal that ants maximised the merits of having queen and worker castes, allowing for much greater divergence in body size compared to social bees and wasps."

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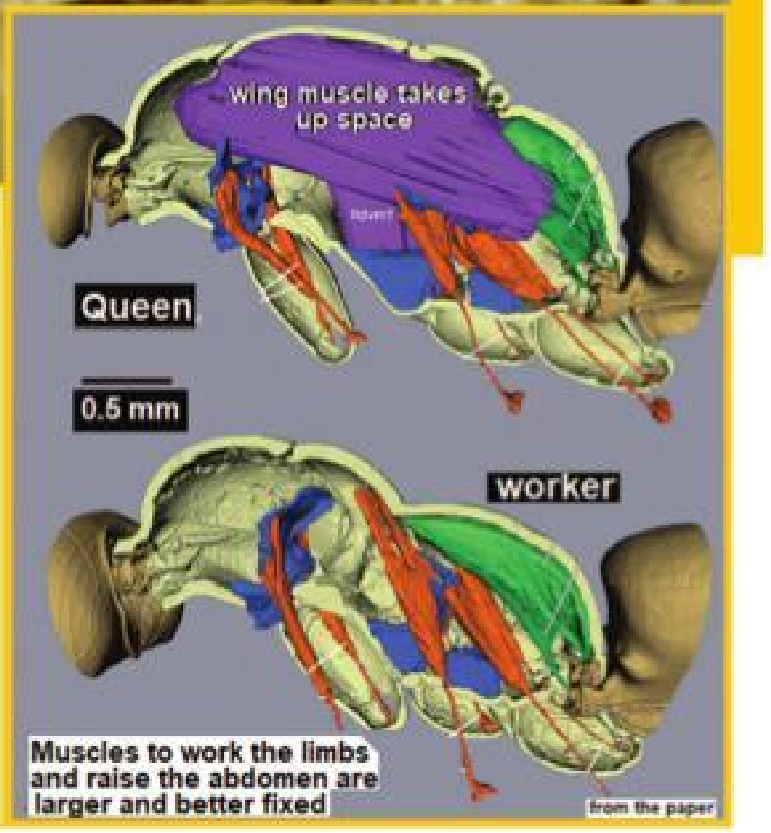
ANT FACTS

- Ants can carry a burden more than 50 times their own weight.
- They communicate, the presence or the way to food or danger, by chemical signals.
- There are more than 10,000 known species of ants.
- It is estimated that there are more than 10 quadrillion (ten thousand million million) ants alive at any moment.



PLASTIC, PLASTIC EVERYWHERE

It breaks down into tiny particles, clogging not only the ocean but also the air we breathe

STEVE ALLEN & DEONIE ALLEN

The rise in the use of plastics has created a substantial increase in plastic waste. Of the 8.4 billion tonnes of plastic produced since the 1950s, around 6.3 billion tonnes have already become waste. With only nine per cent of plastic waste having been recycled, it raises the question – where did it all go?

Unfortunately, much of this waste is finding its way into the environment where it breaks down into very small particles – and there are frightening amounts of it. We do not yet know the full implications of that, but we do know small particles of anything can be harmful to human and ecosystem health. Such environmental plastic not only contains many harmful chemicals, it also picks up anything it comes in contact with such as DDT, heavy metals, mercury and many other pollutants.

As keen paraglider pilots and offshore sailors, we spend a lot of time in places that should be pristine. But having witnessed plastic litter in the middle of the Pacific Ocean, 1,500 nautical miles from land and in the air when flying, we could see that plastic was becoming a problem. Being pilots, we have a good understanding of weather and how air moves. We thought that if plastic pollution is in the air in cities, it is very likely that it will be blown to other areas.

So, we began our research into microplastic pollution in the French Pyrenees, choosing a sampling site as far away from towns and cities as possible. We used an existing weather station that was already catching rain and snow for mercury and other chemical pollutant research.

During the sampling period, the area, 1,400 metres above sea level, was uninhabited and blanketed in snow. It should have been pristine. The rain and snow samples we captured were filtered, leaving just the solid material, which was rinsed off into test tubes with mild acid to remove any organic material.

We then took our samples to the lab in the University of Strathclyde in Scotland. There we used a technique called Raman spectroscopy, named after Indian Nobel Laureate CV Raman, to identify any plastic particles.

We fully expected to find microplastics in our samples but being more than 100 kms away from any towns, which we thought might be a source, we did not expect to find much – an average of 365 particles, per square metre, per day. It was our first proof of atmospheric transport of microplastic. The next logical objective was to look at where it was coming from.

Recent research has shown that up to 30 million metric tonnes of plastic is entering the oceans via rivers each year. We should naturally be concerned with what effect that will have on marine life which we rely on for our food but also our oxygen production.

The ocean has traditionally been seen as a resting place for plastic pollution. Once it goes in, it was thought that it would stay trapped in the ocean currents or sink into the ocean's bottom. However, the ocean ejects seven giga tonnes of material each year in the form of salt and algae, so we decided to research whether plastic could also be ejected into the atmosphere through a mechanism known as "bubble burst ejection".

"Bubble burst ejection" has been well studied since about the 1980s and is known to eject a great deal of material. When a wave breaks, it pushes air into the water. The air forms bubbles and rises to the surface. As it does so it collects hydrophobic material on its surface. Once the bubble reaches air, it shatters ejecting nano-sized spray. That still leaves a hollow in the water, which fills rapidly. When the sides come together, it forms a jet of water, which ejects micro-sized matter up to 30 cm into the air where the wind can pick up the material along with the water.

Like when you drink soda water, the bubble ejection lifts the liquid up to your nose. You can see this on a beach in the form of sea spray or mist. Now imagine that on a global scale, on every beach with an onshore wind.

For this study we chose a research site on the French Atlantic coast, a location well known for large waves and violent storms.

As this research was completely new, we employed two different but well-established atmospheric sampling techniques. The first being a simple vacuum pump with a glass fibre filter to extract any particles at about the same rate as human respiration during exercise (50 litres/minute). We wanted to measure what a human on the beach would be exposed to under normal conditions, like going for a run.

The second technique used a machine commonly known among scientists as a "cloud catcher", which uses a large fan to draw air over layers of Teflon filaments. The water droplets stick to the filaments and drain into a glass bottle.

We found onshore and offshore winds carrying microplastics but on the last day of sampling, the wind dropped to zero and a sea mist from the surf covered the beach. During that sampling time we found 19 microplastic particles per cubic metre of air.

Considering a human breathes around 16 cubic metres of air every eight hours, we are inhaling a lot of microplastics in what we normally think is pure sea breeze. By taking the estimated marine boundary layer, air mass and a five kms length of beach, we found 136,000 metric tonnes could be blowing ashore every year. Not an insignificant amount and probably a conservative estimate.

It is clear that plastic pollution is becoming a serious issue. As yet, we do not have a lot of evidence that it will cause harm, but more research is being published every day pointing to worrisome human and ecosystem health problems. Might there be a threshold where it causes an irreversible effect? If so, will we reach that threshold before we know what level that is?

The writers are respectively, lecturer and Leverhulme Trust Research Fellow in civil and environmental engineering, University of Strathclyde, Glasgow, UK

PLUS POINTS

Record migration

A tireless bird "designed like a jet fighter" has been tracked flying more than 12,000 kilometres from Alaska to New Zealand, setting a record for non-stop avian migration.

The bar-tailed godwit set off from southwest Alaska on 16 September and arrived at a bay east of Auckland just 11 days later. The male bird, fitted with a transmitter and monitored by researchers, was tracked hurtling across the Pacific Ocean at speeds more than 88 kms per hour during its immense journey.

"What these birds do is really unimaginable," said University of Groningen professor Theunis Piersma, who leads the Global Flyway Network, a collaboration of scientists who track extreme migratory journeys.

The record-breaking godwit, known as 4BBRW after the blue, red and white rings attached to its legs, was one of four to set off together from their nesting grounds in the Alaskan tundra. They first flew hundreds of kilometres to mudflats, still in Alaska, where they feasted on shellfish, worms and seaweed to prepare for migration.

The birds require so much fuel to cross the world that they can double in size and consist of almost half fat following their pre-flight meal. They are able to shrink internal organs including their stomach and liver to lighten the load. "By the time they arrive in New Zealand, the tank is really empty; then they are half as heavy again," Piersma told Dutch newspaper *Trouw*.

Satellite data put the length of 4BBRW's epic flight at just under 12,874 kms, although the scientists believe that once rounding errors are taken into account the journey will have been a little over 12,000 kms. The other three birds were not tagged. Strong easterly winds are thought to have lengthened its journey by pushing the group off course.

The previous record for non-stop flight by a bird was 11,667 kms, set by a bar-tailed godwit known as E7 in 2007. It remains a mystery how the birds are able to navigate such long distances.

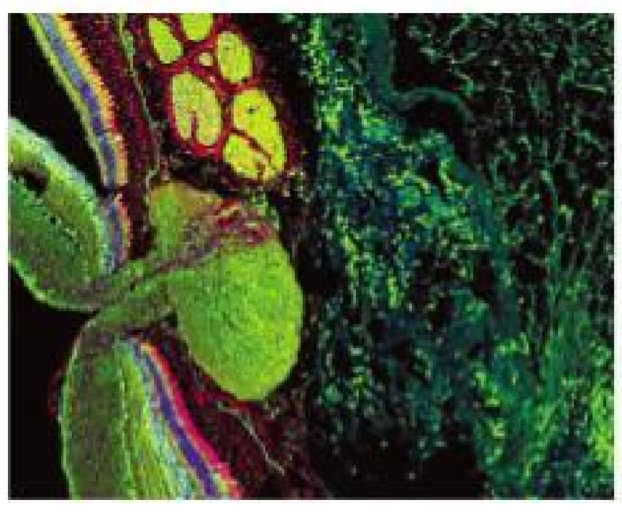
"They seem to have some capability of knowing where they are on the globe. We can't really explain it, but they seem to have an onboard map," Jesse Conklin, from the Global Flyway Network, told *The Guardian*.

The birds are not thought to sleep while they are in the journey, during which they are almost constantly flapping their wings, although they can doze for days upon reaching New Zealand.

"They have an incredibly efficient fuel-to-energy rate," Conklin said, "They have a lot of things going for them. They are designed like a jet fighter. Long, pointed wings and a really sleek design which gives them a lot of aerodynamic potential."

– THE INDEPENDENT

Unique eye



The picture above is of the eye of a rainbow trout, with the retina connected to the optic nerve and surrounded by a bed of capillaries.

Seeing is a metabolically expensive process, requiring lots of oxygen usually delivered by red blood cells in the blood flowing through the capillaries. Unlike for the human eyeball, the bed of capillaries in the rainbow trout are found outside of the eyeball. The distance between the capillaries and retinal tissue can potentially limit oxygen delivery to the eyes of the fish. So how does it get the oxygen it needs to help it see?

Scientists have managed to shed light on the question, identifying a mechanism which acidifies the blood as it nears the eyes of the fish. The acidification, carried out by proton-secreting enzymes in the capillaries, promotes oxygen release from the red blood cells. This boosts the retina's oxygen supply by more than 10 times, ultimately enhancing the fish's ability to process visual input.

The findings by an international team of scientists from Denmark, the US, Canada and Italy were published recently in the scientific journal *eLife*.

– THE STRAITS TIMES/ANN