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THE ANTI-ZOO

50 FREAKS OF NATURE YOU WON'T SEE ON TV

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THE ANTI-ZOO

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A walk on the wild side

A field guide to nature's weirdos

NEW SCIENTIST PRESENTS

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The animal kingdom is a glorious place. Think of antelopes gracefully trotting across the African savannah, bathed in glorious sunlight. Think of tiny hummingbirds, hovering perfectly in place before an equally elegant flower. Think of schools of brightly coloured fish basking over the technicolour paradise of a tropical coral reef.

Or don't. Forget these show-offs, these airbrushed supermodels of nature, and spend some time with real animals. These are the misfits, the counterculture of the natural world. They might be butt-ugly, and if you try and cuddle them they'll probably bite your arm off. Some of them spend their days chowing down on deadly scorpions, and don't mind if they get stung in the process.

So, never mind the cute critters you already know. Meet the mouse that howls at the moon. Find out how moose became experts in chemical warfare, and try not to get tangled up in the world's biggest spider web.

And as you explore these oddities of evolution, consider this. They and their ancestors have survived for millions of years, and in many cases they have been around far longer than humans have. Their strange lifestyles clearly work for them. Each of these animals is a success.

They are also a treasure trove. In their genes they carry records of past evolution, of how life on Earth has changed over millions of years.

They might not be as cute as the panda, but they're just as precious – and nowhere near as inept. The world would be far less interesting, and infinitely more vanilla, if we lost them.

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1. Bigger is better

The largest arthropod to prowl the land

SPECIES *Birgus latro*

HABITAT Coastal forests of islands in the Indian and Pacific Oceans

It's paradise with a twist. As the sun sets over the beautiful Palmyra atoll, south of Hawaii, Earth's largest land arthropod emerges from its lair.

Coconut crabs can reach a length of 40 centimetres, with a leg span of 90 centimetres, and weigh 4 kilograms.

Most such monster arthropods – the group that includes insects, spiders and crustaceans – live in the sea, where the water helps support their heavy bodies. To survive on land, coconut crabs have had to evolve a suite of strange adaptations.

But their exceptional lifestyle has also put them at great risk, and conservationists are only now working out how to protect them.

Coconut crabs – also known as robber crabs for their habit of stealing food from inattentive campers – are not true crabs. They are members of the group that includes hermit crabs, known for living in discarded mollusc shells. Coconut crabs do this when young, but as they grow they start roaming free.

They begin their lives in the sea. Female crabs carry their fertilised eggs around on their bodies, and release them into the sea when they hatch – generally when the moon is new. The juveniles develop in the sea for about a month, after which they head out on to land permanently.

Stephen Belcher/Minden/FLPA

There they face a problem: how to breathe. Gills, which aquatic crabs have, are inefficient out of the water. To get round this, coconut crabs have developed organs called branchiostegal lungs, which are essentially sets of gills turned inside out.

They have only been able to develop these strange organs because, unlike other hermit crabs, they – slightly obscenely – purposely expose their abdomens to the surrounding air to bring in a steady flow.

Nuts for coconuts

As their name suggests they eat coconuts and nuts, using their strong claws to tear open the tough outer shells. In some cases the crabs carry coconuts up trees and then drop them to break them open.

Rather than mouths, crabs have a tube called the gastric mill for "chewing" food. In coconut crabs, this has a tough surface against which hard food like nuts can be crushed.

They also eat fleshy fruit, and have been known to hunt and kill rats and other small animals.

Coconut crabs have been enthusiastically hunted – not least because people tend to eat them – and, on some islands, wiped out. Although the International Union for Conservation of Nature's Red List of endangered species classes them as "data deficient", because the populations have not been studied recently, it is clear that their numbers have plummeted.

Habitat switchers

A captive breeding programme to restock their island habitats is under way, with some early success. In 2009 it was reported that juvenile crabs have been successfully taken through all their stages of development in the lab. But this is only half the solution.

Because coconut crabs live both in the sea and on land, any attempt to protect them has to cover both habitats, and ensure that they can move easily between them.

Most conservation programmes do not allow for this sort of habitat-switching, focusing instead on protecting one particular habitat such as a coral reef.

However, Maria Beger of the University of Queensland in Brisbane, Australia, and colleagues have proposed new systems for protecting animals that need to move between habitats. Their ideas have not yet been tried out in the wild, but if and when they are, they could give animals like the coconut crab a much better chance.

SPECIES *Syringammina fragilissima*

HABITAT The sea floor around Europe and north Africa

‘Living beach ball’ is giant single cell

In the late summer of 1882, a ship called the Triton cruised the chilly seas north of Scotland. As it went, it dredged the seabed for specimens of unknown creatures, under the guidance of the oceanographer John Murray.

Two of the specimens were strange enough that Murray sent them to his colleague Henry Brady for examination. They were chunks of sand a few centimetres across, lightly cemented together and filled with a network of hollow branching tubes.

The samples were fragile and had been badly broken, but Brady was able to identify them as a new species, which he called *Syringammina fragilissima*: “very fragile sand pipe”. A better name would have been “very fragile sand beach ball”, but Brady didn’t see the organism underwater.

It turns out that Murray and Brady had discovered the first specimen of a new group of organisms, the single-celled xenophyophores.

Shunning the convention that single cells are microscopic, *Syringammina* is a brute, growing to

Andy Gooday

a width of 10 centimetres – sometimes even 12 centimetres.

The cell forms a thick strand that can flatten almost into a sheet. In places it splits into several branches, and these branches sometimes reconnect. The whole thing is enclosed in a thin sheath. Although most normal-sized single cells have only one nucleus, *Syringammina* has many, to ensure that its many disparate parts work properly.

As *Syringammina* proliferates, it builds up a crusty structure around itself, called the test – this is what Murray's expedition turned up. To build it, the cell secretes an organic cement, which it uses to stick tiny particles of sediment together.

Whopping mystery

The tests made by *Syringammina* are by far the largest structures created by any single cell.

The actual cell may not be as big – as the test gets ever larger, the cell will abandon parts of it, which may be taken over by a range of tiny animals, such as nematodes.

A study of a similar species, which was observed through a time-lapse camera for eight months, showed that the creature built itself up in fits and starts: it would grow for a few days, then remain the same size for months, then have another growth spurt.

Syringammina may do the same thing; we don't know.

In fact, there is very little about the monstrous beach ball cell that we do know with any certainty.

Let us count the ways. We do not know how it reproduces. The xenophyophores seem to be part of a much larger group called the foraminiferans, and these often switch between sexual and asexual reproduction. *Syringammina* may well do the same thing.

We do not know how it feeds. It may be a suspension feeder, allowing water through its body and sifting out tiny particles of food, or it may poke out a "limb" to pick up food from the seabed.

Farm animal

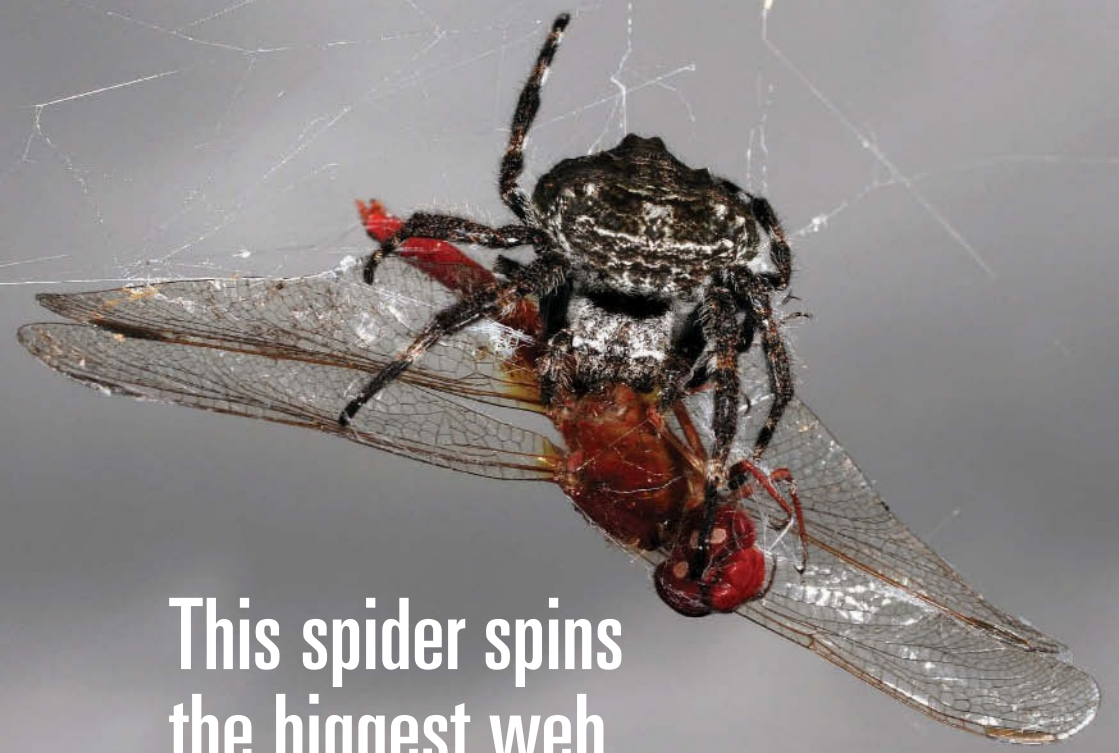
Another possibility has been put forward by Ole Tendal of the Zoological Museum of the University of Copenhagen, Denmark: *Syringammina* may farm bacteria.

Within the tubes of the test, *Syringammina* accumulates particles of waste, which it stitches together into long strings. *Syringammina* might use these strings to cultivate bacteria. The waste pellets would provide food for the bacteria, which *Syringammina* could then eat.

There is some tentative evidence to support this. A 2004 study found that *Syringammina* contains unusually high levels of certain fatty acids that are characteristic of bacteria.

One more mystery. Scattered throughout the *Syringammina* cell – and indeed through the cells of all xenophyophores – are tiny crystals of barium sulphate.

They could serve as ballast, or as something altogether different. We have no idea.



This spider spins the biggest web

SPECIES *Caerostris darwini*

HABITAT Madagascar, alarming arachnophobes and mayflies in equal measure

The spider attaches a line of silk to the tree branch she is standing on, by the side of a river, and bungee-jumps into space. Dangling in mid-air, she begins spewing out silk. And more silk. And still more silk.

Eventually she will have released more than 25 metres of continuous strands, which drift away downwind, across the river. Suddenly she stops, and begins reeling the line back in. It pulls taut. Success! The other end has tangled itself in a bush on the far bank.

This is the first step in the construction of the world's biggest spider web, which will hang above a tropical river.

Perched in the centre of her vast web, the Darwin's bark spider can feast on huge numbers of insects after they emerge from the water.

Strongest silk

The Darwin's bark spider was discovered in Madagascar as recently as 2010, by Matjaž Kuntner of the Slovenian Academy of Sciences and Arts in Ljubljana and Ingi Agnarsson of the

Matjaž Gregori

University of Puerto Rico in San Juan. With Kuntner's colleague Matjaž Gregoric and Todd Blackledge of the University of Akron in Ohio, they have carried out field studies to find out how the spiders build their webs and what they are for.

The Darwin's bark has a built-in advantage. Its silk is the toughest of any spider, which is particularly remarkable as spider silks are tough anyway, and stronger than many artificial substances.

The river-spanning lines of silk are the longest section of the web. The spider's method of building them – trailing silk into the open air and hoping for the best – is similar to the common spider trick of "ballooning". Spiders who want to travel great distances release long strands of silk that act like kites and pull the spiders into the air. Ballooning is found in most species of spider, suggesting it is an ancient behaviour. If that's true, the bridging lines may have developed from it.

Once the bridging line is in place, the spider walks out along it and reinforces both ends. Then she adds one vertical thread beneath the bridging line, forming a "T" shape. This vertical thread becomes the basis for the web proper, a classic orb web that can

Matjaž Gregori

have an area of 2.7 square metres.

So what does this huge net catch? Kuntner and colleagues staked out 46 webs and found that small insects like beetles, damselflies, dragonflies and wasps made up most of the prey.

Lobbing prey

In a separate paper, Blackledge has shown that the majority of female orb-web spiders rely on occasionally capturing exceptionally big animals. These supply a huge amount of food in one go, giving the spiders plenty of energy for laying eggs.

But there was no sign of the Darwin's bark spiders catching big game. The researchers tested what the webs could catch in the most direct way possible: by lobbing different prey animals at them from half a metre away. Nothing bigger than a dragonfly got stuck: larger insects and frogs all got clean away.

It may be that the spiders get big meals by catching insects like mayflies in bulk when they emerge from the river. The alternative is that the team just didn't watch them for long enough to see them catch anything big.

"We aren't yet sure if *C. darwini* is a really neat exception to most orb spiders, or if we simply don't know enough about what they eat," Blackledge says.

SPECIES *Balaena mysticetus*

HABITAT In and around the Arctic pack ice

World's biggest mouth has an erectile secret

It's September, and bowhead whales are migrating west along the northern coast of Canada. Behind them the sea ice is spreading as winter approaches, and the whales must find patches of open water.

As they swim they often hold their vast mouths – the biggest in the animal kingdom – slightly open. It's curious behaviour considering the whales have thousands of kilometres to travel, and an open mouth will increase the drag from the water.

But there's method to this apparent madness. They're cooling off. It turns out that bowheads have an organ on the roofs of their mouths, bizarrely similar

Paul Nicklen/National Geographic

to a penis, which sheds body heat into the cold water.

Bowhead whales are a superlative species. In addition to having a record-breaking mouth, their long, slow existences may make them the longest-lived mammal. We know they can live more than 100 years, and some may reach 200 (although they can't hold a candle to the immortal jellyfish).

They are also the second largest animal on the planet: only blue whales are bigger. Their massive heads make up one-third of their body length, and contain sheets of enormous bristles called baleen. These sheets look rather like Venetian blinds and trap enormous numbers of tiny animals.

They feed by opening their mouths wide and lunging forwards into swarms of plankton, gulping in huge volumes of water. Studies of their brains suggest that, for whales, they have an unusually good sense of smell, which probably helps them find food.

Cool arsenal

To survive in freezing Arctic waters, bowheads have an arsenal of tricks. Their bulbous shape cuts their surface area, compared to the elongated shape of most other whales, which helps keep them warm. They are also insulated by a layer of blubber half a metre thick.

But to regulate their temperature, they also need a way of cooling off. Alexander Werth of Hampden-Sydney College in Virginia and colleagues think they know what that is. In the early 1990s, they dissected the heads of seven bowhead whales, which had been killed by Inupiat hunters in Alaska. The results were finally published in 2013.

Each whale had a rod of tissue running along the middle of its palate. When Werth dissected it, he found that it was made of soft, spongy tissue, and filled with blood vessels.

The team says it probably swells and becomes rigid when extra blood is pumped through it – much like a penis. They call it the corpus cavernosum maxillaris.

Despite the whales having died several hours earlier, the organ was 6 to 8 °C warmer than the other surfaces of the whales' bodies. That suggests it sheds heat, especially when it is engorged with warm blood.

Bowhead whales are almost too well insulated, Werth says. This keeps them warm in the freezing Arctic, but it may also make them prone to overheating when working hard – while migrating, for instance. "They have very few options to radiate heat," Werth says.

Werth speculates that the corpus cavernosum maxillaris may have additional functions. It contains a lot of nerve endings, so it might also be sensory. "It would benefit the whales to have a structure in the mouth to detect prey."

That could be true. In 2012 it emerged that other massive whales have a sensory organ in their mouths that coordinates lunge feeding – when a whale accelerates to engulf a mouthful of prey and water for filtering through its great baleen sheets.

SPECIES *Giraffa camelopardalis*

HABITAT Grasslands and open woodlands of sub Saharan Africa

How did the giraffe get its long neck?

Around 15 million years ago, antelope-like animals were roaming the dry grasslands of Africa. There was nothing very special about them, but some of their necks were a bit long.

Within a mere 6 million years, they had evolved into animals that looked like modern giraffes, though the modern species only turned up around 1 million years ago. The tallest living land animal, a giraffe stands between 4.5 and 5 metres tall – and almost half that height is neck.

Most people assume that giraffes' long necks evolved to help them feed. If you have a long neck, runs the argument, you can eat leaves on tall trees that your rivals can't reach.

But there is another possibility. The epic necks may have little to do with food, and everything to do with sex.

The evidence supporting the high-feeding theory is surprisingly weak. Giraffes in South Africa do spend a lot of time browsing for food high up in trees, but elsewhere in Africa they don't seem to bother, even when food is scarce.

Giraffes' necks are long, but there have been longer ones. Sauropod dinosaurs trump them easily: *Mamenchisaurus*, for instance, had a neck over 9 metres long, four times the longest of giraffe necks.

Long necks come at a cost. Because a giraffe's brain is around 2 metres above its heart, the heart has to be big and powerful. In fact, for the blood to reach the brain it has to be pumped at the highest pressure of any animal. So there must be a big payback to keep giraffes' necks so long.

Girls like them long

A more recent theory – and it's a surprise this didn't come up before, given biologists' fixation with it – is that the long necks are the result of sexual selection. That is, they evolved in males as a way of competing for females.

Male giraffes fight for females by "necking". They stand side by side and swing the backs of their heads into each others' ribs and legs. To help with this, their skulls are unusually thick and they have horn-like growths called ossicones on the tops of their heads. Their heads, in short, are battering rams, and are quite capable of breaking their opponents' bones.

Having a long and powerful neck would be an advantage in these duels, and it's been found that males with long

necks tend to win, and also that females prefer them.

The "necks for sex" idea also helps explain why giraffes have extended their necks so much more than their legs. If giraffes evolved to reach higher branches, we might expect their legs to have lengthened as fast as their necks, but they haven't.

The problem for the sex idea is that it implies that female giraffes shouldn't have long necks, and they plainly do. Sexual selection often drives males to develop spectacular attributes – think peacocks' tails or the feathers of birds of paradise – to impress females, but the females remain relatively dowdy.

Neck and neck

A study in 2009 by Graham Mitchell, then at the University of Pretoria in South Africa, and his colleagues apparently delivered a knock-down blow to the "necks for sex" theory. Mitchell's team showed that, in Zimbabwe at least, males and females had necks that were almost exactly the same length, and that if anything the females' necks were longer.

This led many people to write off the whole sex idea.

However, Rob Simmons and Res Altwegg of the University of Cape Town, also in South Africa, have taken a second look at the results and are not convinced. They say the figures do show that males have proportionally longer necks, and that "Mitchell *et al.* appear to have misinterpreted this result".

They point to a study in Namibia which found that males consistently had heavier necks than females with the same body mass, and that only the males' necks kept growing throughout their lives.

Males' heads were also heavier than females', which is what you would expect if they were being selected for their ability to fight.

Simmons and Altwegg suggest that giraffes' necks may have begun growing as a way of eating hard-to-reach food, but that they were then "hijacked" for mating purposes.

Once the necks had reached a certain length, males could use them for necking and clubbing. At that point sexual selection took over, driving the necks to their current extreme lengths.

Peacocks and birds of paradise aside, there are many birds in which the male seems to have developed colourful plumage as a result of sexual selection, but where the females are also brightly coloured.

Perhaps the sexual selection explanation for long necks in giraffes isn't dead after all.

2/

Houdini fly inflates head to break walls

SPECIES *Cacoxenus indagator*

HABITAT Hanging around bees' nests across Europe

You're walled up in the dark and all your food has gone. You have to escape. But to get out you have to smash your way through a stone wall with your head – without even knowing if you're going in the right direction.

It might sound like a scene dropped from *Saw XXIII*, but this is how the fly *Cacoxenus indagator* begins its adult life. In the same situation humans would struggle, to say the least, but the fly knows exactly what to do.

The story begins in spring, when female red mason bees are building their nests. Unlike honeybees, they are solitary, and to save on the hard graft of construction they rely on other species to dig holes for them. Thin tubes burrowed in trees by wood-boring beetles are a favourite, and playful zoologists have even persuaded the bees to nest inside drinking straws.

Each nest begins as a simple tube. The female drops a small supply of pollen and nectar at the furthest end, and glues a single egg to it. Then she retreats a short distance and rapidly builds a wall of mud to seal the passage. She repeats this several times, filling the tube with a line of "brood cells", each containing a single egg and a food cache.

Over the next few months the eggs hatch and the larvae feed on the pollen and nectar. Then they spin a cocoon and metamorphose into adults, before hibernating through the rest of the year, emerging the following spring.

At least, that's the plan. *Cacoxenus indagator* has other ideas, which involve requisitioning those bundles of nectar and pollen. Adult flies loiter at the entrances of nests and lay up to eight eggs in a brood cell while it is being stocked. When the fly larvae hatch they feed on the nectar and pollen before pupating – starving the bee larvae in the process – to emerge from their cocoons as adults in the spring.

But at this point they run into a brick wall, almost literally. The mud walls are 2 to 6 millimetres thick, and have

Erhard Strohm

dried hard. Each young fly is only 3 millimetres long, so the wall may be thicker than its body length.

Exit strategy

Some of the flies have it easy, says Erhard Strohm of the University of Regensburg, Germany. At least one bee in the nest usually survives to adulthood, and breaks out using its powerful mandibles, passing through as many brood cells on the way as it needs to. This leaves a clear escape route for two-thirds of trapped flies. But the others are on their own.

The fly's solution is to meticulously headbutt its way out, Strohm has found. To do so the flies must first pick the right direction, using the clues left by the mother bee. Within each cell, the wall nearest the exit is convex and the other is concave. Strohm tested 20 flies in artificial nests, and found 19 of them focused their efforts on breaking through the correct wall.

He then filmed flies trying to escape. Each fly pushed its head into a small crevice in the dried mud, then broke pieces off. How? By inflating its head.

To do this it pumps haemolymph, the insect version of blood, into a pouch on its head called the ptilinum. Many flies use this to break out of their cocoons, but *Cacoxenus indagator* takes it a step further. "The pumping is quite strong, so it can exert plenty of pressure," Strohm says. The hole the fly makes is often small, but its body is still soft, so it can squeeze through.

It's a weird escape plan, but it works. Of 98 flies Strohm observed trapped in brood cells, not one failed to escape.

The worm that looks like a tree

SPECIES *Ramisyllis multicaudata*

HABITAT Shallow seas off the north coast of Australia

Nowadays the name Challenger is most associated with the doomed space shuttle, but it wasn't always so.

The shuttle was named after a naval vessel which, from 1872 to 1876, carried out one of the first expeditions to explore the deep oceans. While touring the Philippines, its crew dredged up a sponge and found that its cavities were filled by a bizarre, branching worm, later dubbed *Syllis ramosa*.

For over a century, *S. ramosa* remained unique. But no longer. A second species has been found off the coast of Australia, and there could be many more out there.

Home sweet sponge

Christopher Glasby of the Museum and Art Gallery of the Northern Territory in Darwin, Australia, made the new find. In November 2006 he went diving in the shallow waters of Darwin harbour and, avoiding "the occasional crocodile and

deadly *Chironex* jellyfish", collected a single *Petrosia* sponge.

The hollow spaces inside were filled with the branched body of a worm – a new species, which Glasby and his colleagues have named *Ramisyllis multicaudata*.

Worm-sponge pairs are easy to find, Glasby says, but difficult to dissect because they are fragile. As far as he can make out, each worm has a single head that lurks deep inside the sponge. "Finding the deeply embedded head end is literally like finding a needle in a haystack," he says.

As the worm's body grows, it develops branches that follow the many channels in the sponge. Each branch can develop many sub-branches, which also develop branches, and so on.

As a result each worm can have hundreds or thousands of extremities, many of which poke out through holes in the sponge's surface. At first glance, an infested sponge looks like it has dozens of hairy white tentacles.

Mystery feeder

Glasby doesn't know what *R. multicaudata* eats. It may consume parts of the sponge, but that probably wouldn't sustain it. Alternatively, its skin might absorb dissolved organic material – in which case a branched body would be useful as it increases surface area.

We also don't know what the worm's relationship is to the host. It could be a harmful parasite, but it is also possible that the protruding branches deter

Chris Glasby et al./©2012 The Linnean Society of London

predators, or that the worm's extremities stimulate the sponge's growth or improve the flow of water through the sponge.

Glasby says its branched body may help the worm produce more young. Worms reproduce by forming small buds near their tail ends. A single *R. multicaudata* can have over 100 tails, and, in theory, each could produce young.

Genetic analysis of *R. multicaudata*, *S. ramosa* and 50 other worms suggests that the two branched species are quite distantly related. That in turn suggests they evolved the ability to branch independently, probably by modifying the budding method used to reproduce.

If two species can do it, why not more? Glasby says several specimens of branched worms have been described as *S. ramosa* despite appearing subtly different. "It is quite possible that the diversity of branching [worms] has been underestimated because of the difficulty of finding and extracting them intact," he says.

The turtle that urinates through its mouth

SPECIES *Pelodiscus sinensis*

HABITAT Throughout South-East Asia, though demand for farmed turtles has impacted the wild population

Everyone knows the feeling of desperately needing to go to the loo. Bouncing from one foot to the other, you hare around in search of an appropriate facility, praying all the while that it won't be occupied.

When the Chinese soft-shelled turtle needs to urinate, its approach is a little different. It goes in search of a puddle, and dunks its head under the surface.

That's because the Chinese soft-shelled turtle is unique in the animal kingdom: it urinates through its mouth.

Chinese soft-shelled turtles are most

commonly encountered as food in upscale restaurants. They're widely farmed in several South-East Asian countries. Even as embryos, they are remarkable: a turtle embryo can move to the warmest spot in its egg when it has yet to develop limbs.

In the wild, they live in swamps and marshes where the water is often brackish: salty, but not as salty as seawater. They spend plenty of time out of water, especially in summer, but they often stick their heads into puddles.

Fingers in mouth

The linings of their mouths are covered with tiny, finger-shaped protrusions, discovered in the late 19th century. It turned out that they allow the turtles to breathe underwater: they increase the surface area of the mouth over which oxygen and carbon dioxide can be exchanged. The turtles can also take in other chemicals, such as sodium, through the protrusions.

But that's only part of the story, according to Alex Yuen Kwong Ip of the National University of Singapore. He thinks the turtles only started breathing underwater to make it easier to urinate through their mouths.

Working with Shit Fun Chew of Nanyang Technological University in Singapore, Ip kept four turtles in tanks of water for six days. Each turtle had a tube attached to its cloaca, where urine would normally exit the body. Ip sampled the tank water regularly, and collected any urine passed through the cloaca. Just 6 per cent of the turtle's urea came out of the cloaca. The rest turned up in the tank water.

Ip also tried restraining the turtles on land. When he placed a bucket of water in front of them, the turtles plunged their heads in for between 20 and 100 minutes. They held the water in their mouths for a while, then spat it out – at which point the urea concentration in the water increased.

Oral habit

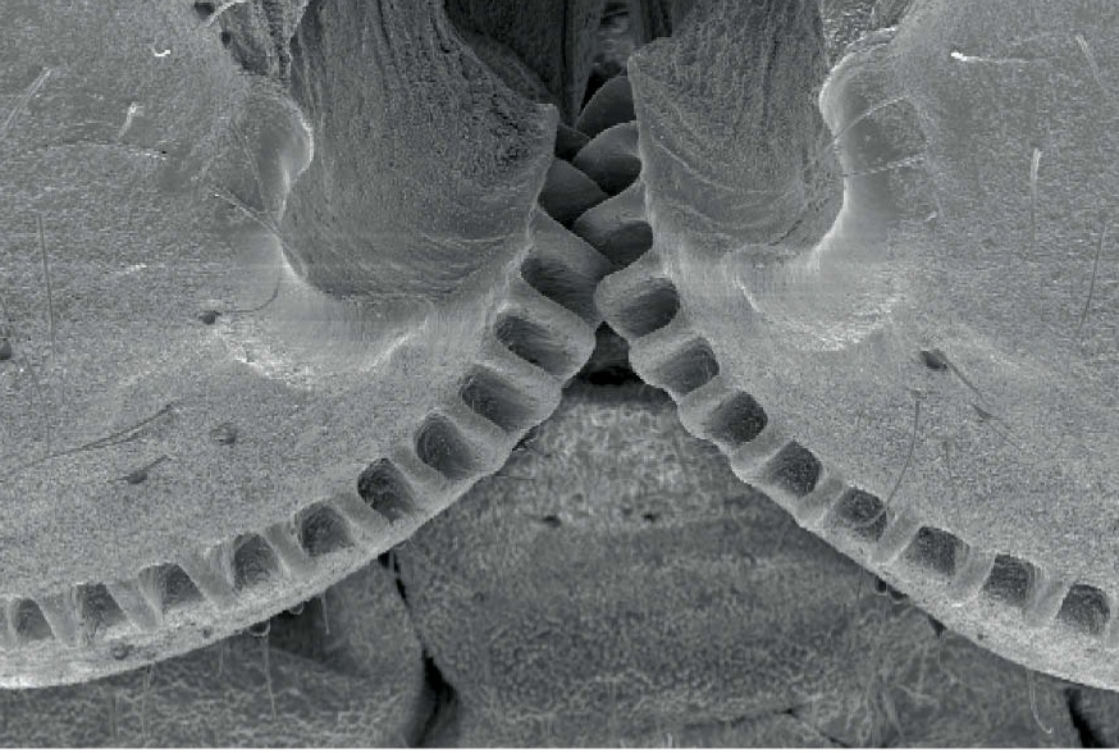
Proteins in the turtle's mouth lining actively transport urea out of its bloodstream. Ip managed to identify one such transporter, and found that it was only present in the mouth lining, not in the kidney.

"I know of no other animals that can excrete urea through the mouth," says Ip. Most fish excrete through their gills, and some amphibians and lungfish may excrete through their skin, but the Chinese soft-shelled turtle's oral habit is almost certainly a one-off. Without the tiny protrusions in the animal's mouth, it could never work efficiently.

Ip thinks oral urination helped the turtles colonise brackish waters. To excrete urea through their cloaca via their kidneys, the turtles would need to drink a lot of water to flush it through. That would mean taking in a lot of salt, which would be difficult to get rid of. The turtles' habits allow them to simply rinse their mouths with brackish water rather than drink it.

As yet there is no record of Chinese soft-shelled turtles washing their mouths out with soap and water.

Tim Fitzharris/Minden Pictures/FLPA



Transformer insect has gears in its legs

SPECIES *Issus coleoptratus*

HABITAT Throughout western Europe, often hanging around on ivy plants

For a disconcerting experience, consider how mechanical you are. Humans may be conscious beings with higher feelings, but really we're just fancy machines with joints, motors, valves and a whole lot of plumbing.

All animals are the same. Hundreds of gizmos have evolved in nature, many of which our engineers merely reinvented. Nature had rotating axles billions of years ago, in the shape of bacterial flagella. And weevil legs beat us to the screw-and-nut mechanism.

The insect *Issus coleoptratus* is

another animal with an unexpected bit of machinery hidden in its body. Its larvae are the first animals known to have interlocking gears, just like in the gearbox of a car.

Prodigious hopper

I. coleoptratus is a type of plant hopper – a group of insects known for their prodigious jumping. It takes off in just 2 milliseconds, and moves at 3.9 metres per second. "This is a phenomenal performance," says Malcolm Burrows of the University of Cambridge. "How on earth do they do it?"

Burrows first ran into the larvae of *I. coleoptratus* in a colleague's garden. "We were poking around and there were these bugs, jumping around like crazy." He took a closer look, and noticed that each larva had meshing gears connecting its two hind legs. A German biologist called K. Sander had seen them before, but his 1957 paper isn't even on the internet.

The bulb at the top of each hind leg has 10 to 12 teeth, each between 15 and 30 micrometres long. Effectively, each hind leg is topped by a biological cog, allowing the pair to interlock and move in unison.

Working with Gregory Sutton of the University of Bristol, UK, Burrows filmed the gears at 5000 frames per second and confirmed that they mesh with each other.

The two hind legs moved within 30 microseconds of each other during a jump. Burrows and Sutton suspect that the gears evolved because they can synchronise the leg movements better and faster than neurons can.

Other animals have gears, but not ones that mesh, says Chris Lyal of the Natural History Museum in London. "When you look at [*I. coleoptratus*'s gears], you wonder, why can't anything else do that?" he says.

The German study from 1957 claims that all 2000-odd plant hoppers have gears. "I've looked at about half a dozen, and they all have them," says Burrows. "I'd be hesitant to say no other animal has them," says Burrows. "But they haven't been described."

Gear change

There's one other mystery. Only larval plant hoppers have gears. When they become adults, they lose them.

"Adults still jump very well," says Burrows, and their legs are synchronised. But instead of gears, they rely on friction between leg segments. "Why do they throw away a neat mechanism?"

It might be that gears are easily broken, and as soon as one tooth is sheared off, the mechanism doesn't work as well. "For an adult that can't moult again, that's going to be a problem." Friction may be a crude way to sync your legs, but it might also be more robust than fragile gears.

Courtesy of Malcolm Burrows

Death by world's longest animal

SPECIES *Cyanea capillata*

HABITAT Cold waters of the Arctic, north Atlantic and north Pacific Oceans

A venomous medusa-like beast as long as a blue whale has emerged as an unlikely defender of the world's oceans.

The lion's mane jellyfish is the largest jellyfish known, and a contender for the longest animal of all time. Its bell can be 2.5 metres across, and its tentacles can stretch over 30 metres. That's about the same length as a blue whale and 10 metres longer than the tentacles of the famous Portuguese man-of-war – which in any case is not a true jellyfish but a hydrozoan.

Scott Leslie/Minden

Aino Hosia, previously of the Institute of Marine Research in Bergen, Norway, now at the University of Bergen, and Josefin Titelman, previously of the University of Gothenburg in Sweden and the University of Oslo, have studied captive lion's manes. They found they will readily prey on sea walnuts – transparent animals of the comb jelly type, and voracious invaders of the world's oceans – and may help to control their numbers in the wild.

The sea walnut is native to the

western Atlantic, but has now spread to the North Sea and even the chill waters of the Baltic. It feeds on tiny plankton, devastating their populations, and so brings about crashes in the numbers of fish that depend on plankton for food. Like many species invading new territories, the sea walnut had been thought to have avoided significant predation – but no longer.

Three steps to a medusa

The lion's mane jellyfish passes through four stages over the course of its life: larva, polyp, ephyra and the familiar medusa. Each medusa is either male or female, and the female carries her fertilised eggs with her until they develop into larvae.

Each tiny, free-swimming larva, also known as a planula, heads off and installs itself on a rock – carefully selected to allow it to hang head-down in the shade. There, it develops into a polyp. This looks like a miniature sea anemone, and is also known as the scyphistoma, as if the terminology weren't confusing enough already.

After feeding for several months the polyp begins reproducing asexually, making many identical ephyrae, generally in early spring. Each ephyra breaks away and sets off on its own, and may – if it gets enough gelatinous prey – eventually become a full-size medusa.

The name "lion's mane" derives from the jellyfish's tentacles, which come in shades between yellow and red. They are covered with tiny cells bearing dangerous toxins that can paralyse prey and cause fatal heart attacks in lab rats.

Humans who get caught in the tentacles generally suffer only mild reactions, unless they are allergic or receive many stings. Slathering yourself with sunscreen apparently protects against the worst of it.

Sting that walnut

Nevertheless, and despite giving it only a limited ability to move around, the tentacles make the lion's mane a formidable predator. It readily catches small fish, and also targets many other jellies, including the large moon jellyfish.

So it should come as no surprise that the lion's mane targets the invasive sea walnut – though not as successfully as it does more familiar prey.

Hosia and Titelman found that the sea walnuts escaped the lion's mane 90 per cent of the time. Even so, they generally suffered damage in the process and were more likely to succumb after repeated assaults.

Still, with enemies like the sea walnut, we need friends like this.

The mud creature that lives without oxygen

SPECIES *Spinoloricus* nov. sp.

HABITAT Deep sediments lacking oxygen in the L'Atalante basin of the Mediterranean Sea south of Greece – and who knows where else…

Roberto Danovaro et al.

This tiny creature may not look spectacular, but it is one of the most remarkable ever discovered: the first that can survive and reproduce entirely without oxygen.

As well as proving that animals that don't need to breathe oxygen have already evolved on Earth, it bolsters claims that complex animals can evolve on other planets even if there's no oxygen. Some have speculated, for example, that sulphur-rich areas of Mars might support life.

On Earth, bacteria, viruses and ancient archaea that survive without oxygen are well known, but they are simple, single-celled organisms. What marks out the new animal is that it both has millions of cells and functions independently.

Toxic depths

Roberto Danovaro of the Polytechnic University of Marche, Ancona, Italy, led the team that discovered the creature, plus two others that live an oxygen-free existence, in sediments buried deep beneath the Mediterranean Sea. They have identified the creatures as loriciferans, tiny sediment-dwelling creatures so named from Greek because their abdomens resemble girdles.

Assigned the genus *Spinoloricus*, the animal is less than a millimetre long. The other two new loriciferan species Danovaro found resemble water fleas. One has been given the genus name *Rugiloricus*, the other *Pliciloricus*. Some specimens contained an unfertilised egg.

The creatures live in conditions that would kill every other known animal. As well as lacking oxygen, the sediments are choked with salt and swamped with hydrogen sulphide gas.

Power supply

None of the animals has mitochondria, the "power stations" that generate energy from oxygen in the cells of all oxygen-using organisms.

Instead, they rely on structures called hydrogenosomes, which generate energy from molecules other than oxygen, including hydrogen sulphide.

Hydrogenosomes are well known in protozoa that live in oxygen-free environments, but the three new creatures are the first animals found that rely completely on them. One possibility is that the loriciferans acquired the hydrogenosomes from protozoa.

Detailed light microscopy images reveal that its abdominal "girdle" consists of eight plates connected to form a cone, tipped with a honeycomb structure of unknown function.

Lisa Levin of the Scripps Institution of Oceanography in La Jolla, California, says that the discoveries offer the tantalising promise that animal life will be found in other environments devoid of oxygen, including beyond our planet.

Perhaps, she speculates, there are animals on other planets with atmospheres different from our own. More encouragement could come from further exploration of our own "inner space", the deep ocean.

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The first solar-powered vertebrate

SPECIES *Ambystoma maculatum*

HABITAT Throughout the eastern US and parts of southern Canada, leaving other salamanders green with envy

When you think about it, animals are weird. They ignore the abundant source of energy above their heads – the sun – and choose instead to invest vast amounts of energy in cumbersome equipment for eating and digesting food. Why don't they do what plants do, and get energy straight from sunlight?

The short answer is that many do. Corals are animals but have algae living in them that use sunlight to make sugar. Many animals, from sponges to sea slugs, pull the same trick. One species of hornet can convert sunlight into electricity. There are also suggestions that aphids can harness sunlight, although biologists are unconvinced.

But all these creatures are only distantly related to us. No backboned animal has been found that can harness the sun – until recently.

It has long been suspected, and as of 2013 there is hard evidence: the spotted salamander is solar-powered.

Plants make food via photosynthesis, absorbing light to power a chemical reaction that converts carbon dioxide and water into glucose and releases oxygen. Corals profit from this reaction by housing photosynthetic algae inside themselves.

Long-term partners

Spotted salamanders, too, are in a long-term relationship with photosynthetic algae. In 1888, biologist Henry Orr found their eggs often contain single-celled green algae called *Oophila amblystomatis*. The salamanders lay the eggs in pools of water, and the algae colonise them within hours.

By the 1940s, biologists strongly suspected it was a symbiotic relationship, beneficial to both the salamander embryos and the algae. The embryos release waste material, which the algae feed on. In turn the algae photosynthesise and release oxygen, which the embryos take in. Embryos that have more algae are more likely to survive, and develop faster than embryos with few or none.

Michael Redmer / Visuals Unlimited, Inc./Getty

Then in 2011 the story gained an additional twist. A close examination of the eggs revealed that some of the algae were living within the embryos themselves, and in some cases were actually inside embryonic cells. That suggested the embryos weren't just taking oxygen from the algae: they might be taking glucose too. In other words, the algae were acting as internal power stations, generating fuel for the salamanders.

Sweet result

To find out if that was happening, Erin Graham of Temple University in Philadelphia, Pennsylvania, and her colleagues incubated salamander eggs in water containing radioactive carbon-14. Algae take up the isotope in the form of carbon dioxide, producing radioactive glucose.

Graham found that the embryos became mildly radioactive – unless kept in the dark. That showed the embryos could only take in the carbon-14 via photosynthesis in the algae.

The algae do not seem to be essential to the embryos, but they are helpful: embryos deprived of algae struggle. "Their survival rate is much lower and their growth is slowed," says Graham.

It's less clear how well the algae get on without the embryos. In the lab, they transform into dormant cysts. The salamander eggs are only around in spring, suggesting that in the wild, the algae spend the rest of the year as cysts. The ponds they live in dry up in summer, so the algae may sit out the rest of the year in the sediment.

Now that one vertebrate has been shown to use photosynthesis, Graham says there could well be others. "Anything that lays eggs in water would be a good candidate," she says, as algae would have easy access to the eggs.

So other amphibians, and fish, could be doing it. It's much less likely that a mammal or bird could photosynthesise, as their developing young are sealed off from the outside world.

SPECIES *Alces alces,* sometimes *Alces americanus*

HABITAT Dribbling on luckless plants in Canada and the northern US, and the far north-east of Asia

Moose dribble turns off grass's toxic defences

We've all eaten something that didn't agree with us, but probably not like moose do. They eat a grass so toxic it can make animals' hooves fall off.

Yet the moose are resolutely hoofed, suggesting they have a way to counteract the toxin. That makes sense, as evolution would favour moose that could handle more of the stuff. There are precedents: some baboons have chemicals in their saliva that bind to toxins in their food, rendering them harmless, and some plant-eating insects go even further and actually deactivate plants' defence systems.

No one thought backboned animals could pull off the insects' trick, but in 2014 it emerged that moose can switch off a plant's toxic defences at source. They do it using a mystery chemical in their saliva that interferes with signals inside the plant. In effect, moose can detoxify their food by licking it.

Moose are the largest species of deer, and in spring the males grow the largest antlers of any living animal. Males are up to 40 per cent heavier than females. The males' size and antlers evolved because they compete so furiously for females. If a female is being courted by a

Image Broker/REX

male she regards as too small, she will moan repeatedly – attracting a larger male who may challenge the first. Males defending a single female or an entire harem also face regular challenges.

The competition plays out in ritualised battles in which two males lock antlers and try to shove each other backwards. It's not a fight to the death, more a test of strength, and often a small male will give in without a fight.

Growing these massive antlers, and then fighting over girls, takes a lot of energy. So moose need to eat a lot. But they have a problem: a significant part of their diet is a common grass called red fescue. These plants contain a fungus called *Epichloë festucae*, which makes a toxin called ergovaline. Grazing animals that eat too much ergovaline can lose parts of their feet, tails and ears, and develop digestive problems.

Smear test

So how come moose can eat it? Andrew Tanentzap of the University of Cambridge and his colleagues decided to find out.

They simulated grazing by clipping red fescue and smearing it with moose or reindeer saliva. Eight weeks later, the ergovaline levels in saliva-smeared plants were between 40 and 70 per cent lower than those in unclipped plants or in clipped plants smeared with water.

"Herbivores can actually fight back," says Tanentzap. "No one has ever thought of this." Many other grazers may have similar saliva tricks, he adds.

The moose saliva also slowed the growth of the fungus, but that is less surprising. Many animals' saliva has antifungal properties – including human saliva. The impressive bit is the effect on ergovaline production, which must involve interrupting a signal from the plant to its fungal inhabitants.

"If these animals continually graze the same plants, then it would be quite beneficial," says Gary Felton of Penn State University in University Park, Pennsylvania.

"We are still uncovering novel roles for saliva." For instance, sheep saliva stimulates plants to grow.

The first non-human meat farmers

SPECIES *Melissotarsus insularis and three other Melissotarsus species*

HABITAT Down on the farm under the bark of African trees, particularly in Madagascar

Lots of ants practise a rudimentary form of agriculture.

Some are gardeners, gathering leaf fragments on which they cultivate a crop of tasty fungus. Others are dairymaids, "milking" the sweet excretion known as honeydew from aphids, scale insects and other insects.

But the *Melissotarsus* ants of Africa and Madagascar are special. If biologists' best guess proves correct, these ants raise their insect herds for meat, not milk – the first example of meat farmers other than humans.

And that's not all. The insects they cultivate may be the best example of true domestication outside of our crop plants.

Devoted to burrowing

You have to know what you're looking for to even see *Melissotarsus*. The ants – barely 3 millimetres long – live most of their lives within the intricate gallery systems they excavate in and under the bark of trees.

They're such committed burrowers that their second pair of legs points up – so they can get a foothold in the tunnel roof as well as the floor.

They share their galleries with several species of armoured scale insects, so called because most species secrete a tough, waxy scale that covers and protects them.

But the ants' charges aren't paying for their keep in the usual way, with honeydew. In fact, they apparently lack a complete gut and thus are incapable of making the stuff.

Nor are the ants nibbling at the waxy scale – despite their name, the scale insects tended by the ants have no scale, and some even lack the wax glands needed to produce it.

"Armoured scales just don't seem to be equipped to produce an exudate that's enough to satisfy an ant," says Scott Schneider, an entomologist at the University of Massachusetts at Amherst.

Dining in private

So what do the ants get from all their work housing and protecting the scale insects? Almost the only remaining possibility is that the ants sometimes make a meal of the insects themselves, Schneider reported in 2011 at a meeting of the Society for the Study of Evolution in Norman, Oklahoma.

No one has yet caught *Melissotarsus* in mid-munch, partly because the ants like their privacy and quickly seal off any peepholes into their galleries.

However, Schneider plans to measure stable isotopes in the ants' bodies, which will indicate whether their diet is mostly plant or animal in origin.

If the ants are indeed eating the scale insects, they may have selected ones that lack the hard, inedible scale and so are easy to eat.

That would mirror what humans have done in breeding their crop plants. Corn, for example, is much less armoured than its ancestor, teosinte.

If this is true, the ants may have created the clearest case of domestication ever seen in non-human animals, says Schneider.

April Noble/from www.AntWeb.org

Polar bears evolved to eat junk food

SPECIES *Ursus maritimus*

HABITAT The defrosting wastes of the Arctic, from Alaska and Canada to Russia

Morgan Spurlock, eat your heart out. For his film *Super Size Me*, he ate McDonald's food at every mealtime for a month, having previously eaten a healthy diet. Spurlock put on a lot of weight, became lethargic and even had palpitations. The stunt rammed home a simple message: too much fatty food can kill you.

If only Spurlock were a polar bear. It turns out that the largest land predators alive have a host of genetic tricks to help them survive their impossibly fatty diet of seal blubber. Not only can they get rid of the lethal levels of cholesterol, but they also have ways to cope with the deluge of fat, avoiding the blocked arteries that give us heart attacks.

That's a lot of abilities, and they all evolved quickly. A 2014 study suggests that polar bears as a species are less than 500,000 years old, making them relative newcomers to the frozen north.

Blubber, glorious blubber

Born on land, polar bears spend most of their time at sea, hunting on the edge of sea ice for seals. Adults mainly gorge on the fat-rich skin and blubber alone. They can smell seals from 1.6 kilometres away, and often lurk for hours near holes in the ice where seals come up for air. Their huge fat reserves, which account for half their body weight, help them survive between meals, as well as giving extra buoyancy when they swim at speeds of up to 10 kilometres per hour.

But they are descended from terrestrial bears that ate a very different diet. "Their ancestors will have eaten healthy food like tubers and berries, and all of a sudden there they were eating almost exclusively fat and blubber from seals," says Rasmus Nielsen of the University of California at Berkeley. "So the fast-food experiment has already been done by nature."

To find out how the first polar bears coped with this shift in diet, Nielsen and his colleagues sequenced the genomes of 89 polar bears and 10 brown bears, their closest relative. Out of 20,000 genes, they found 20 gene variants that were most distinct in polar bears, which evolution has evidently favoured.

The list of genes was dominated by

metabolism, heart function and coat colour. "Usually, the genes that evolve most radically in species are immune and defence genes," says Nielsen. "What's surprising was the focus on cardiovascular function."

Junk food DNA

Of the top 20 genes, nine relate to heart function or development in humans. One variant that scored especially highly was the *APOB* gene. This makes Apolipoprotein B (ApoB), the protein component of "bad cholesterol", otherwise known as low-density lipoprotein (LDL). ApoB normally removes artery-clogging LDL from the bloodstream, dumping it out of harm's way in fat cells or elsewhere.

"The APOB variant in polar bears must be to do with the transport and storage of cholesterol," says Nielsen. "Perhaps it makes the process more efficient." It's not clear exactly what the gene variants do for the polar bears, but Nielsen hopes to find out by putting them into mice and seeing what happens.

The trawl also found two variants that may be related to polar bears' white fur. One, *LYST*, causes depigmentation in the fur of cattle and mice. In humans, defects in *LYST* are associated with Chediak-Higashi syndrome, which causes eye and hair depigmentation.

The changes happened quickly. Nielsen's team estimates that polar and brown bears split from their common ancestor just 479,000 to 343,000 years ago. Conditions in the Arctic were mild between 400,000 and 300,000 years ago. That may have allowed the ancestral bears to move in, setting the stage for the population to split when the ice returned.

"Polar bears are remarkable organisms to have adapted so rapidly to a very different and unique diet that is ultra-high in fat," says Nielsen. "Divergence times for large mammalian species are usually many millions of years."

Speedy evolution

Fossil-based studies put the split at 600,000 years ago, and a 2012 genetic analysis by Charlotte Lindqvist of the University at Buffalo, New York, estimated it was 5 million years ago. Nielsen says his analysis is probably more reliable because it used four times as many polar bears as Lindqvist's study.

But the debate over when polar bears evolved is not over. Lindqvist says the estimates are highly dependent on factors like mutation rate that have to be assumed. "I'm quite sure more dates for the split will be suggested in future."

Whenever it happened, the split between polar bears and brown bears may soon go into reverse. Polar bears are losing habitat as the Arctic ice melts. That may drive them inland to brown bear habitat, where the two species will hybridise, creating "grizzlars" that have apparently already been sighted.

"The polar bear could die out, not through lack of habitat, but through an increased rate of integration and gene flow between white and brown bears," says Nielsen.

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4. Horrifying hunters

Michael & Patricia Fogden / Minden

Mouse eats scorpions and howls at the moon

SPECIES *Onychomys torridus*

HABITAT The arid badlands of the south-western US and adjacent regions of Mexico, in burrows stolen from other rodents

In the dark expanses of the Sonoran desert in the US, a terrifying creature stalks the night, searching for fresh meat. Anything will do: crickets, rodents, tarantulas – the nastier the better.

Even the poisonous scorpion cannot escape the savage monster's little pink paws. It fights bravely, stinging its attacker on the nose. To no avail. The mouse ignores the painful venom and cruelly breaks the scorpion's tail by pummelling it into the ground, then bites its head and feasts on its flesh.

Finally, throwing its head back, the murderous animal howls at the moon.

No, it's not the mythical chupacabra. It's the southern grasshopper mouse, the only carnivorous mouse in all of North America.

Its unique biology and resistance to scorpion venom may one day help researchers treat human pain disorders. But for now, it's just after blood.

Natural born killer

From the day they are born, grasshopper mice are instinctive killers. Even pups born and raised in captivity quickly figure out how to take down prey much larger than themselves.

They appear to learn some of their aggression from their dads. Pups raised by two parents tend to bully other mice more, and attack insects more viciously, than those raised by single mothers.

Their manners don't improve with age. Rather than making their own nests, grasshopper mice take over burrows built by other rodents, removing the occupants by force if necessary.

In tough times, the mice will kill and eat other rodents, even those of their own species. Naturalists tell of finding a circus of different flea species on the animals – seemingly souvenirs from their victims.

Venom? Pah!

But even more striking than their cannibalism is their resistance to the venom of the Arizona bark scorpions (*Centruroides* sp.) that share their desert. They are among the most venomous scorpions in the world, and can cause muscle contractions and respiratory failure in humans. Yet grasshopper mice kill and eat them without pause.

To discover their secret, Ashlee Rowe, previously at Sam Houston State University in Huntsville, Texas, and her colleagues injected a very small amount of scorpion venom into the paw of a grasshopper mouse and a standard-issue lab mouse (*Mus musculus)*.

The grasshopper mouse spent far less time licking its paw, suggesting that the venom was less painful to it.

The team then removed individual nerve cells from the mouse's spinal cord – cells that convey pain signals to the brain – and measured how the venom altered their function.

Normally, scorpion venom activates a protein in the cell membrane called Nav1.7 that makes it fire pain signals. But grasshopper mice, they found, have a mutation affecting a different protein, Nav1.8, that prevents the signal from travelling any further and reaching the brain.

Rowe presented the group's findings at the Society for Integrative and Comparative Biology meeting in San Francisco in 2013.

In humans, Rowe says, mutations in Nav1.7 cause a syndrome called erythromelalgia, in which people feel a characteristic burning pain in the feet and hands.

The researchers are now attempting to figure out exactly how the mutation affecting the mouse's Nav1.8 blocks pain signals, to see if it could help in designing a new kind of painkiller.

The strange reptiles that saw seabirds' heads off

SPECIES *Sphenodon punctatus* and *Sphenodon guntheri*

HABITAT Persecuting seabirds in New Zealand

Headsmen must have suffered from terrible stage fright. Even with a decent axe, it takes both power and precision to take someone's head off with one blow, and they often failed. Apparently it took two blows to kill Mary Queen of Scots, and even then the executioner had to do some impromptu sawing to finally separate her head from her body.

Tuataras, New Zealand's iconic reptiles, have no such problem. They are known for sawing the heads off seabirds, leaving the decapitated bodies lying around to baffle passers-by.

That's thanks to the distinctive way they chew their food, which lets them rip through substances that many other animals would struggle with. Their masticatory skills may even help explain why they have survived so long, while countless other species have died out.

Last of their kind

The two species of tuatara are the last surviving beak-headed reptiles called the Rhynchocephalia – or Sphenodontia, depending who you ask. At first glance they look like lizards, but they aren't. In fact tuataras are about as closely related to lizards as humans are to kangaroos, says Marc Jones, formerly of University College London and now at the University of Adelaide in Australia.

The beak-headed reptiles arose in the Triassic period and flourished during the dinosaur era, but by the time the dinosaurs died out, they were confined to South America. Over the following tens of millions of years, they made their way to New Zealand, perhaps via Antarctica.

Despite their name, the beak-headed reptiles didn't have beaks, but their mouths were nevertheless peculiar. Tuataras have preserved their ancestors' strange mouths. They have two rows of teeth on their upper jaw, one inside the other. Their lower jaw has a single row of teeth, which fits between the two upper rows.

When a tuatara chews, its lower jaw slides forward a few millimetres after it impacts the upper jaw. That means it doesn't chew so much as saw, slicing through its food.

Working with colleagues at the University of Hull in the UK, Jones built

a computer model of a tuatara's skull to understand exactly how it works. He found that as well as sliding forwards, the lower jaw also rotates inwards. As a result, teeth that begin pointing slightly out to the sides eventually point straight upwards. "It's very subtle," he says, but it means they can chew their food even better.

Survival diet

This unique chewing mechanism allows tuataras to eat a highly varied diet, ranging from insects and spiders to frogs, and the aforementioned luckless birds. "They can eat food that's bigger than their mouths," Jones says.

This catholic approach to food may be the key to the tuataras' survival. Other beak-headed reptiles had relatively specialist diets, and so would have been more vulnerable to climate change and other environmental shifts.

Michael & Patricia Fogden / Minden

By contrast, tuataras can shift their diets over the course of the year. For instance, they eat more seabirds over the long dry summer, when other prey like spiders is harder to find. Small birds called fairy prions are a particular favourite. "Tuataras can vary their diet and do well all year round," says Jones.

Tuataras are often thought of as being in decline, but their problems are mostly due to human influences. "They've only really suffered since humans arrived with rats that eat their eggs," Jones says.

Before people turned up in New Zealand, tuataras survived ice ages and sea-level rises, not to mention the dinosaur extinction.

Third eye

As well as their weird mouths, tuataras are known for having three eyes – kind of. They have a "third eye" on top of their head, technically called a parietal eye. It's easily seen on the heads of young tuataras, but gradually gets covered with opaque scales as they age.

This isn't as unusual as it sounds. Plenty of animals have a parietal eye – many lizards do, including some chameleons. However the tuataran third eye stands out for being unusually well developed: it actually has a lens.

Researchers first thought the third eye helped tuataras find prey, but it turns out it is oblivious to movement, Jones says. It's now thought to be involved with the animal's body clock, perhaps helping the tuataras work out when it's the right time of year to breed.

The hardest bat in the world

SPECIES *Otonycteris hemprichii*

HABITAT Isolated patches of desert from Morocco through the Middle East to north-west India, though there might actually be two different species

Does anything eat wasps, a *New Scientist* reader once wondered. The answer was a resounding "yes". That's not surprising in a way, as wasp stings are painful but rarely fatal. So here's a better question: does anything eat scorpions?

We do. Scorpions may be deep-fried or baked with endives and cheese – but we don't let them sting us in the face first. The desert long-eared bat, surely the toughest bat in the canopy, does.

Carmi Korine of Ben-Gurion University of the Negev in Midreshet Ben-Gurion, Israel and his colleagues knew that the bats ate scorpions, because their faeces are laced with scorpion remnants, along with those of other arachnids and insects. Sometimes over 70 per cent of the remains came from scorpions. But they didn't know how the bats coped with such a challenging meal.

Scorpion footsteps

Korine's team went to a park where the bats regularly hunt, and fixed eight live common yellow scorpions to the ground with string. They found the bats foraged in pairs or larger groups, flying just over 2 metres above the ground. Every so often one would drop to the ground, landing on a scorpion.

The team then caught eight bats and watched them hunt scorpions in their lab. The bats ignored dead prey, only attacking live ones that moved. The bats also showed an interest in boxes containing live scorpions, suggesting they were homing in on sound.

To check that was possible, Korine measured the sound of the scorpions walking on soil. He found that at the bats' flight altitude they would hear it as a 30-decibel rustling, which would be easily detectable. The bats also emit echolocation calls, but Korine says vegetation would mask any signals coming back from scorpions.

When a bat landed on a scorpion, it immediately tried to bite the scorpion's head. The scorpion fought back by stinging the bat in the face, and in one case under the eyelid. The bat didn't try to avoid it, or to break the stinger, and showed no ill effects whatsoever.

Once the scorpion was dead, the bat carried it back to a roost and ate it head-first. Usually it ate the whole thing, including the stinger and poison gland.

The bats' devil-may-care approach didn't stop there. They tackled different scorpion species equally, regardless of how venomous they were. They were just as happy with relatively harmless large-clawed scorpions as with toxic common yellow scorpions.

Both pale in comparison with the 10-centimetre Palestine yellow scorpion, known as the deathstalker because of its extremely toxic venom. The bats ate those just as willingly, stings or no.

It's possible that in some cases the stingers weren't able to break the bats' skin, but the bats often went ahead and ate the entire poison gland anyway.

Korine thinks that they must have evolved resistance to the scorpions' venom – though they don't seem to have figured out the endive recipe yet.

Baby assassin bugs lure in deadly ants

SPECIES *Ptilocnemus lemur*

HABITAT Australian forests, although they are hard to spot as they keep a low profile by blending into tree trunks

Here are two helpful tips for hunting other animals. First, be a full-grown adult so you are strong and skilful enough to take them on. Second, if at all possible, surprise them so they can't attack you first.

The feather-legged assassin bug ignores both of these rules. These insects hunt even while they are immature nymphs, often targeting venomous ants bigger than themselves. And to do so, they lure the ants into trying to sting them.

Tempting attack

Plenty of predators trick their prey into approaching by dangling a lure, such as the anglerfish's famous light, and then strike. But assassin bugs are the only hunters we know of that encourage another predator to attack them, and that will not themselves attack until it has grabbed them.

It sounds suicidal, but it works.

The nymphs of assassin bugs already have the adult body shape. Matthew Bulbert of Macquarie University in Sydney, Australia, and his colleagues tracked them to see how they hunted in the wild.

A hungry nymph first waves its hairy hind legs, luring an ant to grab them. It is nothing if not ambitious, often targeting jack jumper ants (*Myrmecia pilosula*), the venom of which can kill an adult human.

Once the ant has a grip and is threatening to sting, the nymph pulls out a wrestling move, swivelling on its leg joint to position itself on top. Then it targets the ant's weak spot, piercing the back of its head.

In lab experiments, the bugs always waited until the ant had grabbed them before attacking it, even if they had not eaten for two weeks.

By inviting attack from an ant, the nymph risks being injured or killed. "It is equivalent to a jackal preying on a lion, and expecting the lion to grab the jackal's legs first," says Bulbert. "It was very much unexpected."

The strategy may seem risky, but Bulbert found it was effective. Once an ant had grabbed a nymph, the nymph killed it almost every time. The team never saw a nymph killed.

The nymphs' lure also pays off in a big way. Jack jumper ants can be three times the nymph's length, so just one provides the bug with a mega meal.

Defence into attack

But the strategy is not perfect. Bulbert found that only a small percentage of ants, usually the much larger ones, fell for the ploy.

How this behaviour evolved is a mystery. "Our best guess at this stage is that it may have started as a defensive strategy used to initially ward off ants, but has eventually been co-opted into a predatory strategy," says Bulbert.

Certainly assassin bugs have evolved a plethora of hunting strategies. One species lures spiders out across their webs by plucking at the threads in a way that resembles the struggles of a trapped insect.

Another has a long neck, allowing it to lean into spider webs and take their owners by surprise.

Mark Moffett / Minden

SPECIES *Physeter macrocephalus*

HABITAT Oceans throughout the world, especially where here are lots of big animals to eat

The biggest living thing with teeth

In the chill darkness 2 kilometres below the surface of the Southern Ocean, one of nature's greatest battles is being fought. One of the combatants is a kraken – the largest invertebrate known to exist, a colossal squid over 12 metres in length. The other is its predator.

Sperm whales can grow up to 20 metres long, making them the largest living animal with teeth. Blue whales are bigger, but they are toothless baleen whales.

So named because its head contains a creamy sperm-like fluid, the sperm whale is one of the few animals that can hunt and kill adult colossal squid. It may be bad news for the Antarctic's krakens, but it is good news for us. The whales' deep-sea depredations act as a carbon sink, slightly easing the effects of anthropogenic climate change.

Almost all marine life is found within 200 metres of the surface, the so-called photic zone. In this sunny region there

Hiroya Minakuchi / Minden

is enough light for microscopic plants called phytoplankton to photosynthesise, absorbing carbon dioxide. In turn, the phytoplankton support a network of animals that feed on them and each other.

Iron dump

In 2010 it was shown that Southern Ocean baleen whales help keep this process going by releasing huge amounts of iron in their faeces. The Southern Ocean is short of iron, limiting the amount of life it can sustain, but these injections of iron help out.

Trish Lavery of Flinders University in Adelaide, South Australia, and her colleagues took the work step further. They found that although baleen whales help keep the iron cycle going, sperm whales inject iron into it by hunting at great depths and defecating when they return to the photic zone.

In effect, sperm whales ferry iron

from the depths to the surface, where the phytoplankton can use it.

Based on existing studies of sperm whale behaviour and anatomy, Lavery calculated that the 12,000 sperm whales in the Southern Ocean collectively eat 2 million tonnes of prey each year – including 60 tonnes of iron.

Of this, about 36 tonnes ends up in the photic zone. That keeps swathes of phytoplankton going, taking in CO_2 from the atmosphere, that otherwise couldn't make a living there.

Of the carbon the phytoplankton absorb, between 20 and 40 per cent ultimately sinks to the bottom of the ocean as various forms of waste. Lavery's team calculated that 400,000 tonnes of carbon gets dumped in this way every year as a result of the sperm whales' activities – far more than the estimated 160,000 tonnes the whales release by breathing.

Deep hunter

All of which raises the question, how do sperm whales bring down such monstrous prey? No one has ever seen a sperm whale attack a colossal squid, but we can still work some of it out.

The whales have one advantage. In the cold Antarctic, colossal squid are rather slow-moving, lying in wait and ambushing their prey rather than actively hunting them. As a result, a hungry sperm whale might not have to chase very hard.

Similarly, the rather less enormous jumbo squid of the eastern Pacific actually go deeper to cool off, and the local sperm whales may hunt them at depth because they are slower and thus more vulnerable down there. What's more, even the sizeable giant squid is something of a weakling despite its fearsome reputation.

Loudest sound

Still, a weapon or two might be handy, and this could be where the sperm comes in. The spermaceti fluid is used to focus loud clicks, which the whales use for echolocation. The clicks can be over 230 decibels, making them the loudest sound produced by any living thing. It's been suggested that the whales use these clicks to stun their prey, but when they were played to prey animals in the lab there was no effect.

The spermaceti also cushions the whales' heads, particularly in males, which have much more of the stuff than females do. This allows fighting males to ram each other (or, in *Moby-Dick*, ships). However, there is no evidence of them ramming prey.

Females have their own hunting method. They live in tightly knit groups called pods, communicating with loud clicks and sharing the care of their calves. A tracking study earlier this year suggested that females hunt in packs, herding jumbo squid into "bait balls" just as dolphins do with fish. Young males live in "bachelor" pods and may therefore do the same thing, but as they get older they become solitary.

But if we really want to find out how they win their titanic battles, we need to get a video camera down there.

SPECIES *Palpimanus gibbulus*

HABITAT Mediterranean countries, particularly Spain and Portugal, tiptoeing towards other spiders

Meet the spider that hunts the spiders that hunt spiders

If you've ever wanted to kill an animal and eat it, pick something that's either smaller than you or can't fight back, or preferably both. Otherwise you might bite off more than you can chew.

Not every predator takes things that easy. The desert long-eared bat happily munches on deadly scorpions, and footage from 2011 showed a ground beetle tackling a toad several times its size. That's impressive, but toads are not exactly vicious predators.

To really display your ballsiness as a predator, you need to take on other predators – preferably ones that would eat you given half the chance.

That's exactly what the spider-eating spider *Palpimanus gibbulus* does. This arachnid thug muscles its way into other spiders' homes and attacks them head-on.

If you have never seen a *P. gibbulus* in action, you're not alone. They hunt at night and are extremely rare, so we know very little about how they behave.

Spying on the relatives

Stano Pekár of Masaryk University in Brno, Czech Republic, and his colleagues wanted to find out how these spiders hunted. But they proved so elusive that the team had to combine *P. gibbulus* data with observations of a related species, *P. orientalis*. Found in Israel, *P. orientalis* is so similar to *P. gibbulus* that the two species can only be distinguished by their sex organs.

The team captured spiders in pitfall

Stano Pekar

traps and by searching under stones, and kept some of them in their lab. To find out what they could hunt, they tested 92 *P. gibbulus* and 65 *P. orientalis*. In each trial they put a single spider in a Petri dish, along with a single prey spider, and observed whether the *Palpimanus* could catch it.

It turned out they could catch each of the 29 kinds of spider they were offered, and caught all but one species in more than half the trials. It didn't matter which family the prey came from, nor what size they were. *Palpimanus* was equally happy catching spiders a third its size or twice its size.

In one series of experiments, they presented *P. gibbulus* with a jumping spider called *Cyrba algerina*, which also habitually eats other spiders. *P. gibbulus* caught it in 90 per cent of trials, although in the other 10 per cent it was itself captured.

Spider stealth

What's their secret? According to Pekár, *Palpimanus* spiders have a battery of adaptations for hunting other spiders.

The most obvious is their massive front legs, which they use to grab their prey. Like many hunting spiders, they have dense tufts of extremely sticky hair on the tips of their legs.

When Pekár glued these hairs together, the spiders became much less successful at hunting.

Palpimanus isn't fast but it's stealthy, closing on its prey so carefully that the prey may not be able to detect any vibrations from its footfalls. That means it can get up close, at which point it lunges, grabs the prey with its forelegs and administers a venomous bite.

In many cases the prey spider bites right back, but this doesn't do it much good. *Palpimanus* has a cuticle tens of micrometres thick, over twice as thick as any of its prey species and possibly the thickest for a spider of its size, so bites rarely do it any harm.

Apart from the trials with *Cyrba algerina*, only 1 per cent of trials ended with the prey species killing *Palpimanus*.

Pekár thinks that *Palpimanus* hunts by entering other spiders' webs and burrows. A related Ugandan species has been seen doing that. Confident in its armour, *Palpimanus* can trap its prey in their homes and overwhelm them.

Its intricate offensive strategy puts *Palpimanus* on a par with the more famous spider-eating spiders *Portia*. Found in tropical forests, *Portia* wait for their prey to be distracted by food before attacking, and sometimes twang their prey's web to mimic the impact of a twig, disguising their approach. They can even plan new strategies to handle unfamiliar prey.

Can *Palpimanus* also learn and plan? There is much less information than there is for *Portia*, says Pekár, so we can't say for sure.

But *Palpimanus* does use different strategies for prey in webs, in nooks and crannies, and in the open, so it is versatile. Pekár suspects it can learn from its experiences and change its strategies accordingly.

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5. Weapons galore

Hipster toad has weaponised moustache

SPECIES *Leptobrachium boringii*

HABITAT New York's Williamsburg, London's Hackney and San Francisco's Mission district. Also slow-flowing streams in isolated mountainous regions of south-west China

It's the start of the breeding season, and a male toad is poised for success. He has an excellent rock in the middle of the stream, an ideal nesting site that will attract plenty of females. Life is good.

Not for long. Another male is coming – big and muscly, a real brawler – and he wants the rock. What's more, he has a moustache and he's not afraid to use it.

Among humans, a lush moustache isn't necessarily a sign of a high-quality male – regardless of what the hipsters of Hackney, Williamsburg and San Francisco want you to think. But for Emei moustache toads, a top-quality moustache is an essential weapon.

Spiky characters

Most amphibians are relatively gentle souls. "Combat is normally wrestling or posturing," says Cameron Hudson of the University of Guelph in Ontario, Canada.

But not for Emei moustache toads. Males are bigger than females, a clue to their violent nature. Among amphibians it's usually the other way around; males only outgrow females in species where males fight. In a few of these, males grow spines on their top lip, giving Emei moustache toads their name.

During the breeding season, each male grows 10 to 16 spines. "They are as sharp as a pencil lead," says Hudson. The toads "do try to stab you a bit when you pick them up", he adds.

They spend most of the year in forests, but in February and March they go to streams to breed. Males arrive first and claim rocks in the fast-flowing water. They spend weeks swimming around their chosen rock, with little food, grunting to attract females.

Puncture wounds

To find out how the breeding season plays out, Hudson and his colleague Jinzhong Fu monitored moustache toads living on a 300-metre stretch of river near Mount Emei in Sichuan, China, over two breeding seasons. They captured and tagged 77 toads, then checked which frog was in

ChinaFotoPress/Getty

control of the nest sites every day.

Hudson saw seven fights between males, and filmed five. He estimates that there must have been at least 14 fights on this one stretch of river, as many males lost their nest sites to others.

The males fought underwater, headbutting each other in the belly to drive their spines into the other toad's flesh. "I've never seen any of them kill each other," says Hudson. "But they get a lot of puncture wounds."

Caring daddies

Females visited the males at nest sites and laid their eggs on a submerged part of the rock for the males to fertilise. Job over, the females promptly headed back to the forest. Their partners stayed behind to care for the eggs: these toads are caring daddies as well as brawlers.

When Hudson examined the genes of males and the eggs they were guarding, he found that many males took care of eggs that weren't theirs. They probably drove out a previous male, and took over his eggs as well as his nest site. "I'm not sure if they care for the other eggs, but they don't harm them," he says.

It's not clear why conquering males refrain from destroying their vanquished rivals' eggs. Having the extra eggs might mean their own are more likely to survive if a predator attacks the nest. Alternatively, females might prefer males that already have eggs, believing them to be high-quality.

It's also not clear what makes for a successful male. The spines don't vary in length much, so size may not be a factor. Hudson says the size and strength of the males may be key, as stronger males could drive their spines further into their competitors' bellies.

All this frantic activity comes to a fairly abrupt end. The last females leave in early March, and the males stop fighting. Their spines fall out. Once the broods hatch, the males head back to the woods and leave the tadpoles to fend for themselves.

Shrimp wields strongest club in the world

SPECIES *Odontodactylus scyllarus*

HABITAT Hitting things throughout the Indo-Pacific, from Guam to East Africa

S.Baron

The snail never saw it coming. One minute it was creeping slowly along the seabed, minding its own business. Then a lightning hammer blow fell. In an instant its shell was smashed and it was at the mercy of a ruthless predator.

The phrase "hammer blow" is used literally. The peacock mantis shrimp has two built-in hammers that can deliver swift and powerful blows, smashing straight through other animals' armour.

But that raises a question. To break a hard thing, you have to be even harder, or you'll just break yourself. So what is it about the hammer of the peacock mantis shrimp that makes it so tough?

Quick hits

Mantis shrimps are not shrimps, though they do belong to the same group. They are aggressive predators. Some mantis shrimps can see circularly polarised light, the kind often used to create 3D movies. The colourful patterns on their bodies reflect polarised light, perhaps as threatening signals.

There are two types of mantis shrimp, with different modifications to their front claws. Some have turned the claws into spears to impale their prey, while others – like the peacock mantis shrimp – have turned them into clubs.

Peacock mantis shrimps deliver one of the fastest blows in the world. Their clubs move at 23 metres per second, and accelerate at over 10,000 *g*. They deliver a force of 700 newtons – the same as the weight of a 70-kilogram mass – or even 1500 newtons.

With this weapon, they can bash through the shells of molluscs and crabs. Larger peacock mantis shrimps have even been known to smash their way out of fish tanks. The blows are so powerful they cause cavitation: they create tiny bubbles in the water that instantly implode, delivering even more energy to their victims.

Hard clubbing

So why don't their clubs break? The shrimps do eventually replace each club when they moult, but not before they deliver thousands of powerful impacts. David Kisailus at the University of California, Riverside, and his colleagues looked at their structure to find out.

They found that the head of the club is divided into three main layers. The outer impact region is mostly a tough mineral called hydroxyapatite, also found in bone. The hydroxyapatite is arranged in neat crystals, making a strong coating.

In the next layer, the hydroxyapatite is less organised. Beneath that is a layer of chitin, the polymer that crustaceans use to make their shells. The layers differ in how bendy they are, so it's hard for a crack that forms in one layer to affect the next. What's more, the chitin is arranged in spirals so that any cracks grow in spiral patterns, barely weakening the overall structure.

Clearly, the peacock mantis shrimp has a strong hammer. If only it would meet a marvel of advanced technology, a skilled archer, a defrosted tough guy, a black widow and a big scary green thing, it could star in a successful movie.

How to eat if your guts are a weapon

SPECIES *Parastichopus californicus*

HABITAT Shallow seas along the west coast of the US

On the sandy sea floor, two spiny goliaths are in a face off.

In one corner is the giant California sea cucumber, a formidable organism at half a metre long. In the other is the sunflower seastar. Don't be fooled by its endearing name: this guy is twice the size of the sea cucumber. That, however, does not make it a shoo-in for victory. The sea cucumber has an unusual trick up its sleeve.

Having failed to escape its foe, the sea cucumber goes for the explosive option. It squirts its digestive system out of its anus in a tangled, sticky mess, confusing the seastar and allowing the sea cucumber to get away.

The sea cucumber has escaped being eaten, but now it has a new problem. Surely, without a digestive system, it can't eat anything? Think again. This animal can eat through its anus.

Mop of tentacles

Sea cucumbers may look like slugs, but they are actually echinoderms, related to starfish and sea urchins. The giant California sea cucumber is a scavenger that prowls the sea floor. Its head has an array of mop-like tentacles, which it splays onto the sediment. The tentacles pick up tiny chunks of food, and it then inserts them into its mouth to feed.

Like many sea cucumbers, it can eviscerate itself when under attack or otherwise stressed. Many animals can shed limbs, tails or skin when in danger, a process called autotomy. Sea cucumbers simply go further than most.

What's more, it seems the giant California sea cucumber can reabsorb most of its organs during winter, when food is scarce, and become dormant.

Its anatomy is, by human standards, a little peculiar. It doesn't have gills or lungs, but it does have a respiratory system that is directly connected to its anus, through which it pumps in water. This flows into a network of branched tubes called the respiratory tree, which takes in oxygen from the seawater.

But the respiratory tree can take in more than oxygen, says Richard Strathmann of the University of Washington in Friday Harbor. It also takes up dissolved organic compounds.

Mark Conlin/OSF/Getty

That may seem a bizarre way to eat, but it's perhaps not too surprising. Most echinoderms can absorb dissolved food through exposed skin, so extending that function to the "lungs" is not too great a leap.

However, working with William Jaeckle of Illinois Wesleyan University in Bloomington, Strathmann has shown that the giant California sea cucumber can go much further.

Bottom feeder

Strathmann and Jaeckle gave captive sea cucumbers two kinds of labelled food. Some got single-celled algae, inoculated with radioactive carbon-14. Others received polysaccharides or proteins that contained iron.

At intervals over the next 26 hours, the researchers took samples from different tissues within the sea cucumbers, and tested them for carbon-14 and iron.

Most of the carbon-14 wound up in the respiratory tree, with very little in the digestive system, suggesting it was being taken in through the anus and respiratory system. The same pattern was seen with iron.

That means the sea cucumber isn't limited to absorbing dissolved nutrients via its anus and respiratory tree – it can take in larger food such as algae, too. It is the first animal known to do so, Strathmann says.

It's not clear how the respiratory tree digests the algae. Nor is it clear why the anal feeding evolved. Strathmann says it could well be a backup to allow the sea cucumber to feed without its main digestive system.

Alternatively, by allowing it to feed on algae as well as rubbish on the seabed, it could be a way to take in a range of nutrients. Other animals, in particular simple worms, may also have evolved anal feeding, and for similar reasons.

Strathmann says the sea cucumber probably uses its anal feeding as a supplement, and still gets the majority of its food through its mouth and digestive system.

"But even as a dietary supplement, nutrition taken through the anus is a remarkable reversal of what we expect."

Robin Hood meets his underwater match

Species *Toxotes chatareus*

Habitat Coastal waters of the Asia-Pacific region, including Sri Lanka, India, New Guinea and northern Australia; typically in murky, brackish water just under the surface

Archerfish may not carry a bow and arrow, but all they need to shoot like one of Robin Hood's merry men is the chance to watch an expert at target practice.

The shimmering fish, with dashes of black on their silver flanks, are the sharpshooters of the estuaries and mangroves of Asia and Australasia.

Having chosen an insect perching unawares on low branches as prey, they press their tongue against the roof of their mouth, snap their gills shut and squirt long shots of water from below the surface that knock the critter into the water. Archerfish can dislodge prey at distances of more than 10 times their own length.

But it's not a matter of "shoot and hope" for the cunning archerfish. They fine-tune the size of their water jets to both the size of their prey and how well the prey is gripping the surface it is standing on.

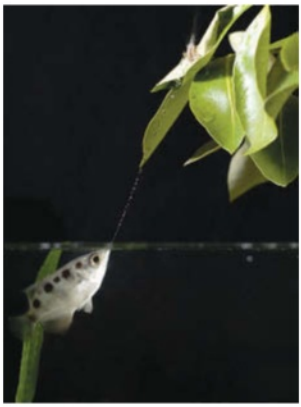
In 2006, Stefan Schuster, then at the University of Erlangen-Nürnberg in Germany, and his colleagues showed that for any given size of prey, archerfish tuned their inbuilt water guns to hit the insect with 10 times the force required to knock it off its perch.

Aiming high

Then there's the tricky business of aiming at something that is above water from beneath the surface. Light bends at the interface between water and air, creating a familiar optical illusion that appears to shift the position of everything on the other side of the surface. Archerfish compensate for this when they aim their watery shafts.

By shooting beams of light of different wavelengths on to the retina of archerfish and recording the amount of light that different cells absorb, Shelby Temple, previously of the University of Queensland in Brisbane, Australia, showed in 2010 that archerfish have specialised colour cells in their retina – much like humans.

Temple, now at the University of Bristol, UK, says this must increase



Shelby Temple/The University of Queensland

their ability to distinguish different colours – the brown of an insect against a green background, for instance. He believes this is key to the fish's remarkable aim.

Once the prey is hit, the shooter must beat its peers to the catch. In less than 100 milliseconds, it assesses the initial movements of its downed prey to predict where it will hit the water. This snap assessment is so accurate that fish and prey usually arrive at the same time.

Watch and learn

Does this come naturally to archerfish? According to Schuster, now at the University of Bayreuth in Germany, to be a sharpshooter you have to first watch and learn.

He found that inexperienced archerfish could learn to hit rapidly moving targets just by observing mates with greater Sherwood Forest skills – without practising a shot themselves.

Schuster kept groups of five unskilled fish, all unable to hit moving targets, in the lab. He released flying insects as targets, but only one dominant fish in each group would practise. The others were forced to watch: if they tried to get within range the dominant fish would chase them away.

Once the dominant fish had learned to hit the target, Schuster removed it and let the others have a go. Almost all matched the hit rate of the practised fish. And in each case, the observers' first try was far better than their attempts before they watched the dominant fish learning to shoot.

Horror lizard squirts tears of blood

SPECIES *Phrynosoma cornutum*

HABITAT Dry and sandy areas of the southern US and Mexico, hiding in plain sight

If ever there was an animal that said "don't even think about eating me", it would be the Texas horned lizard. It has more defences than the Death Star, ranging from excellent camouflage to a subtle gift for risk assessment and bony spines on its head. Best of all, it has a last-ditch retaliatory measure as gory as that of the "horror frog", a beast from Cameroon that breaks its own bones to make claws.

Around 7 centimetres long, the lizard looks like a small armoured dinosaur that has been put in a trouser press. Its body is flattened to the ground, helping to disguise it, as does its mottled skin. Spines run down the side of the body and tail, and sprout all over the head – including two large ones on the top that look like horns.

It eats harvester ants called *Pogonomyrmex*, which would seem a pretty unappealing lunch: they possess some of the most toxic venoms known. The hungry lizards capture the ants on their tongues and immediately swallow them. Folds in their throats then wrap them in threads of mucus that effectively immobilise them. As a result, they can eat dozens of the insects without getting hurt.

But in turn, the lizards are hunted by a host of predators, including birds of prey, snakes and carnivorous mice. Because their camouflage is so good they can often escape by sitting still, but sometimes that's not enough.

Sizing up risk

William Cooper of Indiana University-Purdue University Fort Wayne and Wade Sherbrooke of the American Museum of Natural History in New York studied how Texas horned lizards responded to approaching predators.

They captured 45 lizards and placed them one by one in a large arena. With a lizard at one end, Cooper crept up on it

Raymond Mendez/ Earth Scenes / Animals Animals

to see how close he could get before the lizard fled. The first time he tried it, the animal fled once he got within 1.3 metres. When he repeated the test the lizards were jumpier, fleeing when he was 1.9 metres away.

Cooper also tried a second test, in which he stood still close to a lizard looking away from it, and then turned either towards or further away from it. The lizards' response depended on how close he was. If he was 2 metres away, they didn't flee even if he turned towards them, but at 0.5 metres they ran even if he turned away.

Cooper and Sherbrooke argue that this means the lizards can judge how much risk a predator poses.

In 2010 they also showed that the lizards are quicker to flee if a predator approaches at a run or if it heads straight for them rather than meandering in their general direction.

Tough Texan

Many other animals make these sorts of judgements, balancing the risk of being eaten against the cost of having to run away, which might mean losing out on a food source or a chance to mate. The brain mechanisms responsible may well be many millions of years old.

It's almost surprising that the Texas horned lizard has bothered to retain them, though, given how well defended it is. If a predator does see through its camouflage and the lizard can't escape, it is anything but helpless.

First it turns side-on to the predator, advertising both its length and the spines running down its body.

If that's not enough, it borrows a trick from pufferfish and inflates its body like a balloon. This makes it more intimidating, and as a plus any animal actually attempting to swallow it is liable to choke to death.

Any predator brave or desperate enough to persist will get a nasty shock if it tries to bite the lizard. The tough Texan bows its head, as if in prayer – with the result that the two horns on its head are likely to go through the roof of the predator's mouth.

Extreme weapon

As a last resort, the lizard will assault the predator by squirting a jet of blood out of its eyes. This rather extreme weapon confuses the predator and allows the lizard to escape.

The lizard may release a third of its total blood supply this way, amounting to 2 per cent of its body mass, and the jet can travel several feet. The blood is laced with noxious chemicals, which may come from the venomous ants that are the lizards' preferred diet.

Dogs are particularly vulnerable to the blood, and if they get sprayed they spend a while shaking their heads to get rid of it. The lizards seem to know this and are more likely to use it on dogs than on other predators.

Autohaemorrhaging, as this gory trick is called, is moderately common in insects, but horned lizards seem to be the only group of vertebrates that do it.

It's a wonder anything ever does manage to eat them.

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SPECIES *Nylanderia fulva*

HABITAT Originally from South America, but more recently found terrorising the southern US

Triumph of the crazy ant

Lawrence Gilbert/University Texas-Austin

If you want to prove yourself, take down the best. Muhammad Ali surprised the boxing world by taking down Sonny Liston to become world champion. Likewise, the tawny crazy ant is taking on its worst possible foe – the fire ant.

With a vicious sting powerful enough to kill small animals, fire ants have been running amok in the southern US since they arrived in the 1930s. But in the last 10 years their numbers have been decreasing, thanks to a newcomer, the tawny crazy ant. Not only will the ingenue face down the indomitable fire ants in battles over food, it even moves into their nests. What is the secret of its success?

On the face of it, tawny crazy ants would have to be, well, crazy to take them on. Unusually aggressive for ants, fire ants attack anything that disturbs their nest. Their wasp-like sting causes a burning pain and is toxic enough to fell small animals; it has even killed people by provoking a massive allergic reaction. They prey on larger insects like crickets, nestlings of ground-nesting birds, and reptile eggs.

Brutal foe

Fire ants are savage fighters. Their venom is a mix of alkaloids and enzymes, including neurotoxins that disrupt the nervous system. A fire ant tends to bite its target to hold it still, before injecting the venom with the stinger on its abdomen. Worse, the fire ant does not lose its sting in an attack, so can sting its victim repeatedly.

Alternatively, the fire ant can raise its abdomen during a fight to free up the stinger, from which it exudes a droplet of milky fluid. The ant then flicks this ball of venom at its enemy,

or simply slaps it straight on.

No US ant can compete with fire ants, so they have spread rapidly from the port of Mobile, Alabama, where they were accidentally introduced. They are seriously bad news, destroying crops, causing electrical faults, and even causing roads to collapse under cars by digging holes beneath the asphalt.

Battle zone

Suffice to say the tawny crazy ant – the name comes from the "herky-jerky" way they run around – has its work cut out for it. To find out its secrets, Edward LeBrun of the University of Texas in Austin laid a simple trap. He placed a cricket in an area where both fire ants and tawny crazy ants lived, then sat back to watch.

Fire ants arrived first, and soon several hundred had gathered. Other ants avoid large groups of fire ants, but not so the tawny crazy ants. They came charging in, rearing onto their hind legs and spraying their acidic venom into the crowd. The fire ants retaliated by slapping and flicking their venom.

But it was what happened next which surprised LeBrun. If a crazy ant was hit with venom, it ran out of the battle zone. Then, like a cat cleaning its fur, it doubled over to reach down to the acidopore, the gland that secretes its formic acid venom.

Using its mandibles and forelegs the ant covered itself with its own acid, before running back into battle. LeBrun suspected this grooming behaviour was a way to detoxify the fire ant venom.

So LeBrun and colleagues either sealed up the crazy ants' acidopores with a dab of nail polish, or applied the polish to the sides of their bodies. Then they placed each ant in a jar with two fire ants until one of them dabbed it with its stinger. After eight hours, half the crazy ants with sealed acidopores had died, but almost all of those who could still groom themselves survived.

Wondering if the formic acid in crazy ant venom was the key to its curative properties, LeBrun daubed Argentine ants, which will succumb to a fire ant attack, with a drop of fire ant venom. Some were also daubed with formic acid, and they mostly survived, while those not exposed to formic acid usually died. LeBrun says it's not clear how formic acid detoxifies fire ant venom, but it might neutralise the enzymes that make the venom so potent.

It is not entirely surprising that tawny crazy ants can resist fire ant venom. Both hail from the same areas of South America, where they would have been competitors. But although they are now displacing harmful fire ants in the US, they bring problems of their own.

"If you are allergic to fire ant stings then crazy ants are your friend," says LeBrun, but that is the only plus.

Tawny crazy ants cause more damage than fire ants. They also nest in any cavity they find.

"They come into your house, forage in your house, and cause a nuisance that fire ants don't," LeBrun says.

"You know the song about the old lady who swallowed a fly? It's that issue."

Traitorous fish throw friends to the wolves

SPECIES *Astyanax bimaculatus*

HABITAT Screwing over their friends in clear rivers and ponds throughout most of South America

If you're being chased by a hungry bear, you're more likely to escape if you have a friend running beside you. That way, the bear might kill your friend, not you.

In this situation, as many wags have noted, you're not really running away from the bear. You're just trying to run faster than your friend.

Not cynical enough? You could try to trip your friend up or break their leg, except you're probably too decent to do that. But one fish has no such qualms.

Hydro hijackers

At first glance, a twospot astyanax looks pretty innocuous. This small fish swims in groups up to 50 strong, eating a mix of plankton, plants and debris. People in South America keep them as pets.

However, they are a bit of a nuisance. "There's a big problem with fish entering hydroelectric power station machinery," says Robert Young of the University of Salford in the UK.

So a few years ago, Young and Vinícius Goulart of the Pontifical Catholic University of Minas Gerais in Belo Horizonte, Brazil, started investigating ways to deter the fish from getting into the machinery. That included a few attempts at scaring the fish away. To their surprise, the pair discovered that the astyanax turned on each other if a predator approached.

"It was a fortuitous discovery," says Young. He and Goulart have now studied the fish's treachery in more detail.

They kept twospot astyanax in eight groups of eight, ensuring all members of each group were roughly the same size. Then they exposed them to three simulated attacks, and a control.

Mock ambush

In some trials, the researchers mimicked a predator attack by bringing a resin replica of a hunting fish called a trahira close to the astyanax. In others, the fake predator lurked in a plastic tube and "ambushed" passing astyanax. A third test simulated a bird like a heron trying to peck the astyanax out of the water. There was also a control: a plastic box being gently put into the fish tank.

Johnny Jensen/JJPhoto.dk

When confronted with the predator attack, the astyanax turned on one fish in the group, which became a target for some of the others to chase. They bit it and crashed into it. The unlucky fish fled and hung around on its own for a few seconds before rejoining the group.

The other scenarios, including the control, did not provoke this response. Young says that is because birds and ambush predators do not target weaker members of the shoal: they just go for the closest astyanax. So in these situations, it would not benefit the astyanax to attack one of their number.

"In a life-or-death situation, individuals are selfish," says Young. "But this is one of the few examples of directly selfish behaviour."

Safety in numbers

Small fish often protect themselves by swimming in large groups, making it hard for predators to target a specific fish: there is, literally, safety in numbers. In theory, all animals that could become prey have an incentive to attack their fellows when the group is threatened. So why is it only the astyanax that does?

Young says other species might betray each other in the same way, but perhaps nobody has managed to observe this behaviour yet. "It might be these things are more common than people realise." However, social animals often punish individuals that cheat the group, and this might deter animals from attacking their fellows.

The astyanax may also be more likely to turn on each other than other prey, because they live in such small groups.

In Young's experiment, each astyanax had a one-in-eight chance of being targeted by the predator, odds which provide a strong incentive to throw one of their fellows under the bus. But many fish swim in shoals hundreds or thousands strong. For these fish, lost in the crowd, betraying each other may not be worth the effort.

Even when faced with a hungry troll, the three billy goats gruff were never this mercenary.

SPECIES *Indicator indicator*

HABITAT Worrying bees and other birds throughout sub-Saharan Africa

World's nicest bird murders chicks

If there's one word that sums up a newborn human baby, it's "helpless". Newly hatched greater honeyguide chicks are more capable – chillingly so.

They emerge into pitch darkness, inside a tunnel dug by another bird where their mother has left them. The host bird's own chicks soon hatch and join them.

If this was a slasher movie, now would be the time to cover your eyes.

The young honeyguide kills the other chicks within an hour. All this from a bird that as an adult helpfully guides humans to bees' nests, which the humans then raid for honey.

Early to hatch

Honeyguides lay their eggs in other birds' nests, just like cuckoos. Claire Spottiswoode of the University of Cambridge studies them in southern Zambia, where they tend to parasitise little bee-eaters. These birds dig tunnels in the sandy ground, often in the roofs of aardvark holes, where they

lay their eggs. Spottiswoode was able to insert video cameras into these nests.

Female honeyguides slip into the tunnels and lay their own eggs there. If there are any little bee-eater eggs in place, the honeyguide mother punctures them with her beak. That's not always enough, however, because eggs sometimes survive and the little bee-eater may lay more. Spottiswoode found that only 67 per cent of host eggs were punctured in parasitised nests.

But the honeyguide chick has an advantage. Its mother incubates the egg inside herself, allowing it to hatch two to four days before those of the little bee-eater.

When the rightful chicks hatch at 1.8 grams on average and with thin skin and skulls, the honeyguide is ready. Bulked up to 9.1 grams, it attacks the baby bee-eaters. "They don't stand a chance," Spottiswoode says.

The honeyguide reaches out haphazardly in the dark, perhaps sensing a chick moving, and bites into it. It has sharp hooks on the front of its beak that can inflict plenty of damage.

The honeyguide then chews on its victim, opening and closing its beak, and shakes it like a terrier shaking a rabbit. Once the chick stops moving, the honeyguide discards it – but it can take up to 7 hours for the chick to die.

With no one to compete for the host parents' attention, the honeyguide stays in the nest for another month. It begs for food using a strident call that sounds, to human ears at least, like an entire brood of little bee-eater chicks.

Claire Spottiswoode/ University of Cambridge

Baby cuckoos are known to mimic the sound of a brood of reed warbler chicks, and it may be that honeyguides have evolved the same ability.

At any rate, the honeyguide's calls whip the host birds into a frenzy, and they bring it a lot of food. "They end up tremendously fat, with gigantic pot bellies," says Spottiswoode.

Leading people on

It's a far cry from the behaviour that made the greater honeyguide famous. In return for guiding people to honey the bird gets a meal of larvae and, rather unusually, wax. "I'm guided about once a fortnight when I'm in the field," Spottiswoode says.

A honeyguide gets a human's attention by flying close to them and calling persistently. Then it flies away for a minute or more, before returning and perching in a conspicuous place. When the person approaches the bird flies to another perch. In this way it can lead them for a kilometre or more.

After they reach the nest, the bird calls more softly. At this point it's up to the human to break in. The standard trick is to start a smoky fire, which stupefies the bees and reduces the chances of getting stung.

It seems the behaviour evolved alongside early humans in Africa, although we don't know exactly when. Given that honeyguides never meet their parents and aren't particularly social, it seems likely that the behaviour is genetically controlled. But it may also be dying out, as people in Africa take to

keeping domesticated bees rather than hunting for wild nests.

There's no question that the birds do guide humans. What is controversial is the claim that honeyguides lead other animals to bees' nests.

Badger buddies

Plenty of animals have been said to cooperate with honeyguides, but the standard story is that their partners are honey badgers. It's an odd idea, because despite their name honey badgers are actually carnivores that eat anything from insects to mammals.

The claim dates back to Anders Sparrman, a Swedish traveller who visited Africa in the 1770s and 80s. He didn't see the behaviour himself, but heard about it from local people. Most later accounts of the behaviour can be traced back to Sparrman.

Since then, no one has seen it. "We have to be very sceptical," says Spottiswoode, who points out that the honeyguides might occasionally follow the badgers rather than guiding them.

There is some film of a honeyguide apparently leading a honey badger to a bees' nest. It's featured in the 1974 cinema documentary *Animals are Beautiful People*, and you can see it – with hilarious narration – on YouTube.

Sadly, it seems this footage is fake. The honey badger is trained, while for the most part the honeyguide is dead, stuffed and on the end of a string.

Mireschen Troskie-Marx, director of the Mimosa Film Group that owns the movie, says: "The various cutaways of the wild honeyguides unfortunately don't show real guiding behaviour and the 'two-shots' of the bird and badger appear to have also been contrived."

It's not as nasty a piece of fakery as hurling lemmings off a cliff to show the mythical "mass suicide", as Disney did for *White Wilderness*, but it's not real.

Claire Spottiswoode/ University of Cambridge. Right: Jane Burton / Naturepl.com

The rules of fish Fight Club

SPECIES *Betta splendens*

HABITAT Warm freshwater ponds of South-East Asia, and numerous aquaria worldwide

The clue's in the name. Male Siamese fighting fish are so aggressive that they have the dubious distinction of being perhaps the only aquatic animal whose fights are the subject of organised gambling. Fighting fish will swim through rings or down runways for a

chance to take a pop at a rival – and will even attack their own reflections.

Yet despite a predilection for using their sharp teeth to tear opponents apart and their tails to beat them to a pulp, a 2010 study suggests that differences in the fishes' fighting styles reflect distinct personalities.

Some attack furiously and constantly, like boxers pummelling their opponents into submission. Others are more considered, carefully watching their opponents before deciding when to strike – like martial artists waiting for a sign of weakness. But why?

It's not surprising that the males fight when they feel that territory is being invaded. But they choose their battles, and their tactics, carefully, attacking sooner and more vigorously if the opponent has himself recently been fighting.

The fish also observe a hierarchy, fighting differently according to whether their opponent is senior or junior. Lashing out at a vastly superior competitor is a bad idea, and males don't do it – as long as they haven't lost track of the pecking order.

Fish with personality

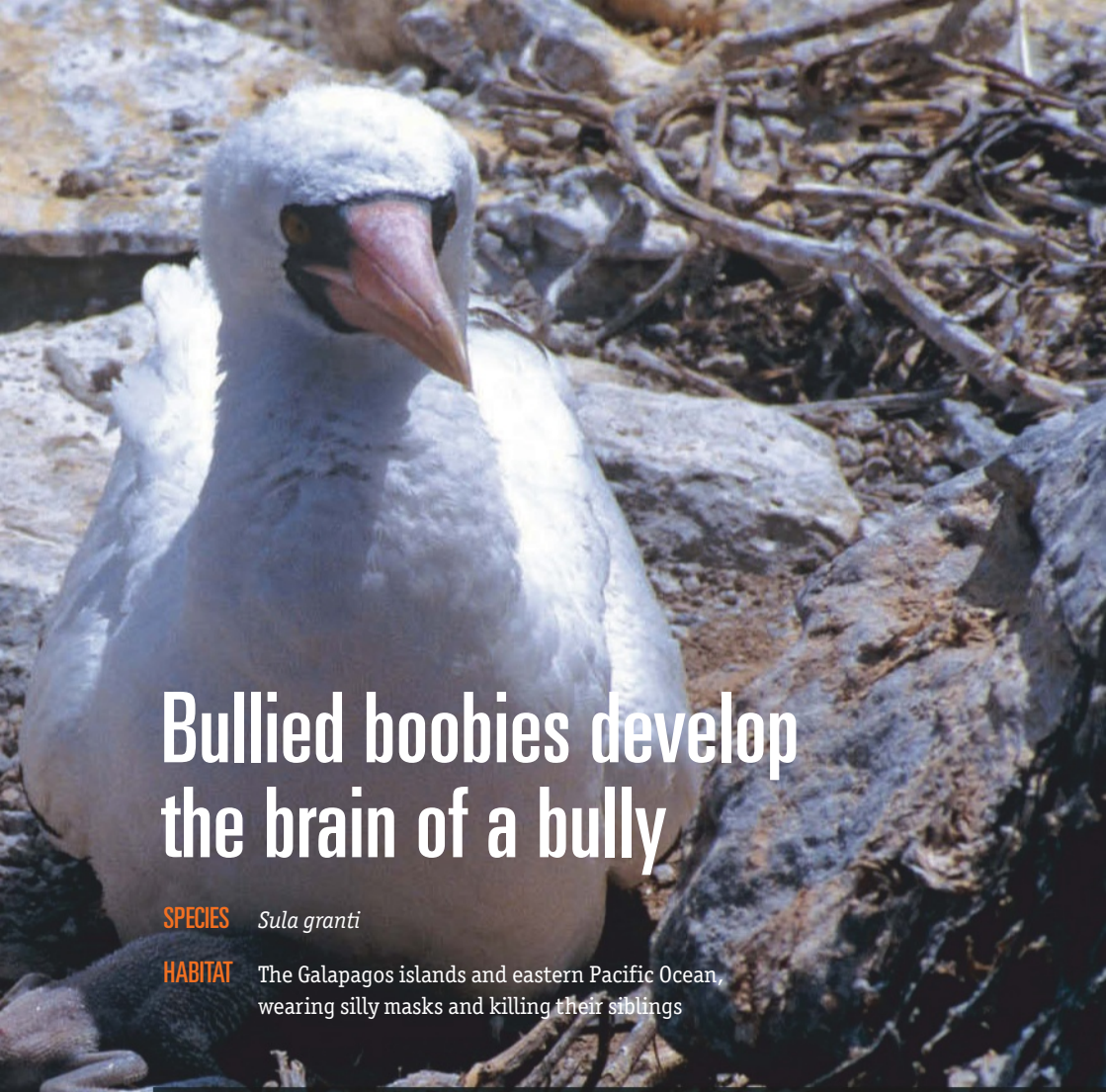
Giuliano Matessi, formerly of the University of Copenhagen, Denmark, and his colleagues have found that the males fall into two broad personality types. They're either "persistent", spending almost all their time patrolling the borders of their territory and signalling to their neighbours; or "sporadic", taking regular breaks to lurk somewhere away from their neighbours. That suggests Siamese fighting fish will have to be added to the ever-growing list of animals that seem to have distinct personalities.

Matessi's team placed individual fish in a cluster of tanks and looked at what happened to the different personality types when they were moved to a new tank, with a new set of neighbours. The persistent fish kept on patrolling and posturing, as before. This is consistent with an earlier study which showed that the more aggressive Siamese fighting fish tend to stay that way, no matter what changes are made to their environments.

However, the sporadic fish chose to spend a lot of time in positions where they could keep an eye on their neighbours without interacting with them. They became only slightly more aggressive.

The researchers suggest that the persistent fish prefer to take a direct approach to finding out about their neighbours, by jumping right in and competing with them. The sporadic fish, by contrast, are more inclined to eye up the competition for a while before doing anything.

The latter might seem a better strategy – know your enemy and all that – but it requires constant vigilance to work. If two sporadic fish which each lost their last conflicts happened to meet, they might both infer that the other is weak and then attack relentlessly. And that would be a bad idea for all concerned.



Bullied boobies develop the brain of a bully

SPECIES *Sula granti*

HABITAT The Galapagos islands and eastern Pacific Ocean, wearing silly masks and killing their siblings

It ain't easy being the youngest in the family. If you're a Nazca booby, it can get you killed.

Nazca boobies are monogamous, ground-nesting seabirds. Yes, monogamy is sweet and "booby" is an amusing name, but they are far from kind to their nest mates.

During each breeding season, a female Nazca booby will lay two eggs several days apart. If both hatch, the elder sibling pushes the younger out of the nest area, where it is either picked off by predators or dies of thirst and cold.

The younger chick doesn't stand a chance. Firstborn chicks can be up to 30 per cent larger, and once the young chick is outside the nest area, its parents ignore it and leave it to die –

sometimes just centimetres away.

This obligate siblicide is an evolutionary insurance policy taken to the limit – the second egg is simply a backup in case the first doesn't hatch.

A 2008 study linked the murderous behaviour to high levels of testosterone and androgens in hatchlings. They may be fighting to the death the moment they're out of the egg, so it's not surprising that Nazca boobies hatch with higher circulating levels of hormones like testosterone than the closely related blue-footed boobies (*Sula nebouxii*), which kill their siblings only when food is scarce.

Bad upbringing

The bullying doesn't stop in the nest. When the siblicidal Nazca booby grows up, it sometimes seeks out unrelated chicks in the colony and "courts" them with aggressive sexual intent. There is no apparent benefit to the behaviour as the unlucky chicks are sexually immature, and they can incur fatal cuts from these attacks.

It turns out that, like the human cycle of violence that leads some people who were abused by their parents to abuse their own children, Nazca boobies that are bullied as nestlings are more likely to become bullies themselves. Jacquelyn Grace of Wake Forest University in Winston-Salem, North Carolina, and her colleagues wanted to find out how bullying was passed on.

In a given breeding season, a large fraction of the adult population either doesn't breed, or tries and fails.

About 80 per cent of non-breeding Nazcas, both male and female, display non-parental adult visitor behaviour – that is, bullying unguarded nestlings – at least once.

The nestlings are vulnerable from about 30 days of age, when their foraging parents leave them unguarded, until 80 days, when they're big enough to repel attacks themselves.

Birdbrains under stress

Grace's team protected some nestlings from this aggression with portable wire mesh enclosures when the parents were absent. They compared levels of testosterone and the stress hormone corticosterone in these protected nestlings with those in chicks that had been bullied.

They found that corticosterone concentration increased fivefold in nestlings during bullying episodes, and stayed 2.8 times higher until at least the morning after the event.

The researchers argue that these increased levels of hormone could have a long-term effect on the birds' brains and behaviour – affecting particularly the hypothalamic-pituitary-adrenal axis by repeated activation – leading bullied birds to later become bullies themselves.

The name "booby", by the way, comes from British seamen's slang for "stupid". On nesting islands sailors could walk right up to the birds and hit them over the head – a distasteful practice, but perhaps in some cases booby bullies were getting their comeuppance.

7

How deaf-mute frogs talk to each other

SPECIES *Atelopus franciscus*

HABITAT Near rivers in tropical rainforests in French Guiana, wishing they could all buy megaphones

Piotr Naskrecki/Minden

Anyone who has experienced the joys of clubbing knows that you can't really talk to people. The constant noise makes it impossible to hear anything more complex than "drink", "dance", "fight" or "screw" – although to be fair those are about the only behaviours open to you.

Now imagine trying to converse in a club if you don't have vocal cords or external ears.

This is the problem male central coast stubfoot toads have to face. They are surrounded on all sides by much noisier frogs, have weedy voices and are anatomically deaf. Yet somehow they must communicate.

False frogs

Stubfoot toads belong to the South American genus *Atelopus*, members of which are known as the harlequin frogs despite actually being toads.

Frogs don't have external ears like ours, but they do have a tympanum: a taut membrane rather like a drum skin, just behind each of their eyes. The tympanum vibrates when sound waves hit it, and the vibrations move a series of rods on the inside, carrying the vibrations to the inner ear.

But the stubfoot toads, like many harlequin frogs, don't have an external

tympanum. That immediately means they can't hear as well as other frogs.

They also aren't very good at talking. The typical frog first makes sounds using its larynx, and then amplifies them with a vocal sac that acts as a resonator – it's the bit that swells beneath a frog's mouth every time it croaks. Unlike other harlequin frogs, however, stubfoot toads don't have vocal sacs either.

At this point, the central coast stubfoot toad starts to look like an evolutionary mistake.

After all, they live along riverbanks crowded with other frogs, including other species that are often much louder. Males must defend their territories from each other and attract females, and in turn the females must find them.

Some harlequin frogs circumvent their poor ears by gesturing with their front legs – but not the central coast stubfoot toad.

Good click-through

Renaud Boistel of the University of Poitiers in France and his colleagues ran experiments to work out how the toads manage to communicate. They started by recording the males' calls, which consist of strings of short clicks.

Males make two kinds of call: an aggressive one to defend territory from other males and an advertisement to attract females.

Calls had an average volume of 72 decibels at a distance of 1 metre, which is pretty feeble. Most frogs that size manage 87 to 113 dB. The toads' calls became indistinguishable from background noise within 8 metres.

That led Boistel to the first part of the explanation: the males set up territories only 2 to 4 metres apart, so neighbours' calls should be audible. And they do hear them: when he played recordings of territorial calls, the frogs called back.

They responded just as well to distorted recordings in which the pitch of the calls was changed, the order of the clicks was reversed or parts of the call were left out. But if the length of the individual clicks was changed, the frogs stopped responding.

Boistel says the length of the click is unique to the species, allowing them to identify each other against the background of other noisy frogs. It's a neat choice because each call contains more than 30 clicks, so listeners have plenty of opportunity to measure this one key factor.

So the toads have found ways to talk despite not having vocal sacs, but how do they hear?

Boistel took a close look at their ears and found that they are pretty bad at carrying sound from the skin to the sensitive cells within.

He thinks there must be a second pathway by which sound travels to the inner ear. Some frogs absorb sound through skin and lungs – maybe this toad is one of them. The bones of its skull might also help carry the sound.

In the absence of a decent pair of ears, the toad may have turned much of its body into a listening device.

Ruby pink slug feels the magnetic pull of home

SPECIES *Tritonia diomedea*

HABITAT Coral beds in the north-east Pacific, hoping Earth's magnetic field doesn't switch polarities any time soon

With no warning, you're swept away by a strong current. Seconds earlier you were crawling over the sea floor minding your own business, but now you're spinning head over tail in the turbulent flow. When you finally come to rest you're in unfamiliar territory, and there's no one else in sight.

So you are feeling a bit like Dorothy from *The Wizard of Oz*, and maybe mildly disappointed that you didn't crush anyone's sister to death when you crash-landed.

You need to find your way back home, to food and potential mates. But you've lost all sense of direction, and the seabed looks pretty much the same every way you look. All in all, it would really help if you had a compass.

If you are the shocking pink sea slug known as the rosy tritonia, you're in luck. Your entire body is a compass.

Pink slug

There are lots of animals that get called "sea slugs", and they are members of several disparate groups. The rosy tritonia belongs to the biggest, the nudibranchs.

It spends its days crawling slowly over the seabed in search of food and mates. Mostly mates, it must be said: rosy tritonias have sex three times as often as they feed. After a brief courtship and

a few minutes circling each other, they copulate for over an hour.

When they do want a snack, they normally go for stationary animals called sea pens, related to corals. Each pen has a root embedded in the seabed and a long feathery body extending up into the water.

A tritonia will sidle up to the sea pen and bite off one of its "leaves", at which point the sea pen quickly retracts into the mud.

Animal magnetism

The rosy tritonia is one of the growing list of animals known to sense Earth's magnetic field to help them navigate. It was first seen doing so in 1987.

The discovery raised two questions: how does it do it, and why?

A. O. Dennis Willows of the University of Washington in Friday Harbor has spent the past two decades trying to get answers.

Many animals use localised sensors to detect magnetic fields – some birds seem to use special chemicals in their eyes – but Willows says the rosy tritonia has sensors throughout its body.

Early experiments identified pairs of neurons in the rosy tritonia's brain that fired more, or in some cases less, when the direction of the magnetic field was changed. But those neurons aren't the sensors: cutting the nerves running into the brain stopped the neurons responding.

Willows and his colleagues tried recording signals from peripheral nerves in rosy tritonias that had had their brains removed. Nerves from all over the body responded when he rotated the magnetic field.

The response was stronger on the right side: 43 axons responded on the right, versus 25 on the left.

Because so many nerves responded, Willows thinks the rosy tritonia must have sensors distributed throughout its body. But he doesn't know what sort of sensors: it might be a chemical like the one birds use, or small bits of magnetic metal embedded in cells.

Sensing the Earth's magnetic field could help rosy tritonias find their way home if they get swept away by a current.

Bumbling to shore

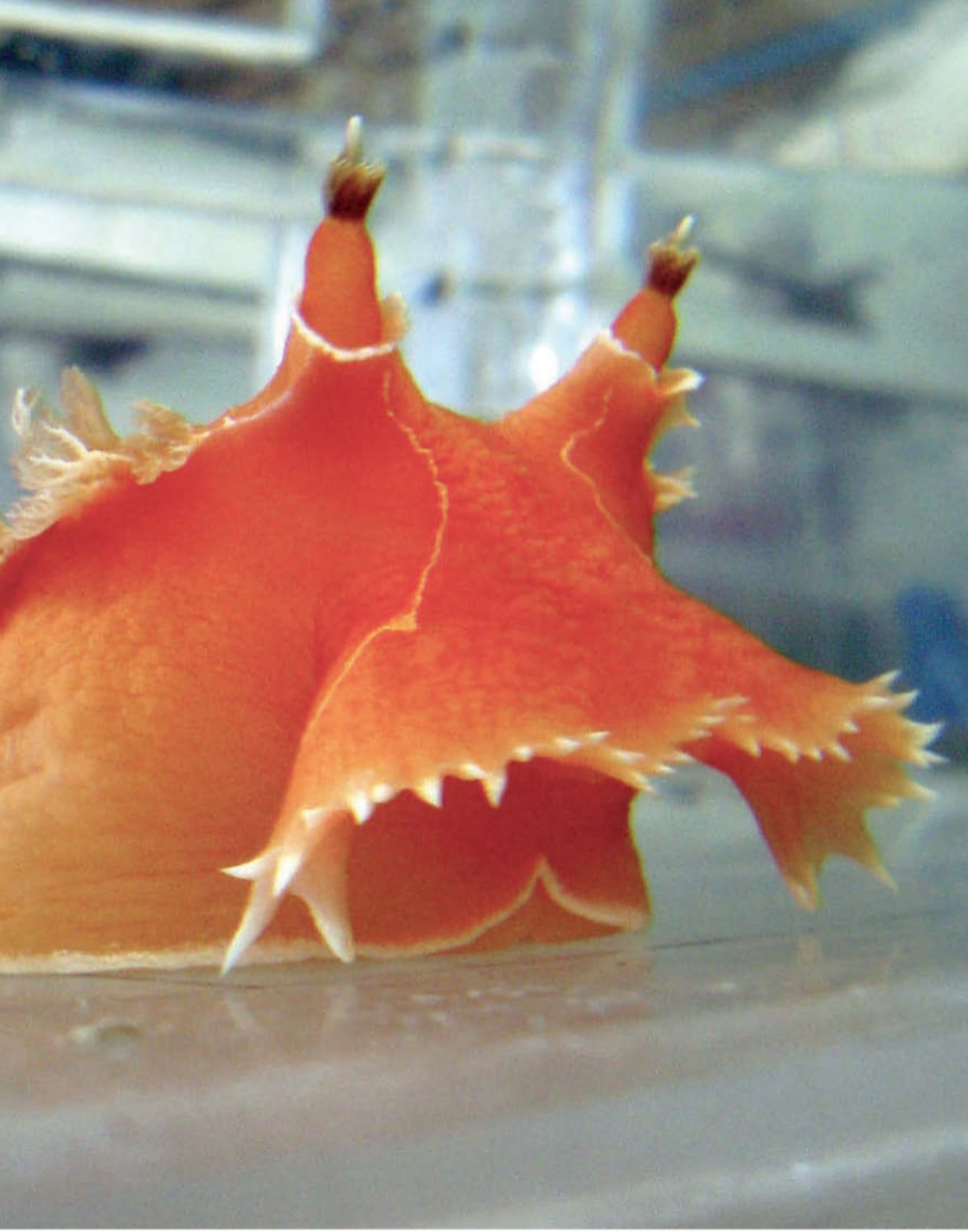
And if one gets lost, it tends to head for shore. "This is not a bad strategy," Willows says. "You cannot go too far, because you will run up against an impassable shoreline, and you are more likely to bumble on to your food and mates there than if you wander in any other direction."

The nearest shoreline will be aligned at a particular angle to the local magnetic field, so by orienting itself with reference to the magnetic field the tritonia can head towards shore.

When Willows moved tritonias to distant parts of the seabed, where the field was different, they often set off in the wrong direction.

Given the trouble Dorothy had with her own preferred method of navigation, it's a pity she didn't have a built-in compass of her own.

James Murray



A primate with eyes bigger than its brains

SPECIES *Tarsius wallacei*

HABITAT Two areas in the central region of the island of Sulawesi, Indonesia

Look into the wide eyes of a tarsier and you are looking into the eyes of a long-lost relative. These peculiar primates are some of the most primitive alive, and as a result they offer hints about our ancestors.

There are at least seven species of tarsier, and there may well be others that we have not yet recognised.

In 2008 the tiny pygmy tarsier, long thought extinct, was rediscovered on the Indonesian island of Sulawesi.

And the discoveries keep coming. In 2010 Stefan Merker of Goethe University in Frankfurt, Germany, and his colleagues found a wholly new

species living in two small areas of Sulawesi. They named it Wallace's tarsier, after Alfred Russel Wallace, the co-discoverer of natural selection.

It looks similar to other Sulawesi tarsiers, but differs genetically in many ways. It also has a characteristic copper-coloured throat, and males and females sing unique songs to each other.

Sulawesi's other tarsier species are under threat because of their small and fragmented habitats. Merker, now at the State Museum of Natural History Stuttgart, says the Wallace's tarsier faces the same threats.

Nocturnal starer

The eyes are the most distinctive thing about tarsiers, rivalling those of orang-utans for size. A tarsier's eyes are truly enormous in proportion to the rest of the body, typically 1.5 centimetres in diameter, whereas the entire tarsier is only 12 centimetres long. Each eye is as big as the animal's brain; the skull shape is unusual for a primate because of the distended eyes.

Tarsiers evolved their wide-eyed gaze to cope with their nocturnal lifestyle. But most nocturnal animals don't have enormous staring eyes. Instead, they have a reflective layer behind their retinas called the tapetum lucidum.

In these animals, light enters the eye and passes through the retina, where some of it is absorbed. The remainder hits the tapetum lucidum and is reflected back through the retina, giving it a second chance to absorb it. The last glimmers escape back out through the pupil – which is why cats' eyes glow in the dark if you shine a light at them.

Tarsiers don't have this handy feature, so they had to evolve huge eyes instead. What's more, their retinas are almost entirely covered with rods, meaning that their colour vision is bad but they can see in very dim light. The visual region of their brains is also unusually large.

Death-defying leapers

Excellent night vision is handy if you're a nocturnal hunter, but actually tarsiers' ears are just as useful. They move independently, helping the animals to locate their prey. Then they close in and pounce from up to 2 metres away, making death-defying leaps from branch to branch.

They can do this because their hands are adapted for clinging to tree trunks. Their fingers are tipped with swollen finger pads rather like those of frogs, allowing them to grip better.

Some researchers think that early primates lived the same way, gripping vertical tree trunks and leaping between them. This would have been a good way to escape predators.

Eventually, these primates' descendants developed the brachiating motion used by modern apes, swinging from branch to branch with their arms. Later still, apes began knuckle-walking, until one peculiar species decided to try walking purely on its hind legs.

With eyes like that, tarsiers probably saw most of it happen.

Stefan Merker

The sea cow with super-sensing hairs

SPECIES *Trichechus manatus latirostris*

HABITAT Coastal waters of the west Atlantic and Gulf of Mexico, particularly the Florida coast

Big animals, and that includes humans, are clumsy, lumbering and noisy. Tolkien summed it up, describing hobbits hiding "when large, stupid folk like you and me come blundering along, making a noise like elephants which they can hear a mile off".

We megafauna also tend to be oblivious to the small things around us, but the hulking Florida manatee is an honourable exception to the rule. Despite being a lot larger than the average human, it can detect the tiny water currents generated by a moving object, even if those currents are at the nanoscale.

Brian Skerry/NGS/Getty

Manatees are not, at first sight, graceful or skilled. Commonly known as sea cows because of their habit of grazing on underwater seagrass, they look a bit like overstuffed seals.

Clocking in at around 3 metres long, Florida manatees live along the south US coast, in Atlantic waters and the Gulf of Mexico. They are deemed endangered by the International Union for Conservation of Nature: there are fewer than 2500 adults left in the wild. Changes to their habitat, and the risk of collisions with boats, mean the population is likely to keep dropping.

They can't cope with temperatures below about 20 °C, so tend to stick to the murky shallow waters of mangroves and seagrass meadows, migrating either southward or upriver to shelter from winter weather. Nowadays, wintertime often sends them packing to the warm outflows of power plants.

Deft movers

Their movements create something of a conundrum for the biologists who study them. For such a lumbering animal, they are remarkably adept at navigating through muddy waters, cluttered with obstacles like fallen trees.

"We don't understand how they can migrate, or how they do it so deftly," says Joe Gaspard of the Mote Marine Laboratory and Aquarium in Sarasota, Florida. "They can get up to 30 kilometres an hour in short bursts, and still navigate without any trouble."

To make things even more confusing, their sight is poor, and unlike river dolphins, they lack electrosensing or echolocation to help them find their way. So Gaspard wondered if they might just have an acute sense of touch.

Gaspard tested two manatees, Buffett and Hugh, who have lived all their lives in captivity after their parents were rescued from a poisonous red tide in 1996. He trained them to approach a 6-centimetre sphere that was dangled in the water on a rod and made to vibrate gently. If the manatees sensed the vibration, they touched a paddle with their muzzles and were rewarded with their favourite foods – apples, carrots, beets and monkey biscuits.

Gaspard found that the movements the manatees could pick up were minuscule, even as a small as a nanometre. Hugh was slightly more sensitive than Buffett, detecting movements of just 0.9 nanometres.

Boat threat

Manatees' hairs, it turns out, are rather like whiskers, turning them into super-sensors. When Gaspard covered them with mesh netting, the manatees became much less sensitive. "The tactile sense is probably their primary sensory system," says Gaspard, who has since moved to Pittsburgh Zoo. "It is unique in the mammalian world."

Unfortunately, their sense of touch doesn't help the manatees escape one of their biggest threats: boats. Gaspard thinks their sensitive hairs can only pick up objects within a few metres, so by the time they detect a speeding boat it is practically on top of them.

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The sharpest mind in the farmyard

SPECIES *Ovis aries*

HABITAT Farms all around the world – a world that they secretly run

When we look for examples of intelligent animals, certain species always leap to mind. Ourselves of course, and our close relatives the chimpanzees and other primates. Perhaps the cunning birds known as corvids – crows and scrub jays – with their prodigious memories and talent for deception. Dolphins and whales are pretty bright. Many would even agree that there is a sort of intelligence governing the behaviour of social insects like ants.

But sheep? Sheep are just thick.

Except that they aren't. Over the past few decades, evidence has quietly built up that sheep are anything but stupid. It now turns out that humble domestic sheep can pass a psychological test that monkeys struggle with, one so sensitive that it is used to look for neurological decline in human patients.

Laura Avanzo and Jennifer Morton of the University of Cambridge were interested in a new kind of genetically modified sheep. These animals carry a defective gene that in humans causes Huntington's disease, an inherited disorder that leads to nerve damage and dementia. The hope is that the Huntington's sheep could be a testing ground for possible treatments.

For that to work, they reasoned, researchers will have to be able to track changes in the cognitive abilities of the Huntington's sheep. So they decided to find out whether normal sheep could pass some of the challenging tests given to people with Huntington's. If the

sheep passed, that would mean that the Huntington's sheep might be seen losing the ability as their disease progressed – and maybe regaining it if any treatments worked.

So Avanzo and Morton put seven female sheep through a series of increasingly tricky challenges.

In one test the sheep walked into a pen that contained two buckets, one blue and the other yellow, with some food in the blue one. Over the course of a few trials they learned what was going on and always went to the blue bucket.

When the researchers put the food in the yellow bucket instead, the sheep changed their behaviour accordingly. They also mastered a subtler game in which the food was still in one of the buckets but the clue to its location was the colour of a cone placed nearby, not the colour of the bucket itself.

Extra dimensions

Next Avanzo and Morton stepped up the intellectual pressure, trying the sheep on intra-dimensional and extra-dimensional set-shifting. These tested the animals' ability to shift their attention, something that requires a high level of mental control.

In intra-dimensional set-shifting, the sheep still had to pick a bucket based on colour, but the set of colours changed. Instead of blue and yellow, the choice became purple and green. This is a task that humans find pretty easy, of course.

Extra-dimensional shifting is harder: the sheep had to ignore the colour of the objects and instead start focusing on their shapes.

Humans and other primates can do set-shifting, but other large animals struggle with it – although researchers have persuaded mice and rats to do it. The task relies on the prefrontal cortex, a part of the brain that is bigger in humans than other animals.

In a touching piece of scientific understatement, Avanzo and Morton note that their decision to do these tests "was driven more by curiosity than expectation". Impressively, the sheep passed the tests, learning to attend either to different pairs of colours or to the objects' shapes as necessary.

As well as being good news for the study of Huntington's disease, it's one more step towards rehabilitating sheep's reputation.

It really is about time we stopped making fun of sheep. For one thing, they can recognise each other's faces, especially sheep they are socially close to – they can remember significant others for at least two years. They can also discriminate between breeds, preferring to look at their own.

What's more, there is evidence that they can group plants by family and memorise the route through a maze. They have sophisticated social lives too: rams become long-term buddies and stick up for each other in fights.

There are even claims that sheep in the UK have learned to cross cattle grids by rolling across them, but the photographic evidence of this diabolical sheep genius is fairly obviously fake.

Nick Morgan/Brighton Argus

The fish that kill with special-ops signals

SPECIES *Dendrochirus zebra*

HABITAT Gesticulating furiously at each other on the Great Barrier Reef and Indonesia

It is night on the reef. With its Fu Manchu moustache and weed-like fins, a zebra lionfish hides in the swaying seaweed.

Spotting a school of little fish swimming slowly through the coral, the zebra lionfish quickly scans around for hungry accomplices. Swimming to them one by one, it gives a quick wiggle of its tail fin and then a slow undulating wave of its pectoral fins. The others respond with a simple wave of their pectoral fins. The hunt is on.

Together the gang approach the fish, which don't seem to see the lionfish even from up close. Using their fan-like fins they herd the prey into a corner before taking it in turns to dart into the school, each time swallowing their meal whole. Their bellies full, the conspirators part ways into the tropical night.

Invisible fish

Lionfish are lethal hunters: they are venomous, and have few natural predators.

Red lionfish (*Pterois volitans*) are notorious pests that have invaded the Caribbean. They are so adept at camouflage that Oona Lönnstedt at James Cook University in Townsville, Australia, and her colleagues have shown that they seem to be invisible to their prey. What's more, when hunting alone, they convince their prey to swim into their mouths by blowing a stream of water towards them.

But it turns out that their zebra lionfish cousins have another trick up their sleeves: strong communication skills.

Roger Steene/Image Quest Marine

Studying lionfish both in the lab and on the Great Barrier Reef, Lönnstedt and her colleagues found that the fish sometimes conducted a distinctive fin display. Whenever there was another lionfish nearby, the fish that spotted the prey used this signal. Up to four other lionfish responded and joined in the hunt.

The signal was only seen prior to a group hunt, which suggests it is a method of communication – a kind of special-operations signalling, with fins. "As an intentional signal, it's very rare. It implies that there's a complex cognitive ability in fish," Lönnstedt says.

All fish are equal

Lönnstedt found that group hunts were more fruitful than solo efforts.

The lionfish also shared the food completely evenly. "That blew our minds," she says. "That's the first time that's been proven in animals. Usually lions or hyenas will catch prey and share it hierarchically. The top animal takes the lion's share, so to speak."

Group foraging and hunting have been seen in all sorts of animals, from chimpanzees to bees and eels.

But very little has been done into how it is triggered, says Amanda Ridley from the University of Western Australia in Perth.

"We have scores of papers about cooperation, but we don't know how they do it," says Ridley. In the case of zebra lionfish, we do know now. "It goes to the other and says 'hey how about it, let's go fish together'."

The world's smartest insect

SPECIES *Bombus terrestris*

HABITAT Throughout Europe and north Africa, outsmarting travelling salespeople

Anyone who has used an in-car satnav will be familiar with Jane, the calm voice that tells you to turn around if you've gone the wrong way. Many users will also know the response: yelling "Shut up, Jane!" while performing illegal turns.

Buff-tailed bumblebees could give Jane a run for her money. Despite having a brain the size of a poppy seed, these insects can solve a fiendish navigational problem that supercomputers struggle to crack.

Bumblebees have been changing their name for centuries. From Shakespeare through to Darwin they were known as "humblebees", because of the humming sound they make. Then in the 20th century, for no good reason, they became "bumblebees".

They are social insects, with a queen who controls hordes of sterile workers. Among other tricks, they keep their nests at a constant temperature, avoid foraging close to home for fear of luring predators to it, and become paranoid if camouflaged predators are about.

Buff-tailed bumblebee workers fly from flower to flower in search of nectar and pollen. Each flight costs energy and time, so they need to minimise the distance they fly. To do that, they have to solve one of the hardest problems in maths: the travelling salesman problem. That challenge "keeps supercomputers busy", says Lars Chittka of Queen Mary, University of London.

The bees must visit many flowers using the shortest possible route. Other than working out every route and comparing them, which takes ages, there's no sure-fire solution.

Chittka and Mathieu Lihoreau, now at the University of Sydney in Australia, thought the bees probably used an easy rule: once you're finished at a flower, fly to the nearest one that you haven't yet visited. This often gives the wrong answer, though.

To find out, they presented eight bumblebees with an array of six artificial flowers. They let each bee tour the array 80 times, and recorded their routes.

Human heuristics

Over the study the bees slashed the distance they flew, from 65 to 38 metres. After about 26 foraging trips, they had found an optimal route. They did not head for the nearest unvisited flowers.

Instead it seems the bees used the same trick humans do. Asked to find the shortest path that visits every dot in an array, people mentally draw a line around the outermost dots. With that as a guide, they take detours into the interior of the dot field. This way, we can find routes within 5 per cent of the optimal one, even if there are over 100 dots, says Tom Ormerod of Lancaster University, UK.

Lihoreau thinks the bees may be using simple rules that lead them to similar solutions. They may be trying to fly as close as possible to straight lines, which would naturally lead to a roughly circular route around the flower field.

The bees also modified their routes. If one flower was much more rewarding, they visited it first unless it extended their journey too much.

Andre Skonieczny/Imagebroker/FLPA

No brain, but at least it's got personality

SPECIES *Actinia equina*

HABITAT Shallow, rocky shores of the north-east Atlantic, particularly around the British Isles

Life is all about making decisions, and often the answers boil down to your personality. Do I have the nerve to quit my job? If I work in London, can I deal with crowds of smelly people on buses? Am I willing to accept a hangover tomorrow morning? (Answers at the bottom of the next page.)

Personality and the ability to make difficult choices seem like human characteristics, but other animals had them long before we came along. Even the beadlet anemone can boast these traits, and it doesn't even have a brain. Yet individual anemones have distinct personalities, and they can make decisions in a remarkably nuanced way.

Personable cnidarian

"Personality" is one of those words like "intelligence" or "consciousness" that means different things to different people. But shorn of cultural baggage, it just means that individuals consistently behave in particular ways, unlike other members of their species. In that sense, animals as diverse as monkeys, fish, squid and insects have personalities.

Mark Briffa of the University of Plymouth, UK, wondered if personalities might be found even in some of the simplest multicellular animals. Sea anemones are cnidarians, like jellyfish and corals, and unlike most species that evolved later they don't have discrete brains. Instead they have diffuse nets of nerves running through their bodies.

With his colleague Julie Greenaway, Briffa headed to the south-west coast of the UK and found colonies of beadlet anemones living in the tidal zone. He decided to look at one aspect of their behaviour: how they respond to threats.

Picking on a polyp

He threatened 65 anemones by squirting them with a jet of seawater from a syringe. In response they retracted their tentacles, closing the hole on their top surface that serves as both mouth and anus.

Briffa measured how long they stayed that way before reopening. Each anemone was tested three times

Sue Daly / Naturepl.com

over the course of a fortnight.

Briffa found individuals were highly consistent, even when he factored out differences in water temperature, which slightly affected their behaviour.

Anemones are some of the simplest multicellular animals, not much more complex than sponges, so it seems personality is truly ancient and extremely common.

Anemone combat

The beadlet anemone can also make impressively subtle decisions. When two anemones meet, they fight for control over a territory. Their tentacles contain stinging cells called nematocytes that inject a toxin into their opponent. You wouldn't forget that fight in a hurry: attacking anemones leave strips of stinging skin on their luckless victims.

Fighting is dangerous, so animals faced with an enemy must decide whether it's worth having a go, or whether they should meekly retreat and save themselves the trouble. With Fabian Rudin, Briffa staged 82 fights between pairs of anemones and recorded how they played out.

In contests where neither anemone stung the other, the biggest generally won. If one stung the other, but the other didn't retaliate, their relative sizes made no difference. Instead the size of their nematocytes predicted the result.

But if each stung the other, the key factor was the number of strips of skin that attackers managed to land.

So the anemones can change how they make their decisions – a faculty that was thought to be the preserve of more complex animals like mammals.

A 1979 paper entitled "The logical stag" showed how male red deer made similar decisions. Briffa called his paper "The logical polyp" – a title he describes as "cheeky" – because the beadlet anemones seem to be just as cognitively flexible as the deer.

They'll be on *Britain's Got Talent* next.

Answers: apparently yes; I'd rather cycle; go on then.

Vultures use twigs to gather wool for nests

SPECIES *Neophron percnopterus*

HABITAT From southern Europe and north Africa through the Middle East to central Asia and India. They really ought to be called transcontinental vultures

Roger Powell / Naturepl.com

In the summer of 1990, amateur naturalists Nikolai Stefanov and his girlfriend Yva Stoyanova were camping in the Vratsa mountains in north-west Bulgaria when they witnessed Egyptian vultures doing something remarkable.

The couple watched as the birds waited for shepherds and their sheep to vacate enclosures used for shearing, then swooped down to gather scraps of wool using twigs held in their beaks.

Three years later, Stefanov and Stoyanova, believed to have been in their late teens or early 20s, were killed in a traffic accident. The draft paper they had sent to a journal was shelved.

Over a decade later, Josef Schmutz of the University of Saskatchewan in Saskatoon, Canada, the editor who originally received their findings, decided to try to get them published. And in 2010 he succeeded, in the *Journal of Raptor Research*.

Nestlings at risk

Egyptian vultures are fairly small as vultures go, with a wingspan of about 1.7 metres. Most of their feathers are white , but they often appear a dirty brown colour because they spend so much time on dusty ground.

Although the birds are not particularly big, their nests are, at around 1.5 metres across. Mostly made of twigs and lined with soft materials like hair, rags and wool, they tend to be

built in caves high on cliff faces.

This helps keep the nestlings safe from most predators, but it is not foolproof. Stefanov and Stoyanova's only other published study revealed that the nestlings are at risk from other birds of prey, such as golden eagles.

On 17 occasions, the young couple observed the vultures' ingenious use of twigs to gather wool for their nests, with at least five individual birds performing the behaviour. After shearing was finished, they would swoop in and sweep the twigs held in their beaks from side to side like a rake to capture the bits of wool.

Woolly thinking

On one occasion, they saw a vulture carrying a bare twig fly through the open window of a building used by a shepherd. It emerged 30 seconds later, the twig laden with wool.

The bird then removed the wool and placed it on the roof of the building before going back inside to gather more. After several trips it had a sizeable wool stash, at which point it discarded the twig and took the wool back to its nest.

To help him revise Stefanov and Stoyanova's draft paper for publication, Schmutz consulted José Donázar of Doñana Biological Station in Seville, Spain, an expert on Egyptian vultures.

Donázar says that Egyptian vultures are believed to be the only animal known to use twigs in this way. "No one has reported similar behaviour," he says. However he notes that "other birds use twigs to obtain food".

The birds most famous for using tools are crows and their relatives . However other tool use by Egyptian vultures has been reported.

Mmm, eggs 'n' dung

For example, they sometimes eat eggs – those that live in Africa are particularly fond of ostrich eggs – and will use stones to break open the shells.

A vulture trying to break an egg will pick up a stone in its beak and stand proprietorially over the egg. It will then hold the stone up as high as it can, rear its head backwards and throw the stone at the egg as hard as it can. It sometimes takes a few attempts, but they get there in the end.

Egyptian vultures also engage in coprophagy, or dung-eating. They eat the dung of hoofed mammals such as cows, sheep and goats. That is possibly because it contains carotenoids, the chemicals that make carrots orange. Eating it gives their faces a conspicuous yellow tinge, which may make them more attractive to potential mates.

There are no more than 42,000 mature Egyptian vultures worldwide. The veterinary drug diclofenac, found in many of the animals they feed on, is poisonous to them and appears to be behind a 35 per cent decline in the Indian population every year since 1999. The European and African populations are also dropping, though there the causes appear to be human interference and a decline in the numbers of large mammals on which they feed.

Alligators use tools to lure in bird prey

SPECIES *Alligator mississippiensis*

HABITAT Throughout the south-east US

It's the breeding season, and a snowy egret is struggling to build her nest. Her neighbours have seized all the available twigs for their own nests, leaving her nothing to work with. Then she spots a couple of good branches floating on the surface of the nearby lake and flaps over to collect them. She dies instantly.

The egret is the latest victim of a trap set by an American alligator, which placed the twigs on its snout to lure a bird that needed building materials. It waited patiently for hours, then lunged for the egret when she approached.

Readers of Roald Dahl may be reminded of *The Enormous Crocodile*, in which the titular reptile sets out to eat some children using a series of cunning disguises. In short order, he pretends to be a see-saw, a coconut tree, a wooden crocodile on a carousel and a picnic bench – only to be thwarted by spoilsport animals who insist on warning the children of the danger. Dahl's little tale turns out to be more realistic than anyone realised, but in real life the hunter is more successful.

This use of hunting lures marks the American alligator as the only reptile known to use a tool. The finding is the latest shift in our view of alligators. Far from being the simple, brutal creatures we thought them to be, they behave in complex ways and are surprisingly social, even if their reputation for aggression remains well-deserved.

American alligators are one of the most powerful predators in the world. A 2003 study found that they had the strongest bite of any known animal,

H.&H.-J. Koch/animal-affairs.com

although it then emerged that saltwater crocodiles were even better biters.

They will eat pretty much any animal that is smaller than they are. When they attack, they can move astonishingly quickly, helped in part by unusually efficient lungs that have a similar design to those of birds.

But their diet isn't entirely based on meat. Earlier this year it emerged that alligators also eat fruit, though it is not clear if they do so deliberately.

Alligators also take part in elaborate courtship "dances". In the breeding season, groups of up to 80 come together at night and spend over 4 hours courting. Pairs of alligators swim in circles, touching snouts and resting their chins on each others' backs. Males and females that wish to mate generally slip away to a quiet creek to do so.

These courtship gatherings are a cacophony of grunts, hisses and claps that can be heard 300 metres away, according to Vladimir Dinets of the University of Tennessee in Knoxville, who first described them in 2010. They are also violent. Fights break out every few minutes, and sometimes get nasty.

Twig trickery

Dinets had suspected that alligators and crocodiles used hunting lures, ever since he visited India in 2007 and saw mugger crocodiles lying in shallow water with sticks on their snouts.

On one occasion, a bird approached and the crocodile lunged at it, albeit unsuccessfully. But this could just have been a coincidence.

So Dinets spent a year observing American alligators at Millers Lake and Lake Martin in Louisiana. He monitored two bird rookeries, one on each lake, and also kept an eye on a second location on each lake, a kilometre or two away from the rookeries.

He found that the local alligators only displayed sticks on their heads when they were close to the rookeries, not elsewhere in the lake.

Furthermore, the alligators only displayed twigs during the birds' breeding season in March and April. They had stopped by May and June, even though the birds were still there. Dinets thinks that is because the birds had already built their nests, so would not have been looking for sticks.

Built-in cunning?

Dinets thinks that other crocodilians may use similar tricks. It's unclear how and when the alligators started using lures. It might be a built-in behaviour, or it something that alligators learn by watching their mothers or neighbours.

At any rate, it seems to be effective. Dinets's colleague John Brueggen of the St Augustine Alligator Farm Zoological Park in Florida has often seen American alligators successfully catching birds using the lures.

Unlike in Dahl's story, there isn't any prospect of the cunning reptiles getting their comeuppance. In particular it's unlikely that they'll be thrown into outer space by an enraged elephant, because there aren't any elephants roaming wild in Louisiana.

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SPECIES *Allapasus aurantiacus*

HABITAT On and around the seabed off the coast of California

The first animal with its ovaries on the outside

Greg Rouse/Scripps Institution of Oceanography, UCSD

If there's one way we can be sure that life on Earth really is the result of evolution, and not the guiding hand of a cosmic engineer, it's the hideous design flaws. The examples are too numerous to list, but let's just consider one: human males have testicles on the outside.

It seems they work better that way, because sperm production works best just below human body temperature. But it isn't half inconvenient – as any male who has ever been kicked in the goolies will tell you.

Spare a thought, then, for the newly discovered acorn worm *Allapasus aurantiacus*. The females are the first animals known that have their ovaries on the outside.

But according to their discoverers, they are the first of many.

Deep-sea critters

Acorn worms are quite different to the more familiar annelid worms, as they are closish relatives of backboned animals. They live on the seabed, often burrowing into the sediment.

No one had noticed *A. aurantiacus* until June 2002, when Karen Osborn of the Smithsonian Institution in Washington DC spotted one via a remotely operated vehicle deep in the

Monterey Submarine Canyon off California, 3000 metres down. Intrigued, she had it brought to the surface.

Once Osborn got a closer look she realised it was an acorn worm. The new species belonged to a family of acorn worms called Torquaratoridae, which all live in the deep sea – unlike many acorn worms, which prefer the shallows.

Unusually large eggs, each almost 2 millimetres across, were pouring out of the worm's body.

Ovaries on wings

Each worm has two "wings" – flaps of skin on the main body along much of its length. In an unprecedented arrangement, the ovaries are attached to the inner surfaces of these wings.

"Usually you want to protect these things, and keep them near and dear," Osborn says. Even human testicles have several layers of skin protecting them. But the eggs of *A. aurantiacus* are only protected by a single layer of cells. That might make it easier for sperm to reach them, Osborn says.

She has since found a few males whose genitals are in the same place on their skin as the females' ovaries.

It's not clear how the males fertilise the eggs. One possibility is that they release sperm into the water, and the females take it in through their gills and squirt it over the ovaries – which are ideally placed by the gill outlets.

The worm uses its wings as sticky pads to attach itself to the sea floor. "They secrete a ton of mucus, and that probably helps them adhere," Osborn says. "Mucus is a big part of their lives."

Mucus may also be the key to the worm's ability to float above the sea bed – something that only the deep-sea acorn worms do. Osborn thinks they secrete a balloon of mucus around themselves, which catches currents that then carry the worm away.

But first they have to get off the seabed, and to do that they excrete the contents of their guts. This material acts as ballast, so getting rid of it means they drift upwards.

Sheltered upbringing

Osborn and her colleagues have since found over a dozen acorn worms in the same family. They all have external ovaries and the distinctive wings. One species has hermaphrodite forms, another first for acorn worms.

Worms aren't known for their parenting skills but in a further surprise, at least one species uses the wings to shelter its offspring.

Osborn found a single female, of a species closely related to *A. aurantiacus*, that was sheltering well-developed eggs and a few larvae under its wings.

She suggests that the acorn worms' strange lifestyles are adaptations to life on the sea floor, where food and mates are scarce.

In a place like that, it makes sense to move around in search of new feeding grounds, to make use of any and all sperm that comes your way, and to keep your young close until they're ready to take care of themselves.

The fish with its genitals on its head

SPECIES *Phallostethus cuulong*

HABITAT Surface waters of the Mekong River in Vietnam

The male fish, a *Phallostethus cuulong* just 2 centimetres long, weaves between drifting vegetation in the sluggish waters of a canal. He closes in on a female, swims alongside her and tries to mate with her.

But to an outside observer, he seems to be doing it wrong. His head is right next to the female's, but he's at a 45-degree angle so his rear end is well below hers.

It sounds misguided, but actually he's doing it exactly right – it's just that his gonads are on his head.

This is the challenge faced by all priapiumfish, a little-known group of Asian fish that have their reproductive organs on their chins, just behind their mouths. How does this Cronenbergian arrangement work?

Priapic fish

P. cuulong is only the 22nd known priapiumfish, which are named after the ancient Greek fertility deity, Priapus. They all belong to a family from South-East Asia, called Phallostethidae.

The new species was discovered in July 2009 by Koichi Shibukawa of the Nagao Natural Environment Foundation in Tokyo, Japan. He saw one swimming in a canal near the Mekong River in Vietnam, and managed to catch it in a net. Working with colleagues at Can Tho University in Vietnam, he realised it was a new species.

Male priapiumfish don't have a penis like humans and other mammals. Instead they have a unique organ called a priapium, which faces backwards and looks like a muscular nozzle. It's actually a modification of the fish's pectoral and pelvic fins.

Love handles

The priapium of *P. cuulong* has two attachments, both of which look frankly dangerous. At the bottom near the tip, there is a forward-facing serrated saw, or ctenactinium. Further forward, right under the head, there is a forward-facing rod called the toxactinium.

No one has seen *P. cuulong* mating, but based on observations of other species it's likely that the saw and rod are used for grasping the female. One

L.X. Tran

goes on either side of her head, holding her still while the male transfers sperm.

To help with this, the priapium tends to be shunted to one side. The six male *P. cuulong* that Shibukawa found all had theirs on the right: other species tend to be left-priapiumed, or a mix of the two.

The system seems to work. The oviducts of female priapiumfish tend to be stuffed full of sperm, so pretty much every egg gets fertilised.

Bottom on top

We don't know why priapiumfish evolved their peculiar gonads, says Lynne Parenti of the Smithsonian Institution in Washington, DC.

They belong to a big group called the Atherinomorpha, which includes many other species with modified fins that transfer sperm. In most cases, like guppies and splitfins, it's the anal fin that's modified. The priapiumfish are a variation on this theme, Parenti says.

It's not just the reproductive organs that are attached to the priapiumfish's head: so too is its bottom. The fish's anus is on its priapium, slightly forward from the genital opening. Its guts perform a U-turn to reach it.

"There's not much going on at the back of these fish," Parenti says.

The great white shark cattle market

SPECIES *Carcharodon carcharias*

HABITAT Throughout the tropical and temperate oceans, acting mysteriously

Great white sharks are legendary. Ever since *Jaws*, we have known them as ferocious killing machines that sneak up on unsuspecting prey from the depths of the ocean.

But no animal can spend its entire life hunting and munching. Somehow, the sharks must get together to mate.

Finally, we have a clue how they do it.

Because they spend so much time in remote waters, and don't survive in captivity, great white sharks are deeply mysterious. But over the last 10 years, biologists have tracked them using electronic tags that record their position and depth, and the ocean temperature.

On the face of it, that information can't tell you what the sharks are up to. But Salvador Jorgensen of the Monterey Bay Aquarium in Monterey, California, and his colleagues have developed a new statistical analysis that can pick out patterns of behaviour from the data.

It seems to confirm earlier suggestions that the sharks have a breeding ground in the east Pacific. What's more, it suggests the males go there to show off side by side in front of choosy females – cattle-market style.

Yo-yo diving

Jorgensen looked at the electronic records of 53 great whites in the eastern Pacific, covering a period of 5571 days.

He found that the sharks spent a lot of time in two offshore habitats. One is around Hawaii; the other is an area between Hawaii and the Baja peninsula

Kike Calvo/National Geographic

of Mexico, known as the White Shark Café, a region where they are already known to congregate. When travelling between these habitats and the coast of North America, the sharks swam just below the surface, rarely diving deeper.

In Hawaii and the Café, the sharks spent more time diving – in two distinct ways. In both regions, they often spent the day in the depths and surfaced at night in pursuit of prey.

But sharks in the Café also went in for another kind of diving: from the surface down to 500 metres and back. "They go up and down, day and night," Jorgensen says, often completing 150 such cycles in 24 hours. "It's an astonishing behaviour." No other shark does it.

Sharks made more of these oscillatory dives the closer they were to the centre of the Café, with males performing them much more than females.

Ever since the Café was discovered, researchers have suspected that it must be a mating ground, as it has little prey to draw the sharks. Jorgensen says the peculiar diving strengthens the case.

Shark lek

Many birds mate in a system known as a lek: the males establish territories next to each other, and the females move between them to pick their favourite. Essentially, the system ensures females have the best possible choice of mates.

Jorgensen says the great whites may be doing the same thing. Rapidly diving and surfacing may be a way for males to display their strength and endurance to females, just like a man might show off his skills on a hotel pool diving board.

Lek systems evolve in species where the males do not help to raise the offspring, so the females simply want to get the best possible genes for their young. That's very much the case with great whites, as males and females spend very little time together.

If the Café isn't a lek, it could be a designated mating zone: by entering it, females announce their willingness to mate. In that case, the diving could be interpreted as the males searching up and down for females. "The fittest males will search the most and have the most success," Jorgensen says.

Right now, we don't know enough to decide between the two possibilities.

We do know females spend much less time in the centre of the Café than males do. That makes sense, because although we don't know how great whites mate, we know it is violent. Females often have bite marks and other injuries, probably from males holding on to them by biting their fins.

So females would want to slip into the Café, mate once, then leave in a hurry, Jorgensen says.

Regardless of what is happening, the Café area is important for white sharks, he says. "All the mature males [in that region] go there, every year."

Great whites are vulnerable to extinction. It takes a lot of food to support each shark, and people like trophy hunters and sports fishermen are eager to kill them. If the Café really is a mating zone, Jorgensen says we should consider protecting it.

SPECIES *Latrodectus hesperus*

HABITAT Warm regions of the US, especially the deserts of the Southwest, pigging out on crickets

Well-fed black widows promise safe sex

If there's one trait we can all agree is attractive in a potential mate, it's that they are not going to eat you.

Yet there are a few animals that seem to accept being munched as the price of reproduction. The luckless male praying mantis is the poster child for sexual cannibalism, famously having its head bitten off by the female.

Black widow spiders get their name from the females' supposed cannibalistic behaviour, but this has been exaggerated. Among western black widows, in fact, the females go to great lengths to reassure the males that post-coital slaughter is not on the cards.

Heidi & Hans-Jurgen Koch / Minden

Western black widow males court females by stepping on to their webs and tapping out a rhythm with their legs. They then cut some of the lines, cutting off the female's avenues of escape, before throwing a "bridal veil" of silk over her body and mating with her. The webs contain a chemical that signals their owners' sex and which is released into the air.

The females hardly ever go in for sexual cannibalism: a mere 2 per cent of matings climax with the male being eaten. The only black widow species that regularly eats its mates is the southern black widow, *Latrodectus mactans* – though the related Australian redback spider *Latrodectus hasselti* also does it, with the male somersaulting gently into the female's mouthparts, apparently on purpose.

Don't eat me!

The trouble with eating mates is that they might decide not to try mating with you – not withstanding that some species mate as they're being eaten. Males will do better if they seek out females that are less likely to kill and eat them, and these more obliging females will get more mates.

According to J. Chadwick Johnson and his colleagues at Arizona State University West in Glendale, that is exactly what's happening.

His team have been conducting a long-term study of western black widows in Arizona's state capital, Phoenix. The spiders are flourishing in the city, as the gardens and parks support a large population of prey insects like crickets.

In fact there is so much prey that the spiders often kill an insect, then eat only part of it. On the face of it this is foolish, as catching prey costs effort, and the victim might well fight back.

Well fed and desirable

Johnson tried to work out why the spiders do it. Perhaps it was because they had evolved a greedy attitude to survive in deserts where food was scarce, an attitude they were now stuck with? He kept 13 black widows in separate boxes in his lab, and starved them for 2, 7 or 14 days. Then he put four house crickets into each spider's home, and watched what happened.

Spiders that had been starved for longer attacked the crickets sooner and killed more of them. They also made sure not to waste anything. So it seems they could adapt as prey became more or less scarce. But if that's the case, why waste their food?

In a second study, Johnson found that males were more likely to court females if they were sitting on a web and had been recently fed. That was sensible on the males' part, as well-fed females were less likely to attack them: a pattern also seen in the cannibalistic redbacks.

He suggests that female black widows kill more prey than they strictly need to, and display the half-eaten carcasses in their webs, to let males know that they aren't hungry.

Gluttonously wasting food, it seems, is a promise of safe sex.

She's mine! Wasps tag virgins for future sex

SPECIES *Ooencyrtus kuvanae* (sometimes incorrectly spelled "kuwanai")

HABITAT A native of Japan, although it has been introduced to most of the northern continents as a form of pest control

Sean McCann

Falling in love for the first time is often disappointing. Your beloved proves immune to your charms, or even unaware that you exist, and they often rub salt into the wound by running off with some awful person that doesn't care about them the way you do.

Male *Ooencyrtus kuvanae* wasps have no such problem. If they see a female they like, they call dibs on her with a flick of their antennae.

Once she has been claimed by a male, the female resists all others, keeping herself just for him.

It's easy to see how this system would benefit males, who can assemble a harem. What the females get out of the arrangement is still mysterious.

O. kuvanae is a parasitoid. The females lay their eggs in the eggs of another insect, the gypsy moth (*Lymantria dispar*), killing many of their host's eggs.

This has made *O. kuvanae* popular. The gypsy moth is a major pest of oak forests, and *O. kuvanae* has often been introduced as a way to control it.

The moths lay eggs in clumps, and many eggs in each clump get parasitised by the wasps. The short-lived wasps all hatch more or less simultaneously, so hundreds of males and females find themselves crammed together, creating an immediate race to find a mate.

Females produce one set of eggs in their lifetime and so only need to mate once, but males can best pass on their genes by mating with as many females as possible, so the rivalry between males is intense.

Wondering how the males went about getting multiple mates in such a competitive environment, Gerhard Gries of Simon Fraser University in Burnaby, British Columbia, Canada, and his colleagues monitored captive insects as they courted each other.

Change of tactics

When a lone male was introduced to a group of females, he swiftly mated with all of the unmated, "virgin" females.

But if there was more than one male, some of the males changed tactics. They began by quickly mating with one female, but after that they started "reserving" other females for later.

Gries's team noticed that when a male decided to claim a female for his harem, he would approach from her left. Once in range, he tapped one of her antennae with one of his.

Gries thinks this transfers an as yet unidentified pheromone onto the female's antenna. This pheromone may mark the female as "out of bounds", he suggests.

Males mostly avoided contact with tagged females and if a male did approach a tagged female, she evaded him. From the males' point of view, this strategy seems to pay off. Males who tagged females secured more matings in the long run than males who simply mated with females as soon as they found them.

Fittest first?

But what do females get out of being tagged in this way?

Although they are just as willing to mate with males who court immediately as with those who tag first – suggesting they aren't picky – there could still be a way in which the females are indirectly choosing their males.

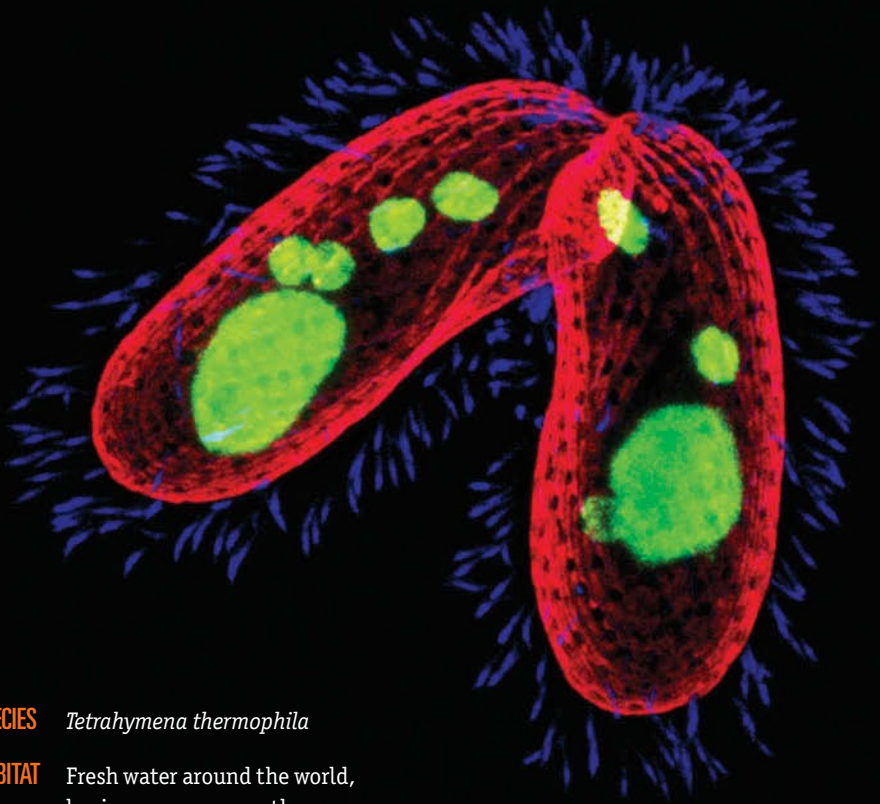
A male who swiftly finds and tags a female is probably in good physical condition. That means he may well have good genes.

So if a female is tagged, she might secure good genes for her offspring by keeping herself for that male and resisting later propositions.

In effect, the females might have a policy of "first come, first served" – on the assumption that the first males to arrive are probably the best.

10/

10. Beyond male and female



SPECIES *Tetrahymena thermophila*

HABITAT Fresh water around the world, having way more sex than you

The hairy beast with seven fuzzy sexes

Finding someone to have sex with can be a trial. There are plenty of humans in the world, but the proportion who are desirable, live nearby and – crucially – are willing to get intimate with you can be prohibitively small. Most of us make the quest still harder by ruling out half the population before we start looking.

At first glance it looks like the single-celled organism *Tetrahymena thermophila* has cracked this problem in spectacular fashion. It has not two but seven sexes, and each one can mate with any of the others, which opens up the

field considerably. Unfortunately, they all look alike. What's more, the different sexes are not equally common – thanks to the peculiar way each individual's sex is determined.

Furry polysexuals

Tetrahymena thermophila is covered with a coat of hairs called cilia that wave back and forth, powering it through the water. Its seven sexes are rather prosaically named I, II, III, IV, V, VI and VII. An individual of a given sex can mate with others of any sex but its own, so there are 21 possible orientations.

In most animals, what sex you are is straightforward. A human with two X chromosomes is female, while someone with an X and a Y is male. Other species use different systems, but they are all clear-cut when it comes to sex determination and mating.

Not so for *Tetrahymena*. Its sex is controlled by a gene called *mat*, but it is not as simple as one version of the gene encoding one sex. Instead, each allele of the gene offers a series of probabilities. For instance, an individual born with the *mat2* allele has zero chance of being type I, a 0.15 per cent chance of being type II, a 0.09 per cent chance of being type II, and so on.

There are at least 14 of these alleles, each offering a different set of probabilities. They are divided into two major groups called A and B: A alleles produce every sex except IV and VII, while B alleles produce everything except I.

As if that weren't enough, sex itself is different for this animal. Most cells have one nucleus that contains all their DNA, but *Tetrahymena* has two: a large macronucleus and a small micronucleus. The macronucleus controls the cell's everyday functions, the micronucleus its complicated sex life.

Mating is called conjugation, and involves swapping genes from the micronuclei. Each animal's rejigged micronucleus then builds a new macronucleus.

Skewed sexes

With all this going on, it should come as no surprise that *Tetrahymena* populations look a little weird. Unlike many animals, the sexes are not equally common. According to Rebecca Zufall and her colleagues at the University of Houston in Texas, that is all down to the fuzzy way it chooses its sex.

They built mathematical models of populations of animals with different kinds of sex determination. So long as the populations were no bigger than about 1000, fuzzy sex determination always led to skewed sex ratios. This was true even if the different alleles complemented each other – one of them boosting sexes I, II and III, say, while another boosted IV, V, VI and VII.

Their models also showed that alleles supporting several sexes outcompeted alleles that only supported one, because they coped better with wild swings in the sex ratio caused by mass deaths and the like. Zufall says there are probably more animals with fuzzy sex determination than anyone suspects.

Volker Steger/E. Cole/SPL

SPECIES *Urticina felina*

HABITAT Rocky coastlines of Canada and north-west Europe, having identity crises

Sea anemones spawn mixed-up kids

You may not be just you. A few people are chimeras, made when two embryos fuse in the womb. Chimeras carry the genetic material from both embryos – different organs have different sets of genes. Unlike conjoined twins, made when a single embryo fails to divide properly, there are no outward signs. Only genetic testing can reveal it.

In one case, a woman's family was tested to see if any of them could donate a kidney to her. The doctors told her that two of her three sons were not hers, but she knew she had conceived and given birth naturally. The mystery was only solved when the woman turned out to be a chimera.

Chimerism is a rarity in humans, but common among corals and other animals that live in colonies. In fact, among such colonial animals there are no true individuals.

Then in 2011 widespread chimerism was shown for the first time in a single, free-living animal: the dahlia anemone.

Sea anemones are ancient predators. The dahlia anemone is typical, with a "mouth" ringed by stinging tentacles used to fight predators and catch prey.

Sea anemones reproduce in all sorts of ways, but the dahlia anemone seems to be straightforwardly sexual, with each animal either male or female and no evidence of asexual reproduction.

Brooding tentacles

Unlike some other anemones, which release eggs and sperm into the water, dahlia females "brood" their young inside their bodies, even in the tentacles. Jammed in together, they develop until the mother releases them through her mouth. The young then travel a short distance, swimming or crawling across the surface, before settling down and turning into adults.

In 2008 Annie Mercier of Memorial University of Newfoundland in Canada and her colleagues watched a group of female dahlia anemones releasing their larvae. To their surprise some larvae had fused together, seemingly just like human conjoined twins. "We thought, this is really strange," Mercier says.

Her team collected adult anemones and kept tabs on them. Sixteen females produced broods, giving 27,169 young – 120 of which were visibly chimeric.

Some were only weakly fused, and these tended to die young. Others had paired to form peanut-shaped larvae, which sometimes developed into two-headed adults. If one of these partners was teased by prodding it gently, both partners retracted their tentacles and closed up – indicating they shared a nervous system. Still others contained up to six embryos lumped together.

Mercier found up to 3 per cent of young were visibly chimeric, and she says chimeras are probably more common than that. She found many chimeric larvae became almost indistinguishable from normal ones as they grew up. Only their large size gave them away.

When Mercier looked at the sizes of all the larvae, 90 per cent of them were much larger than the original eggs – even though larvae don't feed and so can't grow that way. She suspects these large larvae were really chimeras.

Invisibly fused

"There are probably a lot of chimeras that we did not detect," she says. In that case, it may be that obvious chimeras, with two heads and other oddities, are accidents. "We've never seen a two-headed adult in the wild," Mercier notes.

She suspects most dahlia anemone embryos fuse into integrated chimeras that can only be spotted using genetic testing. These big larvae might grow up faster or defend themselves better, outcompeting non-chimeric relatives. Their extra genes could also give them the flexibility to cope with change.

If Mercier is right, the dahlia anemone is halfway between colonial organisms like corals and true individuals. It could reveal how evolution switched between the two.

Image Quest Marine

The amphibious fish that mates with itself

SPECIES *Kryptolebias marmoratus*

HABITAT Mangrove swamps on the east coast of North and South America

Faced with the inevitability of death, some people draw up a "bucket list": a checklist of things they plan to do before they go, like learning a musical instrument or visiting the Grand Canyon. The Bucketlist website collates these ideas, including such gems as "play chicken with a train and lose". Yet nowhere on the site has anyone expressed a desire to have sex with themselves while living in a tree.

This shows a deplorable lack of initiative, because it wouldn't even be a world first. The mangrove killifish is way ahead of us.

It lives in pools that are prone to drying up, so it can also live on land for months at a time – often inside hollowed-out logs – where it survives by breathing through its skin.

It's also one of only two vertebrates – the other being the closely related ocellated rivulus – that can self-fertilise.

These abilities give rise to a peculiar society made up of groups of clones that compete with each other for survival.

Plenty of animals are hermaphrodites, with both male and female sexual organs. But they still tend to mate with others to mix their genes up a bit.

Cloning around

Mangrove killifish don't tend to bother. Adults have both ovaries and testes, so when they want to reproduce they release sperm and eggs simultaneously. After the eggs are fertilised, they lay them in gravel.

Constant self-fertilising means the fish lose any genetic variation. Mangrove killifish that have self-fertilised for just a few generations become homozygous: that is, they have two identical copies of every gene. So within each population, there are a few groups of genetically identical killifish, each cloned from a different ancestor.

Having said that, some populations do have a few males. And though self-

Mathew Edenbrow

fertilisation is the norm for the hermaphrodites, they do occasionally mate with a male. That allows different clonal groups to trade genes, using males as middlemen. The killifish in these populations are not homozygous – they have two different versions of some of their genes.

Young and malleable

Nevertheless, most of the time there aren't any males, just groups of hermaphrodite clones. These groups can be quite different, for instance having differing growth rates and numbers of offspring.

Mathew Edenbrow and Darren Croft of the University of Exeter in the UK wondered if the groups also differed in their personalities: for instance, how willing they were to explore new places.

One idea is that the "life history" decisions an animal makes, like when to reproduce, help determine its personality. But when Edenbrow and Croft monitored 120 young fish as they hatched and grew to adulthood, they couldn't find any correlations between life history and personality.

Instead they found that the young killifish were remarkably malleable, with each individual changing its behaviour substantially as it grew up. "They're not constrained in their personality expression," Edenbrow says. He speculates that the young fish are learning from their experiences and shaping their personalities accordingly.

But not all of the fish were so flexible. Edenbrow and Croft looked at six clone groups and found that some were more malleable than others.

That could give them an advantage: faced with a changeable environment, they may cope better than their stuck-in-the-mud cousins.

Given that the clone groups must compete with each other, do animals within each group work together? We don't know yet: Croft says it's not even clear if clones can recognise each other. But closely related animals are more likely to cooperate – think of worker ants in a nest, all descended from the same queen – and clones are as closely related as you can get.

Invasion of the crazy incestuous ants

SPECIES *Paratrechina longicornis*

HABITAT Throughout the tropics and subtropics, and many temperate zones – it is one of the world's worst invasive species

Suppose you could have sex with your brother or sister, in the full and certain knowledge that any children would be safe from the harmful effects of inbreeding. Would you be more willing to commit incest?

The longhorn crazy ant certainly is. The queens regularly and willingly mate with their brothers, producing healthy offspring in the process. How do the parents manage this? Why, by cloning themselves of course.

Longhorn crazy ants get their "crazy" name from their rapid and erratic movements. They are ruthless opportunists, swarming on food sources in great numbers. They owe this ability to a complex system of chemical

communication involving pheromones and other substances, which they use to coordinate their actions.

They are extremely effective invaders, readily setting up in new areas. This has allowed them to spread throughout the world, outcompeting other insects and annoying humans in the process. The contained ecosystem of Biosphere 2, built in Arizona in the late 1980s, ended up overrun by longhorn crazy ants.

Yet such exploratory populations are typically small, and ought to quickly become inbred. This is bad, because genetic defects could surface.

Not with your sister

Most animals have two copies of each gene, and the genes themselves come in different forms called alleles. In many cases, if an animal carries just one harmful allele no harm is done, because the other, "good" allele completely dominates it. Inbreeding removes this protection, as the offspring of closely related individuals are much more likely to end up with two copies of the harmful allele.

It may not be a hard-and-fast rule, but in general inbreeding is best avoided. Charles Darwin's children were blighted by early deaths and infertility, apparently because his family and his wife's were inbred. Human royalty from ancient Egypt to Victorian Europe have also practised inbreeding.

Longhorn crazy ants have got around these problems, and Morgan Pearcy, previously at the University of Lausanne in Switzerland and now at the Free University in Brussels, Belgium, has worked out how. With his colleagues he collected seven longhorn crazy ant nests from Bangkok, Thailand, in late 2008 and tracked them over several generations.

Alexander L Wild

Chips off the old block

He found that when a queen ant makes a daughter queen she simply clones herself, laying an egg that is her genetic doppelgänger.

Things get more complicated when she makes a reproductive male, however. She mates with a male – probably her brother if she doesn't look beyond her nest – but this time the offspring contain none of her genetic material: they are simply clones of the father. As a result, the two siblings can breed while avoiding the problems associated with inbreeding: their offspring are genetically identical to their parents.

When it comes to making workers, the queens switch to normal sexual reproduction, mixing their own genes with those of the males – often their brothers. As a result, the alleles get mixed together, but because these workers don't reproduce, there is again no danger that the problems associated with long-term inbreeding will arise.

In the lab, queens readily mated with males from their own nest, even though those males were their brothers. Pearcy still has the nests in his lab, and despite several generations of ants mating with their siblings, there is no sign of harm. "They are doing fine," he says.

The most bizarre life story on Earth?

SPECIES *Symbion pandora*

HABITAT In the eastern Atlantic Ocean, on the mouthparts of Norway lobsters (also known as Dublin Bay prawns or langoustines)

There's no question that discovering a new species is very cool. But how about discovering a new phylum?

A phylum is a broad division in taxonomy. For example, all vertebrates, from fish to humans, belong to the chordate phylum.

Animals of different phyla look radically different – think how dissimilar dogs and flies are.

In 1995, Peter Funch and Reinhardt Møbjerg Kristensen, both then at the University of Copenhagen, Denmark, discovered an animal so unlike any other that a new phylum – Cycliophora – had to be created just for it.

Symbion pandora, as they called the new creature, is a tiny animal with a complex body and a bizarre life cycle.

Peter Funch

It still baffles biologists almost two decades after it was formally described, and the latest work on its nervous system isn't helping matters.

Pandora's tube

Symbion is a tiny animal about half a millimetre long, shaped like a bulbous tube with a ring of tiny hairs called cilia at one end.

It lives on the hairy mouthparts of Norway lobsters. Tens or even hundreds can be present on one lobster, feeding on bits of leftover food and apparently doing no harm to their hosts.

The ring of cilia drives food particles into a funnel, which delivers them into a U-shaped digestive tract. Any inedible fragments are ejected through the anus,

FOTO : PETER FUNCH , KØBENHAUNS UNIVERSITET

with the help of a muscular sphincter.

Symbion has no legs, but keeps itself in place with a short stalk ending in an adhesive disc that attaches to the host lobster. Things start to get complicated when you consider its life cycle.

Prometheus and Pandora

Let's start with a feeding animal living on a lobster's mouthparts. This individual – it's hard to assign a sex – can then produce one of three kinds of offspring: a "Pandora" larva, a "Prometheus" larva or a female.

The Pandora larva develops into another feeding adult, in a simple case of asexual reproduction. By contrast, the female remains inside the adult and awaits a male – but, attentive readers will be crying, what male?

The answer lies in the Prometheus larva. This attaches itself to another feeding adult, then produces two or three males from within itself. These dwarf males, which are even more internally complex than the other stages, seek out the females and fertilise them – though the details are unknown.

Once the female has been fertilised, she leaves the adult's body and hunkers down in a sheltered region of the lobster's mouthparts.

Her body, no longer needed, turns into a hard cyst. Inside this, a fertilised egg develops into yet another stage: the chordoid larva.

In due course this larva hatches and swims off to colonise another lobster. Once it has attached itself to one, it develops into another adult and at this point the cycle begins again.

It seems there are two other species of *Symbion*. One lives on American lobsters, and another, which may not be a distinct species, on European lobsters.

Nobody knows how the symbions arose, or where they fit into the evolutionary tree/thicket/web (you can choose your own metaphor).

Studies of their genes suggest that they may be related to the entoprocts and bryozoans, two groups of marine animals that look like goblets on long stalks. The "goblets" are topped with rings of cilia called crowns with which the animals feed – rather like the symbions do.

There is just one problem: no one is really sure where the entoprocts belong in the tree of life either.

Bits missing

Another way to look at the problem is to compare symbions' nervous systems with those of other animals. The symbion phylum, and the entoprocts, are part of a larger group called the Lophotrochozoa – so which of these do their nervous systems share similarities with?

Bizarrely, the answer may be "none". A recent study by Kristensen and his colleagues showed that the various symbion larvae have nervous systems quite unlike other lophotrochozoans. They seem to be missing several key components, perhaps because they lost them at some point in their evolution.

It seems the symbions will keep their aura of mystery for a while yet.

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