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Sample translation

Enchanting Evolution
Why fish climb waterfalls
and bats give blood

by Hanna Nyborg Støstad

Contents

Foreword

I've always been fond of animals, but it wasn't until I started studying biology that I realised how little I really understood *why* they do what they do. As I learned more, I became increasingly fascinated by the natural world around me. For example, I'd hear a bird sing and try to figure out why it did so, and how that behaviour might have arisen and evolved. Seeing nature through the eyes of evolution opened up a whole new world to me.

For four years, from 2014 to 2018, I was lucky enough to work full time on evolution and animals at the Natural History Museum in Oslo, doing a PhD in evolutionary biology. During that time I heard many stories about animals and evolution from colleagues all over the world. Some of the stories are so extraordinary that they seem almost beyond belief; some are brutal and shocking, while others are funny and lovely. In this book, I want to share my favourite stories to help more people gain an insight into the world of evolution.

There are many scientific debates and plenty of literature I haven't dealt with in the main text, so if you are especially interested in a particular subject or if there's something that's puzzled you, you can check the list of sources at the back of the book. It contains references to the scientific papers that underpin the examples I describe, listed in the order in which they appear in the book, along with several textbooks and other types of articles, as well as some supplementary explanations. The species list at the back of the book provides both English and Latin names. There is also a list of important environmental protection agencies that help protect the Mexican blind cavefish, the lemurs and the golden poison frogs.

Introduction:

Leafcutter ants

There is an agrarian society in the rainforests of Colombia. Its main diet is a fungus that grows only here, and its farmers work hard to ensure that the fungus thrives by clearing weeds and treating the crops with nutritious fertiliser. Its workers set out to find fertiliser for the fungus, moving in orderly and systematic columns, while its queen stays at home.

These farmers, workers and queens are not people, but ants. Leafcutter ants have the second-most complex society on Earth after our own. But whereas human agriculture has only existed for around ten thousand years, the ants' system is better established: it is more than 55 million years since the ants first began to cultivate fungus.

The history of a leafcutter colony starts with a swarm. This is when many ants, thousands upon thousands of them, fly off at the same time to start a new nest. During the swarm, one of the female ants mates with a male ant, receiving so much sperm that she will never need to mate again. She is now ready to become the queen of her new colony, where she has no need of a king.

When she finds the perfect spot for the new nest, she first makes a small underground cave, where she "plants" some fungus she's brought with her from her previous nest. Then she withdraws, hiding away in another dark cave to lay her eggs. The eggs quickly hatch into small larvae, which grow into adult ants. Their job is to help the queen take care of the colony and the fungus, while she devotes herself solely to laying more eggs. All the new ants are sisters –

daughters of the queen. Like the queen, they don't mate, so none of these daughters will have any offspring of their own.

Instead, the ant sisters work to maintain the colony. There are four types of ant in addition to the queen: two types of soldier ant, large and small, which defend the colony from attack; and two types of worker ants, also large and small, which work full time in different ways to cultivate the fungus. The big worker ants work out in the forest, where they gather leaves from the trees around the nest; when they find suitable leaves, they use their powerful mandibles to cut them into smaller pieces. Then they return to the nest carrying the pieces of leaf, which can often outweigh them. They follow familiar trails and, since there are thousands of worker ants, they organise into systematic columns along these "motorways" to avoid crashing into each other.

When they get back to the nest, the leaves are handed over to the small workers, which chew them up into a sticky mulch that they apply to the fungus. The fungus grows the same way mould grows on blue cheese, and when it is big enough, the ants can harvest and eat it. The fungus is completely reliant on the ants' fertilising input, but the ants are also completely reliant on the fungus, since they are unable to digest raw plant matter. So they take good care of it. Not only do they provide it with nutrients – specialised small worker ants also protect the fungus from a nasty parasitic fungus by keeping the fungus gardens clean. Waste material is carried out to a compost heap outside the nest.

After roughly a year, there is a new swarm. And then a new, fertile generation is hatched: both females who will become new queens and males who will live a short life in which they will mate with new queens from other colonies. When the swarm is over, the males die, while the queens leave to establish new colonies, where they plant the fungus again.

It seems incredible that evolution has shaped this complex society. The subterranean nests may be up to 80 metres deep and 80 metres in radius, containing more than eight million specialised ant inhabitants. Could such a system really have come about entirely without intentional, intelligent design?

Evolution doesn't plan, but there are good reasons why the ant society works the way it does. The animals now living on Earth can give us great insight into the workings of evolution. And by taking a closer look at some of the most exciting animals, we can find out how it is has been possible for such complex societies and other astonishing lifestyles to evolve.

This book is divided into four parts. The first is about the individual's battle for survival and how that battle has caused animals to evolve highly specialised lifestyles. In part two animals must relate to family life: potential partners, rivals, children and parents. Part three deals with the interaction between animals that are not close family members – both other animals within the same species and those from different species. The fourth and final part adopts an even broader perspective: how animals must adapt to an ecosystem undergoing rapid change.

I hope that, like me, you will not only be entertained by the enchanting world of animals, but will also gain a better understanding of *why* all living animals are the way they are and do the things they do.

[…]

Chapter 4:

New Discoveries, New Species

Evolution doesn't know in advance what will be useful. The development of life on Earth is a process of trial and error, based on random mutations and new combinations of genes, and it can take a long time for the right combination to emerge. If the trial is successful and an advantageous trait suddenly appears, this can pave the way for new lifestyles and the use of new resources that have never previously been exploited. Just think how many different professions were created when electricity was discovered! Important "discoveries" like this can happen in nature too.

Tokyo Bay, 1944. On the surface, all is calm; but deep beneath the dark waves, a drama is playing out. An American submarine has moved into Japanese waters on the hunt for Japanese warships and tankers. The submarine crew are facing a challenge: They must be aggressive enough to have a chance of success, but at the same time they must avoid discovery. The Japanese are searching for them with hydrophones – equipment that can pick up sound waves under water, and the submarine crew know that they may be discovered at any moment. They set course for a coral reef where they can hide, and there they remain, awaiting the right moment for attack.

The Japanese forces for their part work intensively to find the American submarines that they know pose a threat to them in the bay. They have to interpret the hydrophone signals correctly if they are to protect the huge

Japanese tanker that is on its way out of the bay. But all that comes out of the hydrophone system is noise. They hear nothing other than an intense crackling sound, which varies in volume depending on the place, but always dominates the output of the hydrophone system. The Japanese have tried to get researchers out into the bay to investigate the mysterious sound, but the American bombers make the work almost impossible. When the submarine glides out from beside the coral reef and attacks the tanker, it is too late. The pride and joy of the Japanese is torpedoed and ends up at the bottom of the ocean.

You can also hear this mysterious crackling sound today if you duck your head beneath the water, especially in tropical regions. It is reminiscent of a distant motor or the sizzling of fat in a frying pan. But this sound isn't caused by a boat's motor or any other human activity. The Japanese hydrophones were outmanoeuvred by a tiny little shrimp.

For it was pistol shrimps making that mysterious crackling sound – which isn't really a crackling sound at all, but lots of consecutive sharp bangs. The sound is created by the pistol shrimps' spectacular method of capturing its prey. A pistol shrimp looks like a small pale lobster, only a few centimetres long, and – like all other shrimps – it has two claws, one on either arm. Unlike regular shrimps, however, pistol shrimps have one normal claw and one much bigger one, which is called a snapping claw or pistol claw. Both claws have two "fingers", which can be opened and closed, in the same way as you can pinch your thumb and forefinger together. The smallest claw is used only to eat food, but the pistol claw has superpowers: it can be snapped shut with such tremendous force that it creates a bang with a volume of around 210 decibels!

That compares with around 150 decibels when an actual pistol is fired, making the shrimps one of the ocean's loudest creatures.

If you've ever tried to clap your hands under water, you'll realise how impressive it is for such a tiny creature to snap powerfully enough to make a bang like that. When the shrimps snap their claws shut, the water is forced out between the two "fingers" of the claw, which are called dactyls, and is shot out straight in front of the shrimp like a jet stream. In the vacuum behind the stream of water – in other words between the dactyls – the pressure becomes extremely low because all the water has suddenly vanished, and tiny air bubbles form in this vacuum. The air bubbles grow super-fast to fill the vacuum left by the water, until the difference in pressure between the bubbles and the surrounding water becomes too great and the bubbles implode with a tremendous bang. As if the bang wasn't spectacular enough, so much energy is created by the implosion of the bubbles that the temperature inside the bubbles rises to over 5,000 degrees Celsius in a millisecond – which is roughly as hot as the surface of the sun – and a tiny little spark of light is emitted! The pistol shrimp's snap is one of only two known cases of such sonically created sparks of light in the animal kingdom (the other is the mantis shrimp, which has a similar if somewhat feebler snapping technique).

Even so, it is not the light or the temperature but the deafening sound that is most important for the shrimp itself: the sound spreads in the form of an intense shockwave in the surrounding water and stuns or kills small fish, which the shrimp can then capture at its leisure, using its two different claws as a knife and fork to eat them with. The pistol shrimps have found their own unique hunting method.

The nearest I've come to a pistol shrimp myself is via an acquaintance who had a saltwater aquarium at home. Many of his small fish suddenly began to die. He couldn't understand why and checked temperature, pH, salt levels and so on – to no avail. Then one day he spied a little creature that had grown big enough to attract his attention. A pistol shrimp! It had probably arrived with the sand they'd put in the aquarium and had used its pistol claw to kill the smallest fish. He managed to catch the shrimp in a net, thereby saving the lives of the remaining small fish. An added bonus was that this eliminated the irritating crackling sound he'd been hearing in his bedroom but had been unable to locate.

As well as being an efficient hunting weapon, the pistol shrimps' bang can also be used to blast a small cavity in the ocean bed where it can live, and to communicate with other shrimps. They often live in colonies – as they do on the coral reef in the Tokyo Bay – and work together to scare off enemies. Having this kind of pistol claw therefore gives the shrimp a clear advantage and not so many disadvantages – perhaps just the energy it takes to form the claw when the shrimp is developing from an egg, and a bit of energy each time the claw is snapped shut.

There are hundreds of pistol shrimp species that snap like this, and the trait has spread across the entire world. Along with several other colleagues, scientists Tomonari Kaji and Richard Palmer have used ultra-high-speed cameras and other technological innovations to analyse the snapping and have compared more than a hundred species of pistol shrimp. They have discovered that the shrimps initially had a simple pincer, not unlike our thumb and forefinger. Around 160 million years ago, this pincer started to develop into a claw where the upper dactyl (the "finger") wasn't fully fixed to the joint but could slide back along a small ridge on the upper part of the joint, locking into an open position. When the claw is to be shut, a two-part muscle system comes into play. One part of the closing muscle pulls the upper dactyl down towards the lower one, so that it stands quivering towards the edge, ready to be snapped shut, and builds up tension. When the other part of the closing muscle then pulls the dactyl forward slightly, it slides over the edge. Then, in a millisecond, all the tension is released with enormous force! Bang – the dactyls snap shut, creating low pressure, high temperatures, a flash of light and a sonic shockwave.

The pistol claw is a good example of how a new adaptation can lead to rapid development of many new species. The fact that the claw could be locked into an open position where it could build up tension was an extremely useful trait that offered great advantages and few disadvantages. Many shrimps have inherited this trait from their forebears. Since there came to be so many pistol shrimps, there was room for some of them to specialise further, and many different pistol shrimp species evolved. Some of them live in coral reefs while others live in caves; some live in tropical regions of India while others live in the slightly cooler Mediterranean.

One of my lecturers from England, Peter Mayhew, was involved in a project that investigated the rapid development of new insect species. What "discoveries" enabled insects to spread across the entire world and to evolve into so very many different species? Mayhew and his colleagues found that one important factor was the capacity for *complete metamorphosis*. This is where the insect passes through several totally different stages of life – like the caterpillar that becomes a butterfly. That enables insects to exploit several different types of resources over their life – they may, say, specialise in eating leaves as small caterpillars and nectar as older butterflies. They can also focus on different tasks: the caterpillar is an eating machine, which enables it to grow as quickly as possible, whereas adult butterflies invest their energy in flying round looking for a partner. The capacity for complete metamorphosis laid the foundations for an enormous evolution of insect species: it is estimated that around 45% to 60% of all species living today are insects that undergo complete metamorphosis!

Rapid evolution of many new species may also happen when new geographical regions are discovered. Roughly two million years ago, a small flock of finches flew across the ocean – perhaps aided by a strong wind – and found a desolate archipelago: the Galapagos. These volcanic islands in the middle of the Pacific Ocean, which emerged relatively recently on a geological time scale, were more or less undiscovered at that time, with few species. However, there were a number of different plant species there, which offered various types of food for the newly arrived birds. Some of the finches developed thick, powerful beaks that were perfect for crushing big, tough seeds, while others evolved thin, sharp beaks that allowed them to make holes in the cactus fruits and eat the flesh inside. Over a pretty short time, many species arose, each specialists in their own type of food. This group of birds is known as Darwin's finches, as they were important for the young Charles Darwin when he was developing his theory of natural selection. There are now around fifteen species of Darwin's finches, depending slightly on how one classifies them.

Darwin's finches are a classic example of rapid evolution of new species, and this explosive evolution is often explained by the fact that there were no other birds exploiting the various lifestyles. But that isn't strictly true. In fact, several thousand years *before* the finches arrived in Galapagos, another type of bird arrived at the archipelago: mockingbirds. There are now four mockingbird species on Galapagos, but they are all very similar, with the same type of beak. Biologists have tried to find out why the finches specialised into so many different species while the mockingbirds did not. It seems that it is down to differences in the genes that code for a protein called *calmodulin*. The amount of calmodulin determines how long a chick's beak grows inside the egg. Calmodulin is found in all birds, but there is variation in levels of production, and the amount produced then influences the length and shape of the beak. Darwin's finches have many complex genes that collaborate to regulate how much calmodulin is produced, whereas mockingbirds have simpler genes that are not especially capable of regulating calmodulin production. In other words, they have a less flexible genetic starting point. When the mockingbirds arrived on the Galapagos Islands, they were therefore restricted to one type of beak, and would have had to undergo large genetic mutations in order to evolve new beaks. The finches, on the other hand, were easily able to evolve new types of beaks with only minor changes in their genes, and that is how so many new species came about.

The finches discovered a new region, whereas the insects and the pistol shrimps discovered new physical traits. These discoveries brought many advantages and led to explosions of new species. These species explosions progressed very rapidly by evolutionary standards, but they were nonetheless gradual. In the case of pistol shrimps, it took a long time to evolve the pistol claw. First, they evolved a semi-developed snapping claw. That worked better than a simple, "primitive" claw, but was not as powerful as the pistol claw. The pistol claw as we know it today was not fully evolved until around 18 million years ago – in other words more than 140 million years after the evolution from a simple pincer began. At every step along the evolutionary way, the claw became slightly better than its predecessor – if the interim variant had been deficient, it would never have survived long enough to evolve further.

Evolution can only make use of what is available. As illustrated by the mockingbirds, it is unlikely that totally new lifestyles will emerge unless there is a pre-existing genetic basis for them. In the next chapter, we'll go back to the beginning of advanced behaviour: how did complicated adaptations emerge from nothing?

SOURCES, CHAPTER 4

New discoveries, new species

The story of the submarine that sank the tanker is based on historical facts, and there are historical sources that describe how submarines in this area used the pistol shrimps as cover against hydrophones during the Second World War. There are also sources that describe American submarines torpedoing Japanese tankers. Nonetheless, the course of events I describe is, to a certain extent, my own account.

Historien om pistolrekene er inspirert av en podcast fra Radiolab, Bigger than Bacon, fra 2016. https://www.wnycstudios.org/story/bigger-bacon

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To work out a rough timeline for the evolution of the pistol claw and its various stages, I consulted Richard Palmer, one of the authors of the pistol claw article I wrote about in the text. He told me the first shrimps to show signs of any kind of pincer were from the Oplophoridae family, which evolved around 161 million years ago, and that the pistol claw proper, with its two-part muscle, appeared with the Alpheus genus, around 18 million years ago.

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