Microscope image of Toxoplasma gondii

Parasites:
Nature's Puppeteers

Parasites have evolved many ingenious ways of exploiting their host organisms - some can even control their host's behaviour! PhD student Boris W. Berkhout explains how some parasites gain this control, and how his research will shed light on the evolutionary arms race between host and parasite.

When we get the flu or a similar disease, our body tries to fight off the attack through our immune system. This defence usually works well; we might feel ill for a couple of days and stay at home watching Netflix, but after that we soon start to feel better and can go back to work on our PhD projects. Unfortunately, not all diseases make it that easy for the infected individual. Some parasites, in particular, will try hard to make their host pretty sick, with certain species going so far as manipulating their host into being eaten by predators! Why would they do this?

> "Rats would normally run away from the smell of cats, but when they are infected with *T. gondii*, they become weirdly attracted to the odour"

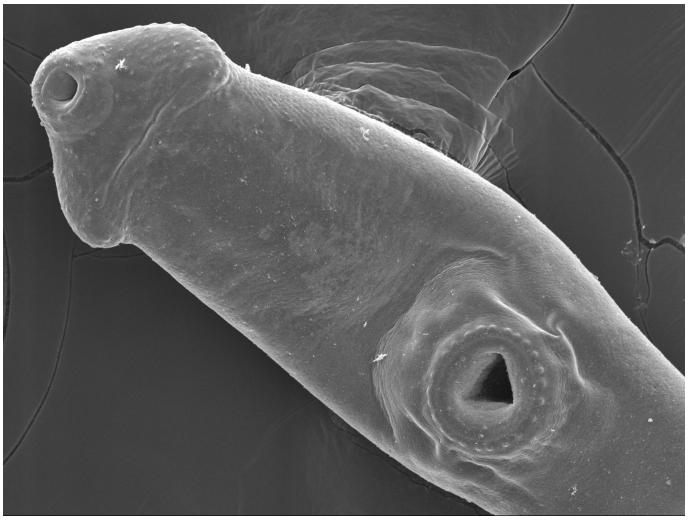
Climbing the food chain

Many parasites have complex life cycles, meaning that they require several different host species to complete their life cycle. A famous example is *Toxoplasma gondii*; this protozoan can use many warm-blooded animals, like rats, dogs and humans, as its first host. However, when it wants to sexually reproduce, it needs to infect a cat. So to move from rat to cat, the parasite alters the behaviour of its rat host. Rats would normally run away from the smell of cats, but when they are infected with *T. gondii*, they become weirdly attracted to the odour. Thus, upon encountering a cat, the poor infected rodent runs towards it *kamikaze*-style and usually gets eaten, passing *T. gondii* up to its feline host. In this way, the parasite can complete its life cycle.

> "The parasite cunningly infects and 'encysts' in the foot, impeding the cockle's digging behaviour"

Son of a beach

Even for parasites, though, life is not always easy. Take, for example, the trematode worm *Curtuteria australis*. It lives in cockles in coastal areas of New Zealand. This time, the parasite needs to infect a marine bird, like an oystercatcher, to sexually reproduce. The snag is that oystercatchers and other marine birds feed on a range of prey near the beach, such as fish, starfish, polychaete worms, and bivalves like cockles, but preferably on whichever food is most easily accessible. This can pose a problem for *C. australis* as



Scanning electron micrograph close-up of *Curtuteria australis* its cockle host can hide. This sometimes makes them harder to find than other prey so the birds may not feed on them. To remedy this situation, the parasite has a devious way of putting cockles at the top of the menu.

Cockles hide from predators by burying themselves in the sediments using a big muscle called the 'foot'. Thus, all that *C. australis* does is manipulate the digging behaviour of the cockle so that it can no longer bury itself. To do this, the parasite cunningly infects and 'encysts' in the foot, impeding the cockle's digging behaviour. The more cysts there are in the foot, the more rigid it becomes, and consequently the harder it becomes for the cockle to bury itself. Conveniently enough though, the cysts do still allow the cockle to 'unbury' itself quite easily. This wouldn't always be a problem for the host; cockles seldom come out of the sediment anyway and don't need to rebury themselves often. However, once in a while, the cockle will try to find a better place for feeding, and that is when, after relocating, it finds itself laying helplessly on the sediment and unable to dig – an easy prey for a passing bird. When a bird then eats the cockle, *C. australis* can mate and complete its life cycle, just like the rat-cat case.

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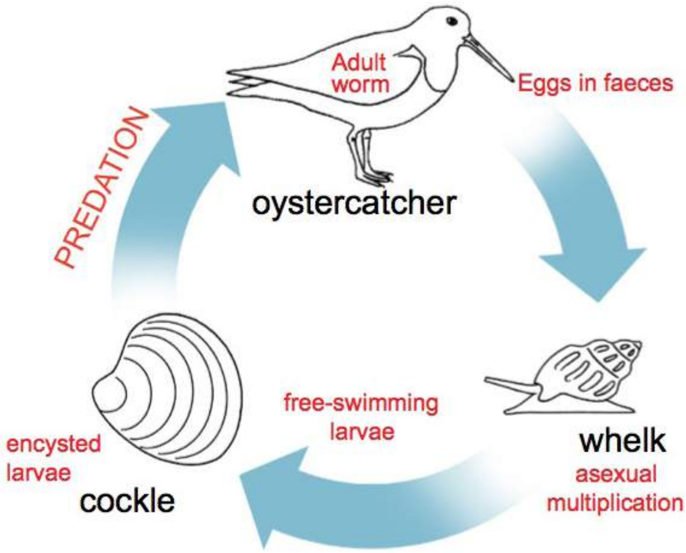
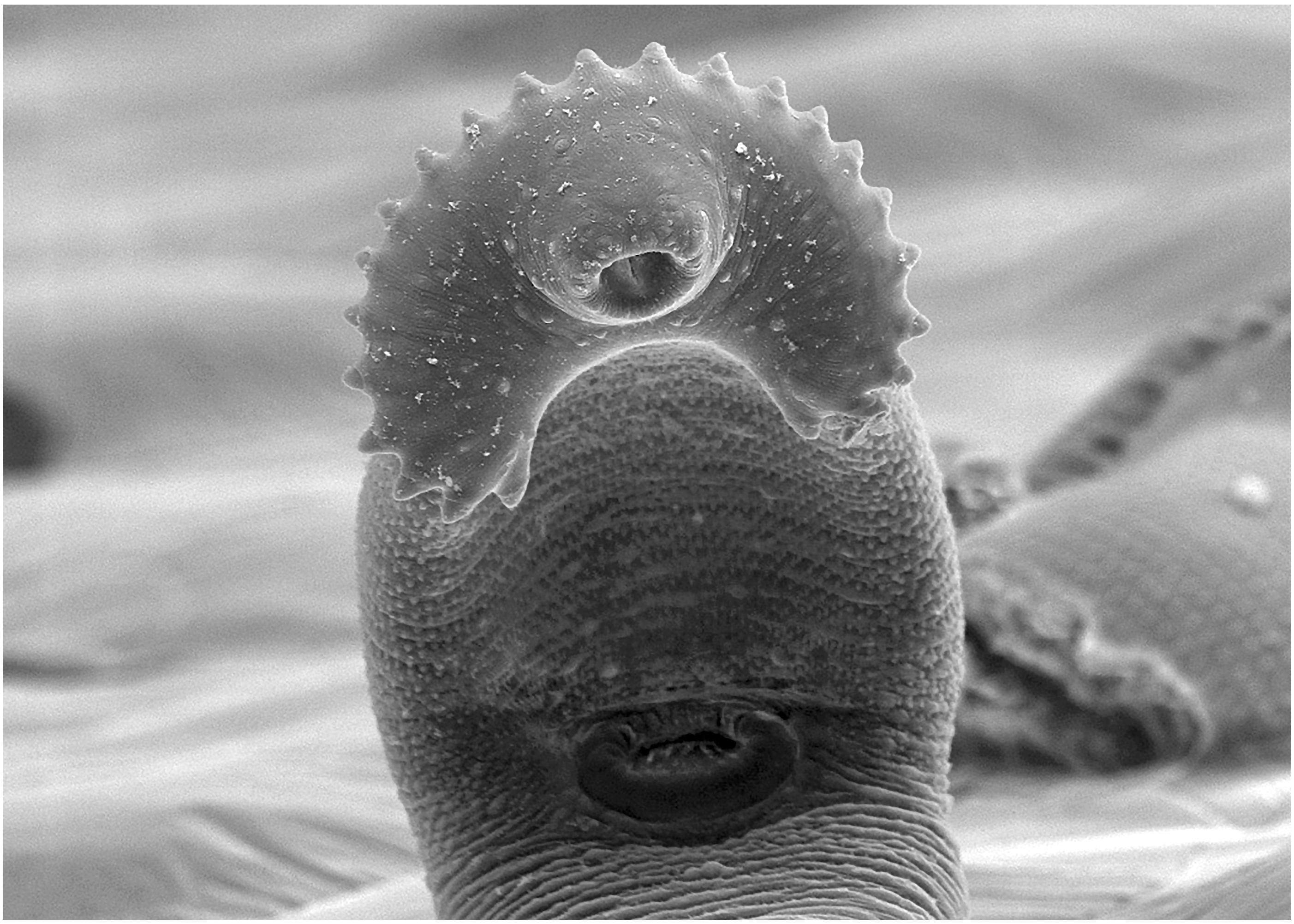


Schematic of the life cycle of the Trematode Curtuteria Australis, showing its complex journey up the food chain

Unfore-sea-n occurrences

There is yet another complication in *C. australis's* plans: birds are not the only ones looking for a tasty meal. There are plenty of fish in the sea, literally, who will not let an easy snack pass by. Unfortunately for the parasite, it cannot reproduce, or even survive,

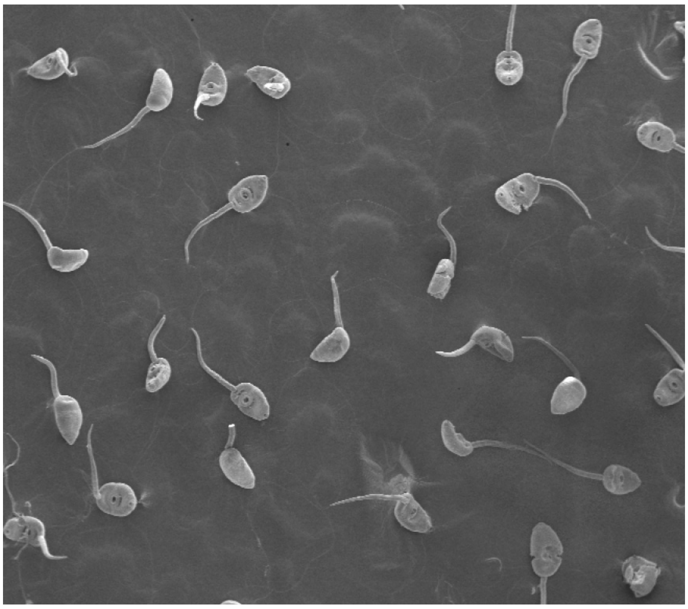


Scanning electron micrograph of a Trematode parasite fresh from its cockle host

“This variation in suitable and non-suitable (dead-end) hosts during the day could prompt the parasite to make the cockle surface during the day, but bury itself during the night”

in fish; this is what they call a dead end for the parasite. So how does *C. australis* make sure it ends up in a bird and not a fish? As far as we know, it can't. However, theoretically, there are several ways in which the parasite could overcome the problem of being eaten by the wrong host.

One option for *C. australis* is showing an 'environment-dependent response'. This means that in beaches where birds feed mainly on cockles (and other bivalves), there's a good chance that at some point the cockle will be eaten by a bird, regardless of whether it's buried or not. In this scenario, the parasite doesn't need to impair cockle-burying too much – it just encysts in different tissues and leaves the foot alone, minimising the chances of being eaten by a dead-end host. Conversely, in environments where there is plenty of other easily accessible prey, the buried cockles are less likely to be eaten by a bird; here it would be better for the parasite's chances to heavily sabotage the burying behaviour of the cockle. Even if that means risking being eaten by the wrong predator.



Scanning electron micrograph of a group of Trematodes similar to *Curtuteria australis*

Another option is that there's a temporal component to the host manipulation. This is possible if the different predators feed at different times of the day or during different times of the year. While the birds might feed by day because they are visual predators, the fish may feed during the night to avoid themselves being eaten (by the birds). This variation in suitable and non-suitable (dead-end) hosts during the day could prompt the parasite to make the cockle surface during the day, but bury itself during the night. This trick would probably require a bit more advanced host manipulation.

A close-up of a Schistosome parasite that enters humans by contact with infected water

A similar thing could happen on a seasonal scale, especially if the preferred bird host is a migratory bird that is only present during certain times of the year. It wouldn't be smart for the parasite to make the cockle surface in winter when the bird host is off enjoying warmer temperatures near the equator, but it would be better during summer when the birds are present.

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A heated relationship

Similar to *C. australis* manipulating its cockle host, many other parasites can direct their host's behaviour. They do this in many different ways: some excrete hormones, others directly affect the bodily condition of the host (like *C. australis*), and some will affect gene expression. In my own research, I study host-parasite interactions with an extra level of complexity; my project focuses on how the interaction between parasites and hosts is affected by changes in temperature, as well as the effect on the whole life cycle of the parasite. For this, I use *Schistocephalus solidus* – a parasite that infects stickleback fish and has a complex life cycle – and study the effect of temperature on each of *S. solidus's* life stages in the lab. This project is generating detailed data that can then be used to inform mathematical models and make predictions. will help to uncover how changing environments are altering the millions of years old arms race between hosts and parasites.

“In my own research, I study host-parasite interactions with an extra level of complexity”

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