Mutual sabotage in parasites

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Often, multiple parasites attack one host - here for example, the tapeworm Schistocephalus solidus (green) and the threadworm Camallanus lacustris (blue) in the copepod. If the parasites have different developmental stages, a conflict of interest is pre-programmed. Credit: MPI f. Evolutionary Biology/ N. Hafer

Some parasites have only one goal: to develop completely in their intermediate host, await the right time to infect their definitive host and procreate there. Many parasites manipulate their intermediate host's behaviour. This causes the host to act differently and, depending on the parasite's requirements, be more or less evident to its natural predator. But what happens when parasites in different developmental stages or even different species of parasites with contradictory goals infect the same host? Researchers from the Max Planck Institute for Evolutionary Biology in Plön, Germany, have discovered that two different species of parasites in different developmental stages in the same copepod will mutually sabotage each other's efforts and disable the other's manipulation. According to the researchers, the parasite in the infective stage always retains the upper hand in cases of conflicts of interest.

Apart from in Tom and Jerry, most mice would never dream of voluntarily staying in the direct vicinity of a cat. Some mice do though, and even appear to be drawn to cats. However, this is not completely natural behaviour, as they are in fact being manipulated by a third party. Mice act as the intermediate hosts for Toxoplasma gondii – a parasitic protozoan which uses cats as a definitive host for its procreation. In order to be trophically transmitted from the intermediate hosts to the definitive host, the parasite modifies the mouse's brain and, consequently, its behaviour. The mouse becomes more careless and thus easier prey for cats. The same parasite is also capable of using humans as intermediate hosts and manipulating our behaviour. Mood swings, an increased readiness to assume risks and schizophrenia have all been attributed to a toxoplasmosis infection. Infected people also often display delayed reactions, which is why they are involved in traffic accidents more frequently.

From alternate host to end host

The cestode Schistocephalus solidus is similarly able to bend its

intermediate host's will to its advantage: in this case, it is a copepod, which firstly needs to be eaten by fish. These fish then serve as a source of food for birds, in which the worm finally completes its development cycle. However, the copepod is not only the cestode's intermediate host, but can also be the intermediate host for the nematode Camallanus lacustris. Both parasites develop in the copepod and only become infective after a certain period of time. Only then can they infect the fish as the definitive/intermediate host. If the copepod is eaten by the fish too early, the parasites do not cause the fish any harm. In fact, the action is fatal for the parasites, as they subsequently die. As such, the two parasites need to wait for the right moment, and until that time they modify their host's behaviour in such a way that it becomes less susceptible to predation.

The cestode and the nematode reduce the copepod's activity, and consequently the risk of it being eaten by a fish, to a minimum until they have reached their infective stage. As soon as the parasites become infective, their strategy reverses completely: the copepod should now become as active as possible so that it is eaten by a fish as soon as possible. If there are both infective and not yet infective parasites in the same copepod, a conflict of interests develops between them.

This conflict between different developmental stages and different species was investigated by the Max Planck researchers in their experiment. To do so, they infected copepods with both infective and not yet infective cestodes and nematodes and then measured how long the copepods remained active following a simulated fish attack. If the different infective stages live in different host organisms, the not yet infective parasites have a stronger effect on the host's activity than the infective ones.

Infectious stages sabotage the non-infected ones

However, if both stages infect the same host, things look very different. According to the researchers, an infective parasite will always sabotage the manipulation exerted by a not yet infective parasite, as it goes against its own interests. Whether the competitor is of the same or another species appears to be irrelevant. "The not yet infective parasite wants the copepod to remain inactive so as not to be eaten. But the infective parasite manipulates the host's behaviour in the other direction: the copepod becomes more active," says Nina Hafer of the Max Planck Institute for Evolutionary Biology.

The researchers are still not sure why the infective parasite sabotages the not yet infective parasite instead of waiting for it to become infective too. "Actually, the infective parasite has less to lose than the not yet infective parasite. It still has a chance of reaching the next host and procreating at some point. For the not yet infective parasite, on the other hand, the sabotage can mean a premature end," explains Nina Hafer. "However, there are also disadvantages associated with waiting, such as the possibility of the copepod's dying in the meantime." After all, an infective parasite was initially a not yet infective parasite as well, and it manipulated the host accordingly. It is possible that on reaching the infective stage, it simply disables all old sabotage mechanisms and, in doing so, has a negative effect on the not yet infective parasite at the same time.

The nematode appears to have a stronger hold on its host than the cestode: an infective nematode is able to suppress the manipulation of a not yet infective cestode completely, whereas an infective cestode can only partially counteract that of a not yet infective nematode.

The results of the study show for the first time that a parasite can not only sabotage or completely disable the effects of a member of the same species on a host, but also do the same to the manipulation of a less closely related species. This can have important ecological consequences

and, for example, have an effect on diseases such as malaria or toxoplasmosis. "For instance, parasites could disable the manipulation of pathogens completely or partially, thereby making it more difficult for the pathogens to spread," says Manfred Milinski, Director at the Max Planck Institute in Plön.

More information: Nina Hafer et al. Inter- and intraspecific conflicts between parasites over host manipulation, *Proceedings of the Royal Society B: Biological Sciences* (2016). DOI: 10.1098/rspb.2015.2870

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