Identifying Parasites

MIKOŁAJ K. ZAPALSKI
Faculty of Geology, University of Warsaw
m.zapalski@uw.edu.pl
Dr. Mikołaj Zapalski studies modern and fossilized corals, and interspecific interactions in the fossil record. He is a winner of the scientific award of PAS Division Three.

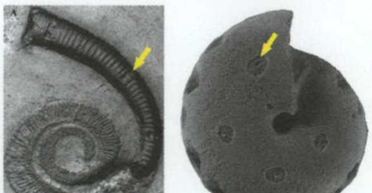
Parasitism is extremely widespread in present-day animals, but has this been the case during all geological periods? Research indicates that it is likely to have been the case; the more advanced the ecological interaction between species, the longer it has taken to co-evolve. In many cases, predators can switch to different prey almost overnight, while parasites are usually bound to a single host species

Parasitic behavior is one of the most widespread interactions between species, yet it is not very easy to observe. For symbiotic and predatory relationships, the species taking part in the interaction are usually easy to identify. For example, the relationship between a hawk hunting pigeons or a cheetah chasing an antelope is clear. But for parasites, usually only the host is visible, with the parasite being concealed on or within it. Observing tapeworms in the intestines of pigs, or trematode flatworms in the livers of goats, is far more difficult than observing a predator stalking its prey. Most people would find it easy to name a dozen or more different predatory animals, yet would likely struggle to name a comparable number of parasites. Meanwhile it has been estimated that at least 14% of all known species are parasites, with an average of four parasitic species per host species.

Tracking down pests

Studying fossilized parasites is hindered by difficulties in their observation and identification. The fossil record includes many examples of predatory behavior, mainly revealed as bite marks or other injuries to prey animals. Identification of parasites is a major problem since the effects of parasitism are usually not immediately obvious, and the interspecific relationship is frequently just metabolic without causing anatomical changes in the host. Parasites very rarely kill their hosts; when they do, it usually indicates a short evolutionary history shared by the two species. In the majority of cases, death of the host brings about death of the parasite, therefore a well-adapted parasite is one which exploits its host without killing it. For example, the vast majority of foxes found in southern Poland carry the *Echinococcus multiocularis* tapeworm; around 86% of the animals are infected by between 1-100 individual parasites, with around 4% carrying over 1000. This suggests that individual tapeworms are almost imperceptible for foxes, demonstrating that a well-adapted parasite can cause little to no symptoms in the host. Unfortunately for researchers, this makes them even more difficult to identify. Additionally, many parasites have no hard body parts, such as shells or carapaces, making them extremely unlikely to undergo fossilization.

How, then, can we identify fossil parasites? The task is difficult but not impossible. By bearing in mind that the interaction benefits one organism and harms the other, as well as the fact that the relationship is long-term (in contrast to predation) and that the host is usually the parasite's habitat, we can attempt to discern the parasitic identity of certain fossilized organisms.

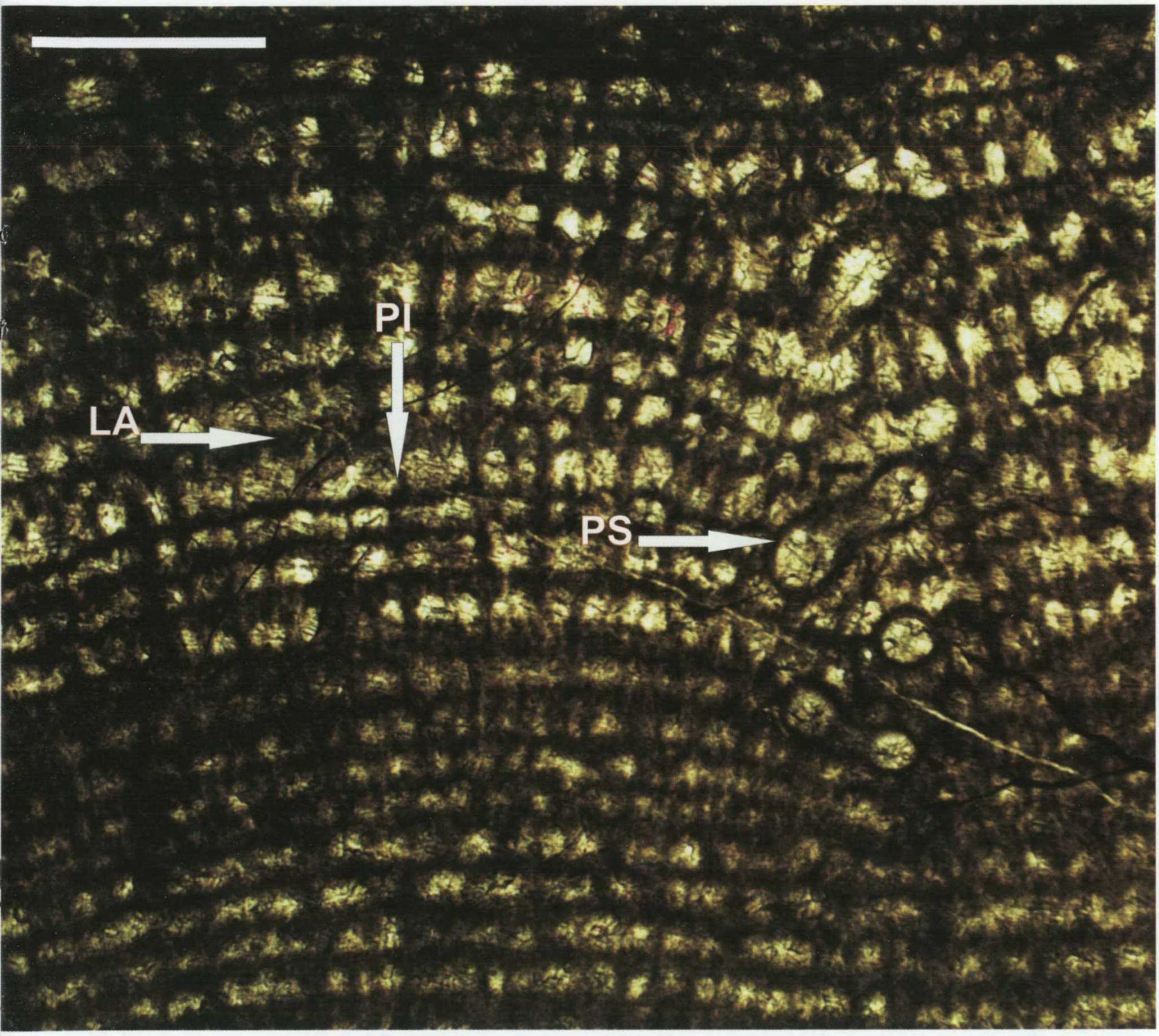


Devonian ammonites (*Ivoites* on the left, *Sobolewia* on the right) from Morocco showing traces of "pearls" (indicated by yellow arrows), most likely following infestation by trematodes. Specimen on the left is approx. 10 cm, the one on the right 2 cm. Source: *Acta Palaeontologica Polonica* (De Baets et al. 2011).

Illustration from Baets et al. (2011)

Ancient times

The marine invertebrates known as stromatoporoids were abundant in warm Devonian seas. Classified as sponges, they



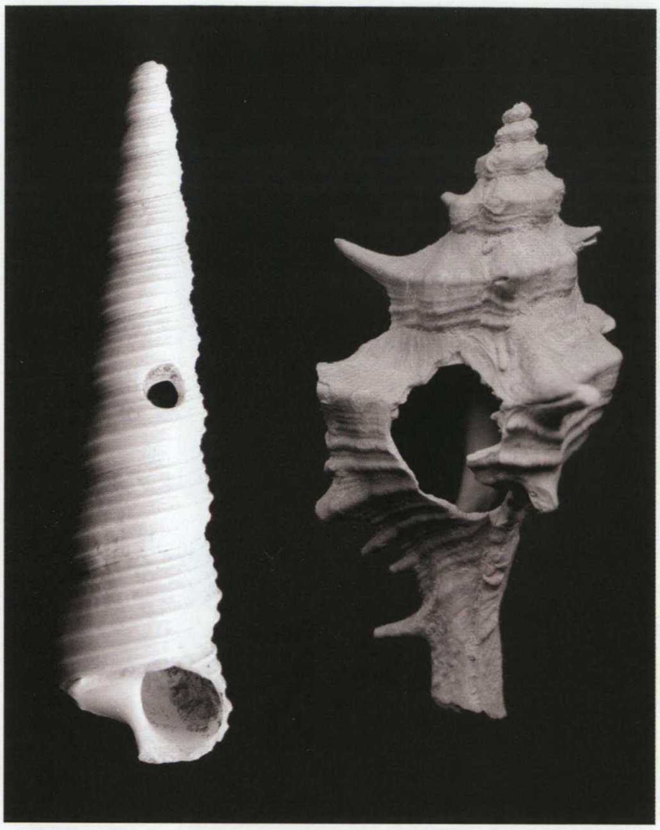
B. L. M. Hubert

Cross-section of a skeleton of a *Actinostroma* stromatoporoid with a *Torquaysalpinx* parasite from Devonian rock near Ardennes. Stromatoporoid skeleton: LA - laminae; PI - pillars Scale: 1 mm

had massive skeletons of calcite covered by soft tissue. Their skeletons were made of concentric laminate layers, with the laminae connected with vertical pillars. It was noted as early as in the 19th century that fossilized stromatoporoid skeletons occasionally include additional structures clearly originating from other organisms. The structures, usually tubular or helicoidal, punctured laminae forming additional incremental layers. Devonian material found near Ardennes shows that individual laminae are visibly bent downwards around these tubes. This demonstrates that the rate of growth of the host around the predatory organism was reduced, indicating a negative effect on the host and fulfilling the "host as habitat" criterion. Studying subsequent incremental layers allows us to estimate the age of the stromatoporoid. We can also determine how long the host had been inhabited by its "guest"; in the majority of cases, it can be demonstrated that the interaction lasted at least several seasons (although the variation in density of incremental layers has been interpreted in a number of ways).

Isopods are common parasites in all groups of modern animals. Representatives of the Bopyridae family are parasites inhabiting the gills of crabs, causing distinctive distension of the host's gill chamber. In Jurassic rocks found in Poland, crabs from

Identifying fossilized parasites



From the collection of Prof. W. Bałuk

Traces of predatory behavior from the Miocene. *Turritella* snail (on the left) with a hole drilled by a predatory *Natica* snail. On the right, *Murex* snail with a hole most likely punctured by a stomatopod (crustacean). Specimen size: a few centimeters. Wacław Bałuk collection.

the Prosoponidae family have been found with precisely such distended gill chambers. This is one of the best documented cases of parasitic behavior in the fossil record, clearly showing how the host's phenotype has been altered - another important factor in the identification of parasites.

Isopods also parasitize vertebrates. The present-day *Cymothoa exigua* parasitizes fish in a remarkable manner: it attaches itself to the host's tongue, which slowly withers and dies off. With time, the parasite functionally replaces the missing tongue. It is an unusual adaptation, and the only known case in which the parasite effectively replaces the host's organ. *C. exigua* parasitizes at least eight fish species, leading to the conclusion that this parasitic relationship has a relatively long evolutionary history. In fact in 2011, Wilson et al., studying Cretaceous (Albian) sediments in the Toolebuc Formation in Queensland in Australia, discovered fossilized ray-finned fishes of the *Pachyrhizodus marathonensis* species together with numerous isopods closely related to the present-day *Cymothoa.* Although the latter were scavengers, it is perfectly likely that they occasionally attacked live fish, attaching themselves to organs with a good supply of blood vessels, such as the tongue. This could have led to the evolution of the sophisticated form of parasitism described above.

Soft-bodied parasites

Vertebrates' digestive tracts are also commonly infested by protozoan and invertebrate parasites. As they cannot be fossilized due to their having no hard tissues, it would seem impossible to demonstrate their presence in ancient animals such as dinosaurs. The simplest way of detecting a parasitic infection in the digestive tracts of humans and other present-day animals is by studying feces; this was the approach taken by the paleontologists George Poinar and Arthur Boucot, who studied fossilized feces (coprolites) of dinosaurs from the Early Cretaceous rocks in Bernissart in Belgium. By macerating the fossils in a particular way, the authors were able to extract and identify Entamoeba spores and eggs of trematodes and nematodes. This spectacular discovery shows that Cretaceous dinosaurs were hosts to at least three different types of parasites.

Soft-bodied parasites can also be identified in fossils if the host itself secretes a hard shell to try and separate itself from the invader. In 2011, De Baets et al. described arrays of calluses on the internal surface of Early- and Mid-Devonian goniatite (cephalopod) shells, which they identified as evidence of pearl formation. Although the analysis can be interpreted in a number of ways, it reveals the structures to be similar to present-day pearls formed by molluscs following infection by trematode larvae. As such, it was possible to show that trematodes parasitizing molluscs is an extremely old biological relationship.

The oldest known metazoan parasites have been described as dating back to the early Cambrian period - around 540 million years ago. It seems that parasitism is an extremely old type of interaction, even though scientific papers describing fossil parasites are very rare, numbering in the tens rather than the hundreds. This hints at the vast amount of information not covered by the fossil record, and the difficulty in the correct identification of such "hidden" interactions. ■

Geological Museum, Polish State Geological Research Institute

Reconstruction of a dinosaur from the collection of the Geological Museum of the Geological Institute in Warsaw

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Further reading:

Brusca R.C., Gilligan M.R. 1983. Tongue replacement in a marine fish (*Lutjanus guttatus*) by a parasitic isopod (Crustacea: Isopoda). *Copeia* 3, 813-816.

De Baets K., Klug C., Korn D. (2011). Devonian pearls and ammonoid endoparasite coevolution. *Acta Palaeontologica Polonica* 56, 159-180.

Poinar G. Jr., Boucot A.J. (2006). Evidence of intestinal parasites in dinosaurs. *Parasitology 133*, 245-249.

Radwańska U., Radwański A. (2004). Chore i okaleczone zwierzeta jako ofiary pasożytów i drapieżców w jurze Polski - przegląd stanu wiedzy. [Ill and Injured Animals as Victims of Parasites and Predators in Poland's Jurassic - Overview of State of Knowledge]. *Tomy Jurajskie 2*, 99-111.

Wilson G.D.F., Paterson J.R. i Kear B. (2011). Fossil isopods associated with a fish skeleton from the Lower Cretaceous of Queensland, Australia - direct evidence of a scavenging lifestyle in Mesozoic Cymothoida. *Palaeontology 54*, 1053-1068.

Zapalski M.K., Hubert B.L.M. (2011). First fossil record of parasitism in Devonian calcareous sponges (stromatoporoids). *Parasitology 138*, 132-138.