Study offers explanation for why there are so few insects in the ocean

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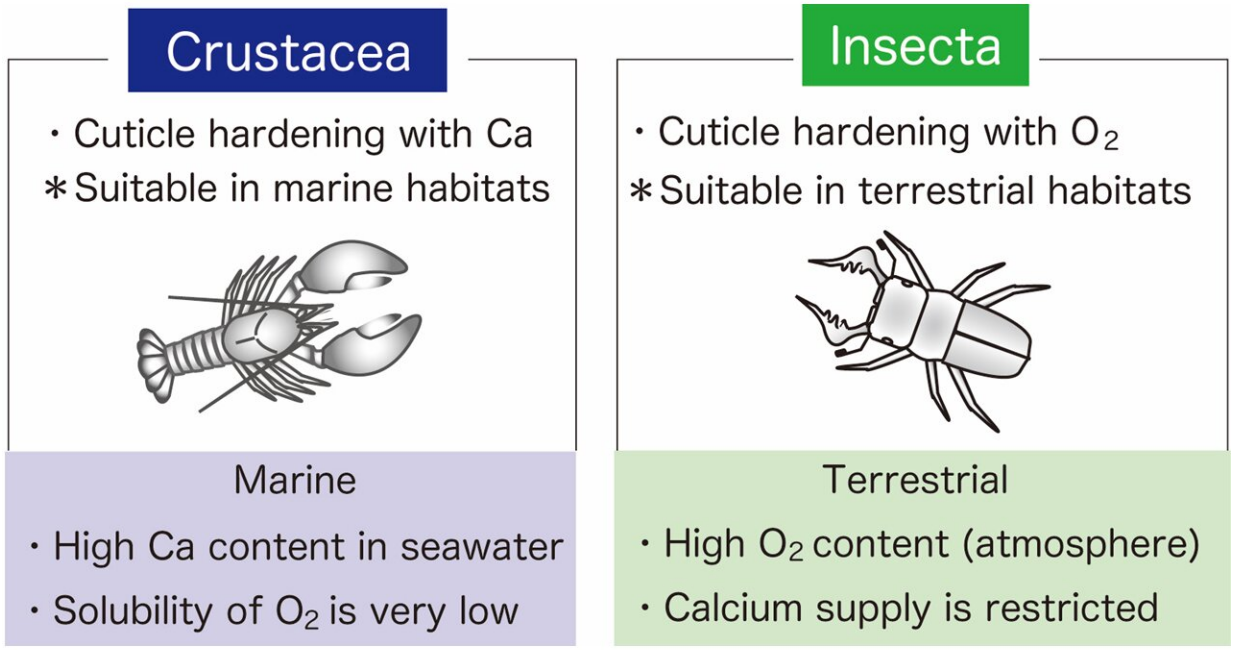

Crustaceans harden their shells with calcium, while insects harden them with oxygen. These match what is abundant in their respective habitats. Credit: Tokyo Metropolitan University

Scientists from Tokyo Metropolitan University have proposed a hypothesis for why insects are so rare in marine environments. They previously showed that insects evolved a unique chemical mechanism to harden their shells that uses molecular oxygen and an enzyme called

multicopper oxidase-2 (MCO2). Now, they argue that this gives them a disadvantage in the sea, while it confers advantages that help them on land, placing MCO2 at the heart of insect eco-evolution.

Insects are some of the most successful organisms on the planet. They are said to make up the most biomass of all terrestrial animals and have a significant impact on the global ecosystem. However, their abundance is matched by their startling rarity in the sea. Very few insects call the sea home, even though their biological ancestors came from there. It is a pervading mystery of science, one which scientists have been trying to answer for many years.

Now, researchers from Tokyo Metropolitan University led by Assistant Professor Tsunaki Asano have proposed a solution based on evolutionary genetics. The latest in molecular phylogenetics has taught us that both crustaceans and insects are part of the same family, Pancrustacea, and that insects were a branch that left the sea and adapted to the land. They share an important feature, an exoskeleton consisting of a wax layer and hard cuticle.

In previous work, the same team showed that when insects adapted to terrestrial environments, they evolved a unique gene that creates an enzyme called multicopper oxidase-2 (MCO2) that helps them harden their cuticles using oxygen. MCO2 mediates a reaction where molecular oxygen oxidizes compounds called catecholamines in the cuticle, turning them into agents that bind and harden the surface. This is in contrast to crustaceans who harden their cuticles using calcium from sea water instead. The team's claim is that this makes the land far more suitable for insects due to the abundance of oxygen. The sea is now a harsh environment due to both the lack of oxygen and the abundance of better adapted organisms.

But it is not just that the sea is not as hospitable for insects anymore. The

hardening and drying of the cuticle via the MCO2 pathway lead to a biomaterial which is not only protective, but also lightweight. They postulate that this may be why insects gained the ability to climb plants, glide, and eventually fly. This allowed them to migrate and occupy previously empty niches in the ecosystem, a strong driving force that led to their sheer numbers. Again, this is in contrast to crustaceans, whose shells are significantly denser, with a strong correlation between density and the degree of calcification.

Of course, insects are hardly the only arthropods to adapt to the land, so it's clear that MCO2 is not strictly necessary for success in "terrestrial niches." However, the nature of insect cuticles speaks volumes about their success in the terrestrial environment. In fact, the team believe that MCO2 might be a defining feature of insects—"no MCO2, no insects." Their work promises an entirely new highlight on the role that cuticle hardening might play in insect evolution and terrestrialization.

The research is published in the journal *Physiological Entomology*.

More information: Tsunaki Asano et al, Eco-evolutionary implications for a possible contribution of cuticle hardening system in insect evolution and terrestrialisation, *Physiological Entomology* (2023). DOI: 10.1111/phen.12406

Provided by Tokyo Metropolitan University