Genomic research unravels mystery of invasive apple snails

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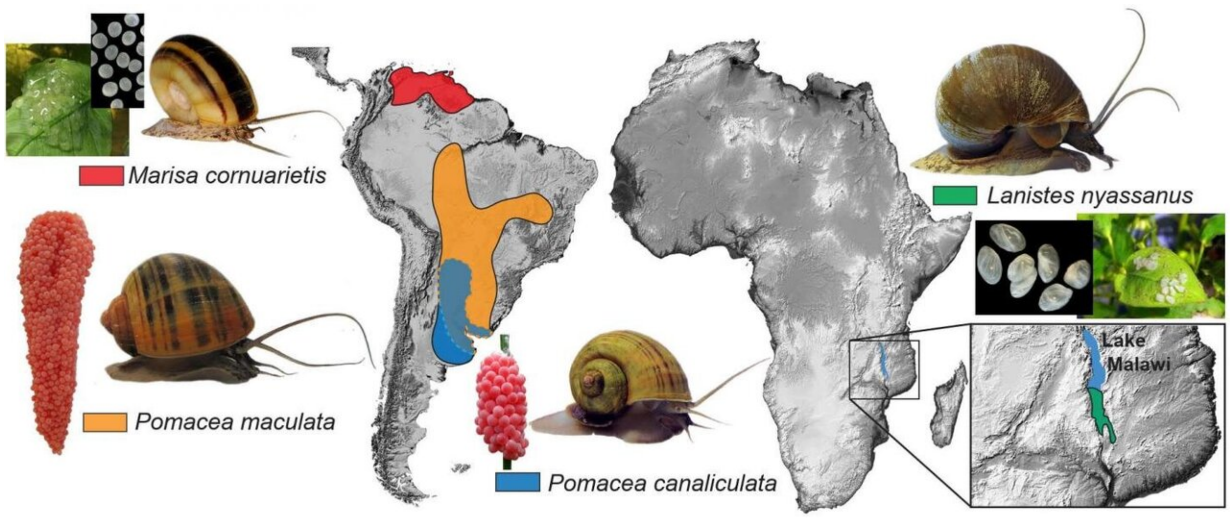


A figure showing the native range of the four apple snail species included in the study, and pictures of their adult and egg forms. The reddish-pink calcareous eggs of the two Pomacea species are deposited on land, whereas the white gelatinous eggs of *Lanistes nyassanus* and *Marisa cornuarietis* are deposited underwater. Credit: Hong Kong Baptist University

Biologists from Hong Kong Baptist University (HKBU) have led a study to sequence and analyse the genomes of four apple snail species in the family Ampullariidae. The researchers discovered that the apple snails have evolved to become highly sensitive to environmental stimuli, digest cellulose (a major component of the plant cell wall), form hard calcareous eggshells and pack neurotoxins in eggs. The findings could facilitate the development of effective genetic control measures for these destructive crop-eating snails.

The four apple snail species are the African Lanistes nyassanus, and the South American Pomacea canaliculata, Pomacea maculata, and Marisa cornuarietis. Among them, the two Pomacea species are the most invasive. Freshwater Pomacea are widely distributed in tropical and subtropical freshwaters. These natives of South America have spread to many other parts of the world. In China, Japan, Thailand and the Philippines, they are considered the number one rice pest.

Pomacea invaded Hong Kong in the early 1980s and they are now widely distributed in various freshwater habitats in the New Territories. Though most rice paddies have been abandoned in Hong Kong, the snails found their way to vegetable gardens and damaged semiaquatic crops, especially water spinach and watercress. They have also reduced wetland biodiversity by grazing on plants and preying on animals that live at the bottom of ponds and streams.

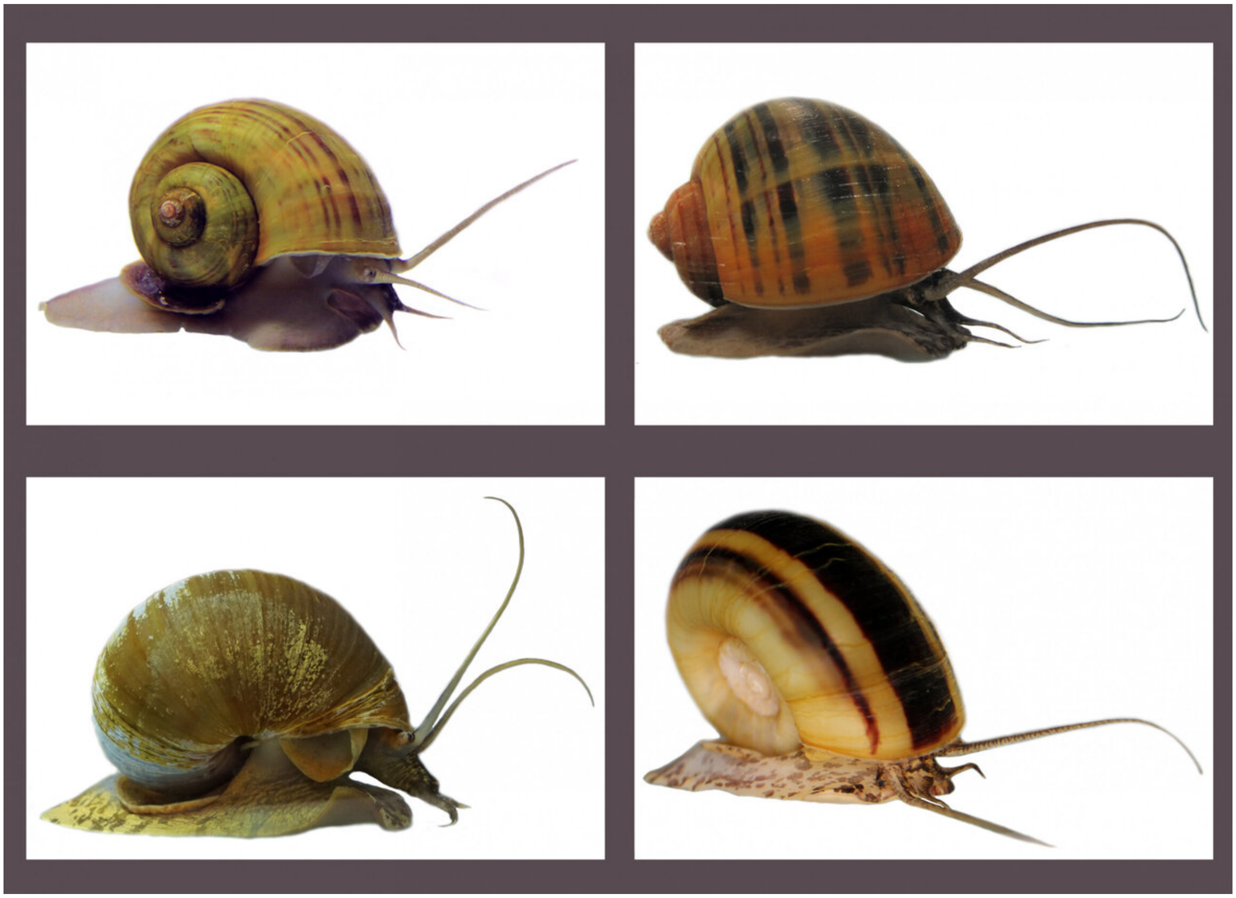
A research team led by Professor Qiu Jianwen, Associate Head and Professor from the HKBU Department of Biology sequenced and assembled the genomes of four apple snail species. In addition to colleagues from HKBU, the team included collaborators from Hong Kong, mainland China, U.S., Argentina and France.

Genome sequencing shows that apple snails have a long evolutionary history dating back more than 150 million years to the ancient continent of Gondwana. After the breakup of Gondwana roughly 100 million years ago, they have evolved separately in Africa and South America. While in Africa and South America Lanistes and Marisa have retained respectively the ancient trait of laying egg underwater, in South America Pomacea have evolved to lay their eggs on land. Comparing the African and South American apple snail species thus allowed the researchers to reveal some of the genomic innovations which have enabled Pomacea to be so invasive.

Environmental sensing and plant digestion

By comparing the genomes of apple snail species and other molluscs, the team found 28 gene families that were substantially expanded. This included some genes functionally related to chemoreception which are highly expressed in sensory tentacles, indicating that they may have enhanced environmental sensing ability.

Cellulose is the skeleton structure of green plants which helps the plant to remain stiff and strong. Different from most animals that rely on gut bacteria or fungi to break down cellulose, these apple snail species encode multiple copies of cellulase genes which enables them to secrete cellulases directly to actively decompose cellulose. This ability may help explain why apple snail species can digest a broad range of plant materials and exploit a variety of freshwater wetlands.



The four apple snail species featured in the study: (clockwise from top left) Pomacea canaliculata, Pomacea maculata, Lanistes nyassanus and Marisa cornuarietis. Credit: HKBU

Formation of a hard eggshell

The research team also compared the genomes of Marisa and Lanistes, who both deposit eggs underwater, and the two Pomacea species that lay eggs on land. The ability of the amphibious Pomacea to live in water and lay eggs on land is considered a key adaptation which enables them to avoid aquatic egg predation and parasitism. To enable this dramatic change in reproduction, Pomacea eggs must be able to survive on land.

The team found that the new acquisition of a calcium binding protein (CaBP) allows Pomacea to form a hard eggshell that physically protects the egg and prevents them from drying out.

Novel defence protein

Apart from the hard eggshell, Pomacea has acquired a novel neurotoxic perivitellin called PV2 in their eggs to help defend against terrestrial predators. Previous studies have shown that PV2 is a complex of two proteins: a membrane attack complex/perforin (MACPF) that is neurotoxic, and another protein called tachylectin that binds with the predator's target cell membrane. Through comparative genomic analysis, the team found that after multiple times of duplication the gene has acquired a new function (i.e. secreting PV2 through the albumen gland). Thus gene duplication may be responsible for the origin of PV2, another key innovation which enabled the ancestors of Pomacea to move from laying eggs underwater to on land.

Implications

Since Ampullariidae is an early diverging family of Caenogastropoda, one of the species of molluscs and the most diverse group of which accounts for over 60% of all gastropod species, the genomes of apple snail species are ideal for comparative studies with other molluscs, for which only a few published genomes are available.

Professor Qiu said: "The genomic data discovered by the team is a valuable resource for understanding ancestral genomic features within the ecologically important and biologically diverse caenogastropods. Given that several invasive apple snail species are notorious agricultural pests, the genomic resources from this study can be used to develop effective control strategies, including the synthesis of chemical molluscicides and the design of genetic control measures using ribonucleic acid (RNA) interference."

Provided by Hong Kong Baptist University