A crowning success for crayfish

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The Australian freshwater crayfish Cherax quadricarinatus belongs to the invertebrates, but its teeth are covered with a substance strikingly similar to vertebrate enamel. Credit: Shmuel Bentov / Ben-Gurion University

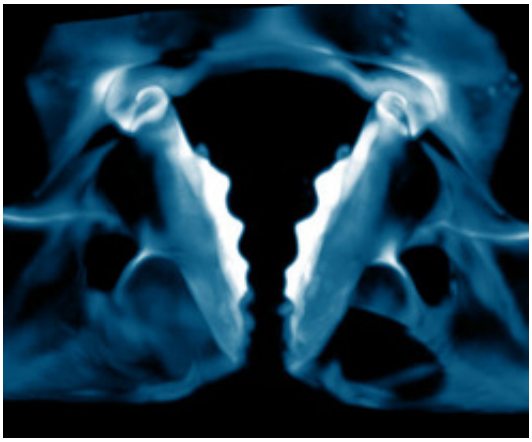
Nature sometimes copies its own particularly successful developments. A team of scientists from the Max Planck Institute of Colloids and Interfaces in Potsdam and the Ben-Gurion University at Beer-Sheva in Israel has now found that the teeth of the Australian freshwater crayfish Cherax quadricarinatus are covered with an enamel amazingly similar to that of vertebrates. Both materials consist of calcium phosphate and are also very alike in terms of their microstructure. This extremely hard substance has apparently developed in freshwater crayfish independently from vertebrates, as it makes the teeth particularly strong.

In terms of hardness, enamel sets a unique standard, which is hardly met by any other other biological material. The hardness and strength of the

outer layer of the crown of the tooth in humans and other vertebrates are due to tiny crystals of calcium phosphate, which also strengthen bones. And because the composition and structure of the enamel have made it exceptionally strong, the evolution in freshwater crayfish, too, has produced a highly mineralised protective layer for the mandibles that is very similar to enamel in vertebrates, as Barbara Aichmayer and her colleagues at the Max Planck Institute in Potsdam in cooperation with Amir Berman and Amir Sagi of the Ben-Gurion University in Beer-Sheva have now discovered. “We assume”, she explains, “that in the course of their evolution both vertebrates and freshwater crayfish developed enamel-like structures independently of one another. These amazing materials are a perfect answer to similar demands on the masticatory organs.”

The enamel of freshwater crayfish is heavily fluoridated by nature

The mandibles of the freshwater crayfish are part of the cuticle which, as in other crustaceans, consists essentially of a network of chitin fibres. The shell is hardened in particular by disordered calcium carbonate, which is termed amorphous by scientists. In the mandibles of freshwater crayfish, the softer compound material of chitin and amorphous calcium carbonate, however, is covered with a thin layer which, like human enamel, is composed predominantly of crystalline calcium phosphate. This is remarkable because the constituent calcium phosphate is rarely found in the exoskeleton of invertebrates. The elongated shape of the crystals and their arrangement perpendicular to the surface of the teeth, too, match the structure of human enamel to a large extent and produces similar mechanical properties. The structure makes the material extremely hard and at the same time highly resistant to crack propagation, giving the tooth perfect protection against destruction.



X-ray micro-computer-tomography of the mandibular apparatus of a freshwater crayfish. The enamel, mainly consisting of calcium phosphate crystals, appears bright. Credit: Shmuel Bentov / Ben-Gurion University

However, there is one aspect in which the teeth of freshwater crayfish differ from those of vertebrates: Their enamel contains a high level of fluoride that makes it much less water-soluble - all without taking fluoride tablets. In freshwater, the habitat of the freshwater crayfish, this is particularly important, because minerals containing calcium dissolve more easily there than in salt water.

Freshwater crayfish renew their enamel at a low metabolic cost

In human teeth, both the hard enamel on the crown and the underlying softer dentin are composed of calcium phosphate crystals. “Freshwater crayfish, on the other hand, are very economical with calcium phosphate, the production of which is for them metabolically much more costly than the construction of the rest of the cuticle”, says Barbara Aichmayer. Freshwater crayfish renew their cuticle again and again as

they grow. They dissolve the amorphous calcium carbonate out of the chitin tissue and partially store it in order to reuse it in the new shell. This is not possible with the crystalline calcium phosphate on their mandibles. They shed their costly enamel with the rest of the cuticle and build it completely anew. So in one respect, freshwater crayfish are way ahead of us. They renew their teeth at a low metabolic cost again and again, whereas our enamel, despite its hardness, gradually wears out and cannot be replaced.

More information: Shmuel Bentov, et al. Enamel-like apatite crown covering amorphous mineral in a crayfish mandible, *Nature Communications*, May 15, 2012; DOI: 10.1038/ncomms1839

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