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The effects of environment on *Arctica islandica* shell formation and architecture

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Abstract

Mollusks record valuable information in their hard parts that reflect ambient environmental conditions. For this reason, shells can serve as excellent archives to reconstruct past climate and environmental variability. However, animal physiology and biomineralization, which are often poorly understood, can make the decoding of environmental signals a challenging task. Many of the routinely used shell-based proxies are sensitive to multiple different environmental and physiological variables. Therefore, the identification and interpretation of individual environmental signals (e.g. water temperature) often is particularly difficult. Additional proxies not influenced by multiple environmental variables or animal physiology would be a great asset in the field of paleoclimatology. The aim of this study is to investigate the potential use of structural properties of *Arctica islandica* shells as an environmental proxy. A total of eleven specimens were analyzed to study if changes of the microstructural organization of this marine bivalve are related to environmental conditions. In order to limit the interference of multiple parameters, the samples were cultured under controlled conditions. Three shells presented here were grown at two different water temperatures (10 °C and 15 °C) for multiple weeks and exposed only to ambient food conditions. An additional eight specimens were reared under three different dietary regimes. Shell material was analyzed with two techniques: (1) Confocal Raman microscopy (CRM) was used to quantify changes of the orientation of microstructural units and pigment distribution and (2) Scanning electron microscopy (SEM) was used to detect changes in microstructural organization. Our results indicate that *A. islandica* microstructure is not sensitive to changes in the food source, and likely, shell pigment are not altered by diet. However, seawater temperature had a statistically significant effect on the orientation of the biomineral. Although additional work is required, the

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results presented here suggest that the crystallographic orientation of biomineral units of *A. islandica* may serve as an alternative and independent proxy for seawater temperature.

1. Introduction

Biomineralization is a process through which living organisms produce a protective, mineralized hard tissue. The considerable diversity of biomineralizing species contributes to high variability in terms of shape, organization and mineralogy of the structures produced (Lowenstam and Weiner, 1989; Carter et al., 2012). Different architectures at the micrometer and nanometer scale and different biochemical compositions determine material properties that serve specific functions (Weiner and Addadi, 1997; Currey, 1999; Merkel et al., 2007). Besides these differences, all mineralized tissues are hybrid materials consisting in hierarchical arrangements of biomineral units surrounded by organic matrix, also known as “microstructures” (Bøggild, 1930; Carter and Clark, 1985; Rodriguez-Navarro et al., 2006) or “ultrastructures” (Blackwell et al., 1977; Olson et al., 2012) or overall “fabrics” (Schöne, 2013; Schöne et al., 2013). The carbonate and organic phases represent the fundamental level of the organization of biomaterials (Aizenberg et al., 2005; Meyers et al., 2006). The mechanisms of microstructure formation and shaping, especially in mollusks, has attracted increasing attention during recent decades. At present, it is commonly accepted that the organic compounds play an important role in the formation of the inorganic phases of biominerals (Weiner and Addadi, 1991; Berman et al., 1993; Dauphin et al., 2003; Nudelman et al., 2006). However, the identification of the exact mechanisms driving biomineralization is still an open research question. Previous studies conducted on mollusks show that environmental parameters