

## POSTMOULT UPTAKE OF CALCIUM BY THE BLUE CRAB (*CALLINECTES SAPIDUS*) IN WATER OF LOW SALINITY

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### Summary

After moulting, blue crabs (*Callinectes sapidus*) acclimated to a salinity of 2‰ were able to calcify as rapidly and accumulate as much calcium as crabs in sea water. Immediately after moult, the total masses of calcium, magnesium and strontium present in the whole body were 4.6, 15.6 and 3.0%, respectively, of their intermoult values. During the time of most rapid calcification, calcium uptake was  $5.4 \pm 1.4 \text{ mmol l}^{-1}$ , which is comparable to the maximum rate found in seawater-acclimated crabs. The concentrations of bound and free calcium in the blood changed very little with acclimation salinity, remaining at approximately 3 and  $8 \text{ mmol l}^{-1}$ , respectively, both during intermoult and 1 day postmoult. Free calcium changed relatively little through the moult cycle, varying between 6.9 and  $8.1 \text{ mmol l}^{-1}$ , but bound calcium rose to a peak of  $6.4 \text{ mmol l}^{-1}$  prior to moult then dropped to  $2.6 \text{ mmol l}^{-1}$  after moult, concurrent with a decrease of approximately 80% in the protein concentration of the blood. The concentration of total magnesium in the blood increased from a premoult low of  $9.0 \text{ mmol l}^{-1}$  to a postmoult high of  $11.7 \text{ mmol l}^{-1}$  and remained elevated throughout the period of rapid mineralization. During the postmoult period of rapid calcium uptake, the internal-to-external concentration ratio for total calcium was 6.6 to 1. The activity ratio, however, was only 2.5 to 1 because 28% of the calcium in the blood was bound to protein, and because the lower ionic strength of the medium resulted in a 2.5-fold higher activity coefficient for the water compared to blood. The transepithelial potential at postmoult ( $-5.4 \pm 0.7 \text{ mV}$ ) was significantly more negative than at intermoult ( $-3.1 \pm 0.6 \text{ mV}$ ). In artificial 2‰ sea water, the transepithelial potential ( $-9.3 \pm 0.7 \text{ mV}$ ) was higher than the equilibrium potential for calcium ( $-12.0 \pm 0.5 \text{ mV}$ ), implicating active transport in the uptake of calcium.

### Introduction

The body of a crustacean is soft after moulting, affording almost no protection against predators and no structural support other than that produced by hydrostatic pressure. No doubt there is great selective pressure for these animals to harden the new carapace rapidly, primarily through the deposition of calcium

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carbonate into the organic matrix. Crustaceans that mineralize their exoskeleton must be physiologically equipped to move large amounts of the requisite ions to the new exoskeleton in a relatively short period. This is less problematic in sea water, which contains a relatively high concentration of calcium ions, than in environments where calcium is far less available. There are a number of possible strategies which facilitate hardening of the exoskeleton in low-calcium environments and which seem to be more prevalent in freshwater than in marine crustaceans. (1) Storage: in some species, the storage of calcium from the old exoskeleton in the blood, gut or midgut gland (summarized by Greenaway, 1985) provides some of the calcium needed after moult for hardening of the new exoskeleton. (2) Reduced mineral content: in comparing two species of crayfish, Mills and Lake (1976) noted that the total amount of calcium accumulated was less in the species inhabiting an environment with a lower calcium concentration, suggesting that the total amount of calcium accumulated can be dependent on the availability of calcium in the environment. (3) Reduced uptake rate: in calcium-limited environments the time needed for calcification may increase without a reduction in final content. The rate of calcium accumulation in *Gammarus pulex*, for instance, is slower in water with less calcium (Vincent, 1969). (4) Reduced activity of calcium in the blood: although the total concentration of calcium in the blood of crustaceans in fresh water is greater than the total concentration of calcium in the external medium, it is the calcium activity that determines the electrochemical gradient. The relationship of activity to total calcium content is a function of the ionic strength of the solution and the proportion of calcium in ionized form. Anything that lowers the calcium activity in the blood will reduce or eliminate the unfavourable electrochemical gradient correspondingly. Although there are few data on the proportion of total calcium that is bound in the blood, there may be a tendency for freshwater species to have lower calcium activities while maintaining total concentrations equal to those of seawater species (Table 3 in Greenaway, 1985). (5) Active transport: in some freshwater species, net calcium accumulation occurs in waters with extremely low calcium concentrations (Vincent, 1969; Malley, 1980) where the electrochemical gradient is certainly directed outwards. Under these conditions crustaceans must rely on active transport since a net passive influx is not possible against the existing electrochemical gradient.

The blue crab, *Callinectes sapidus*, is notable for its ability to survive in salinities ranging from fresh to hypersaline water. It cannot reproduce at low salinities and has the high water and salt permeabilities (Cameron, 1978) characteristic of a marine species, but it can successfully moult in fresh water. Calcium regulation over the postmoult period in seawater-acclimated blue crabs may involve only passive mechanisms (Cameron, 1989), but the large difference in calcium concentrations of blood and water at low salinities suggests some other mechanism of regulation when crabs acclimate to fresh water. We investigated the pattern of calcium metabolism in moulting blue crabs acclimated to 2‰ salinity as an example of the method used by a euryhaline species at a very low salinity. In particular, we looked for the methods of calcium accumulation more frequently



































