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Evolution & Behavior

Shrunken heads: a curious strategy to survive winter

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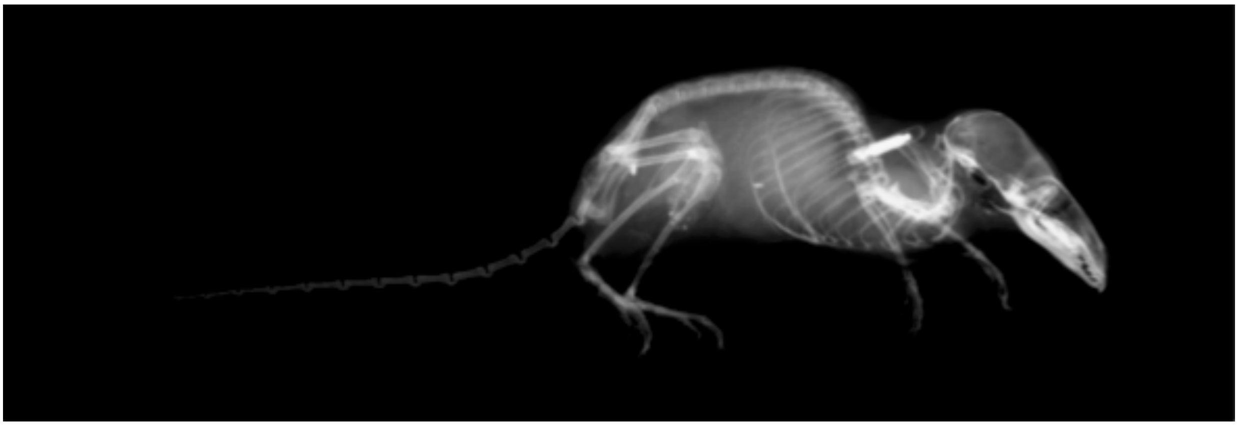
ABSTRACT

Could a mammal's skull and brain adapt their size to cope with environmental changes? Some shrews have developed an astonishing strategy for overwintering which involves a reversible shrinkage of their braincase and brain.



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Phenotypic plasticity is a remarkable capacity of organisms to change their morphology, physiology, and behavior to adapt to their environment. This ability enables individuals to cope with changes in the environmental conditions within their lifespan. Organisms inhabiting seasonal environments undergo seasonal plastic changes to cope with the fluctuations in resources associated with seasonality. Among vertebrates, we observe two main overwintering strategies: migration and hibernation. These are usually combined with morphological and physiological changes as fat storage, molting plumage or coat, and behavioral changes as food storing. However, there are some animals which cannot hibernate or migrate to more resourceful areas and thus have developed alternative adaptations. One of the most astonishing yet poorly documented cases is the seasonal changes in morphology in red-toothed shrews. This was firstly described by Prof. August Dehnel in 1949, when he extracted skulls from common shrews all year round. When comparing skulls from different seasons he observed that the braincases of winter subadults on average were almost 20% smaller than the ones from the first summer, when they are still juveniles. In the second summer, when they are adults, the braincases were again 15% larger than in winter subadults. This rare phenomenon (so-called Dehnel's phenomenon) was subject of several studies along the next two decades. They discovered that in winter the entire body size decreased, including a shortening of the spine and adecline in the mass of major internal organs. Butthe most astonishing finding was the seasonal differences in brain mass: brains from winter subadults weighted 20-30% less than in summer juveniles; in spring and summer adults brain mass increased again in 10-15%. They concluded that Dehnel's phenomenon was an extreme case of seasonal plasticity by which shrews in winter shrink their body, including their braincase and brain. Function and maintenance of brain tissue are metabolically expensive, so reducing it would allow individuals saving energy during the winter.

These studies also generated some controversy. In that time, the brain was generally still perceived as a fixed organ with low plasticity, and knowledge on processes of bone remodeling was still poor. Therefore, the kind of plasticity proposed by Dehnel, which involved massive reversible changes in skull and brain size, was quite unexpected and put into question. Skeptics claimed that the seasonal variations did not necessarily reflect individual changes since the data in different seasons come from different individuals. Thus, the apparent winter shrinkage could be caused by a difference in average size at the population level. They proposed that perhaps the biggest individuals suffer higher mortality during autumn, so the smallest individuals (with their smaller skulls and brains) would survive untillwinter. This hypothetical size-biased selection would cause a winter decrease in the average body, skull and brain size. Thus, there were two alternative hypotheses to explain Dehnel's phenomenon. But with time there was a gradual loss of interest in the topic and the debate remained unsolved.

The definitive answer could only be provided if we were able to monitor the shrews' skulls across seasons, this is, to obtain skull measurements of the same individual along time. To this purpose, we did a mark-recapture in wild common shrews. We trapped them during one year and took X-ray images in each recapture, on which we measured the skull. All individuals that we recaptured in winter showed a clear decline in skull size up to 20% (braincase height) in a single individual from July to February. Also, the shrews recaptured in spring exhibit a re-growth of the braincase up to 13%. We recaptured twelve individuals both in winter and the second summer which showed both winter shrinkage and the following regrowth in spring, verifying the reversibility of the process. Therefore, we were able to confirm Dehnel's phenomenon 68 years after its first description.

The detailed mechanisms of the changes in skull size remain unknown. There is evidence indicating that it is probably caused by a resorption of bone tissue at the level of the cranial sutures during autumn followed by tissue regeneration during the regrowth phase. But the underlying processes at the cellular and molecular levels remain the subject unclear.

Understanding the causes of this phenomenon can help us to identify the evolutionary drivers that shape the size and structure of the skull and the brain. Moreover, it has implications for medical research. Elucidating the proximate causes could mean an important advance for the study of degenerative bone diseases as osteoporosis. We think that this will become a compelling study model for different areas in biology and medicine.