University of Florida Book of Insect Records

Chapter 4 *Most Tolerant of Cold*

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In laboratory tests, Hinton (1960) found that dehydrated larvae of the African chironomid Polypedilum vanderplanki *(Diptera) could survive submersion in liquid helium (-270 C). This phenomenon seems related to its ability to tolerate extreme desiccation.*

The aim of this paper is to identify the insect species most tolerant to cold. 'Most tolerant to cold' is here taken to mean ability to survive the lowest temperature. The search was an open ended one, such that the results could come from individuals studied under natural or laboratory conditions.

Methods

I first searched the secondary literature, such as general ecology, entomology and physiology textbooks. All author's names associated with work on cold tolerance were then subjected to a literature search. The Agricola data base 1970-1993, was also searched for reference to papers on cold tolerance in insects.

Results

Hinton (1960) found that the dehydrated larvae of the African chironomid *Polypedilum vanderplanki* were able to withstand exposure to liquid helium (-270 C) for up to 5 min. with a 100% survival rate.

Discussion

Surprisingly, the insect able to survive the lowest temperature is not found in polar regions, but in tropical West Africa. *Polypedilum vanderplanki* inhabits shallow pools which are subjected to repeated dehydration, and accordingly *P. vanderplanki* has evolved the capacity to tolerate severe desiccation in an anhydrobiotic state. It seems likely that it is due to this phenomenon that the insect is able to survive extreme temperatures. Hinton (1960) placed the larvae directly in liquid helium from room temperature. Only larvae that had been desiccated to a water content of 8% survived freezing at -270 C and subsequently metamorphosed, after warming and rehydration. When frozen fully hydrated, the larvae failed to recover, apparently because of damage to the fat body (Leader 1962). In contrast, elimination of body water in freezing-tolerant nonanhydrobiotic species can often be detrimental to the chances of survival at low temperatures (Salt 1961).

The lowest temperature survived by any insect in a nonanhydrobiotic state is -196 C by the prepupae of the sawfly *Trichiocampus populi*. Tanno (1968) employed a three step procedure consisting of freezing the prepupae at -20 C, transferring them to -5 C for several hours and then slowly cooling them to -30 C before placing them in liquid nitrogen. After slow thawing, 75% survived and emerged as adults. It is possible that *T. populi* could also survive -270 C in liquid helium, but it has never been tested. Asahina & Tanno (1964) attributed this freeze tolerance ability to the presence of very high levels of the sugar trehalose.

It is generally believed that survival of freezing occurs only if the site of ice formation is restricted to the extracellular space (Mazur 1984). This is also assumed to be true in the above two cases, although intracellular freeze tolerance has been reported by Salt (1959) in the fat body cells of the goldenrod gall fly *E. solidaginis*. In the case *of P. vanderplanki* , it is clear that tolerance of freezing is in no way adaptive, since it is never subjected to sub-zero temperatures in its natural tropical environment, but is instead linked with its extraordinary ability to withstand a water content as low as 3%, which certainly is adaptive. The insect able to survive the lowest temperature for adaptive reasons is *Pterostichus brevicornis* . In laboratory tests, Miller (1969) found that the winter adult of this carabid beetle tolerates temperatures as low as -87 C, through use of the cryoprotectant glycerol. This beetle should thus be able to survive any natural temperatures in its Arctic environment.

In many freeze tolerance experiments, workers define survival on the basis of directed coordinated activity like walking, feeding, and avoidance responses after rewarming (Miller 1969, Lee & Denlinger 1991). However, Baust & Rojas (1985) have rightly questioned this definition of survival in a biological context. For the purposes of this paper, Miller's definition is adequate, but it could be argued that the only adaptive survival is reproductive survival. Few workers have tested whether insects that survive low temperatures maintain their ability to reproduce.

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