Figure 1. Scanning electron micrograph of an adult ice worm. Arrow indicates the head; arrowhead identifies the clitellum. Scale bar = 0.5 mm.

The Ice Worm's Secret

By Daniel H. Shain

While many Alaskans and most tourists find ice worms *(Mesenchytraeus solifugus)* an intriguing part of Alaska folklore, cultivated by Robert Service's tales of the Yukon, ice worms do in fact exist. ...Their bellies were a bilious blue, their eyes a bulbous red... *(Service 2004)*. In fact, they do not have bilious blue bellies and bulbous red eyes; rather, they have a non-discrete appearance resembling a small earthworm *(Figure 1)* and keep a low profile on temperate Alaska glaciers.

Their unique adaptations permit ice worms to thrive in this extreme habitat (~32°F / 0°C, the freezing point of water), where life stops in almost all other animals *(Belehradek 1935)*. Remarkably, ice worms go about their business, crawling, feeding, and other worm activities at speeds essentially the same as their soil-dwelling relatives. Earthworms generally survive between 50 - 68°F / 10 - 20°C. An appreciation for this adaptation can be gained in several ways: by putting an earthworm in a refrigerator in which it no longer moves and eventually dies; or, skinny-dipping in a glacial run-off stream makes the point much more dramatically.

A fundamental challenge for ice worms is generating sufficient levels of energy to sustain life, which becomes increasingly difficult as temperatures fall and molecular motion slows. As an analogy, it is more difficult to start your car at low temperatures, and the engine runs inefficiently when cold. While automobiles use gasoline as an energy source, the currency of energy in biology is a molecule called adenosine triphosphate (ATP). Just as gasoline provides the energy to move your car, ATP provides the energy for driving most biological processes—growth, metabolism, movement. Because additional energy is needed for maintaining biochemical reactions at low temperatures, we hypothesized that ATP levels in ice worms would be relatively higher than those in other organisms.

Not only was this true, but a perplexing observation was made. Ice worms increased their cellular ATP levels as temperatures fell *(Figure 2)*, a response opposite to all temperate organisms examined—algae, bacteria, plant, worm, and yeast *(Napolitano et al. 2003)*. In other words, ice worms appear to produce more energy as temperatures become colder, even as low as 21°F / -6°C where ice worms begin to freeze. From an energetic standpoint, this is quite difficult to explain since most processes such as metabolism and respiration slow down with temperature, including energy production in "normal" organisms. What then is the ice worm's secret? The answer, of course, remains unknown. It seems likely that ATP accumulation in ice worms results from unequal changes in ATP production versus consumption at low temperatures. Thus, both processes decrease with temperature as required by thermodynamic laws, but energy consumption decreases at a faster rate than energy production, generating a net increase in ATP. Not a bad trick for a worm confined to poetry books by most. More than likely, the ice worm has a few more tricks up its clitellum, a sleeve-like structure around the midbody of most worms *(see Figure 1)*.

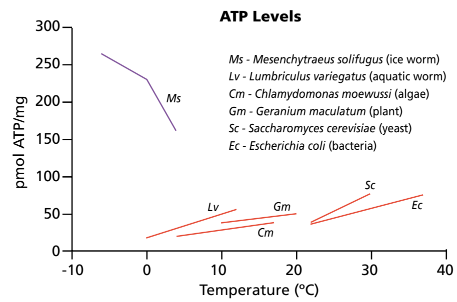

Figure 2. Energetic differences between ice worms and temperate organisms. Ice worms display elevated ATP levels that increase as temperatures fall, while temperate species have elevated ATP levels as temperatures rise.

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