Birds migrate. Bears hibernate. Turtles and frogs retreat to the bottom of lakes. Most animals must avoid harsh winter conditions; few can survive freezing. Larvae of the goldenrod gall fly (Eurosta solidaginis), can survive freezing to -40°C or below. The study of survival at low temperature is called cryobiology. This article provides an introduction to the winter biology of this widely distributed and unusual species, and suggests classroom activities that illuminate principles of cryobiology through insect overwintering.

A variety of opportunities for educational activities are found in the complex, yet easy-to-manipulate, trophic relationships between goldenrod plants, insects that induce gall formation, and the natural enemies of these gallmakers. Gall collection, measurement, and observation (exit holes, larval response, temperature, etc.) can help students develop scientific process skills including observation, classification, measurement, inference, prediction, control of experimental variables, and material manipulation (Peard, 1994). Galls can also be studied to learn about insect ovipositing behavior and plant responses to three types of gallmakers—each with its own distinct gall type (Newell, 1994). Likewise, classroom activities can focus on the collection and study of galls to discover principles of ecology and insect life cycles (Kahn, 1997).

One aspect of goldenrod gallmakers that has received little attention in the science education literature is the winter biology of these unusual insects. In autumn, the overwintering larva enters a state of dormancy, called diapause, and gradually acquires the capacity to survive freezing to temperatures of -40°C and below (Baust & Lee, 1981). In contrast, a beetle larva and two parasitic wasps that also overwinter in goldenrod galls are intolerant of freezing and must avoid internal ice formation.

**Life Cycle**

Only a single generation of the goldenrod gall fly occurs each year, with more than 11 months of the insect’s life spent inside the gall. Adults emerge in late spring. Mating occurs on the apex of the plant where the male waits to attract females soon after they emerge from the gall (Abrahamson & Weis, 1997). After extensive inspection of the goldenrod plant for a suitable site, the female deposits her eggs (usually singly) into the leaves surrounding a bud. Each female deposits about 20-25 eggs in her life (at least under laboratory conditions).

Eggs hatch within 5-8 days, and the larvae immediately tunnel inward to the meristematic bud tissue where a chamber is created as the larvae feed on the plant matter found there. The presence of the larvae induce the plant to form a spherical stem gall, approximately 15-30 mm in diameter. The precise mechanism of induction remains a mystery, but it clearly involves complex control of the developmental processes within the plant (Abrahamson & Weis, 1997).

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