in eastern North America in the early 1940s. Since then, they have contributed, with some help from parasites, to natural regulation of this pest species.

In their natural state, nuclear polyhedrosis viruses are also contributing factors in terminating outbreaks of forest tent caterpillars that infest aspen trees. Preliminary testing on viruses isolated from this pest species occurred at the Northern Forest Research Centre in Edmonton, Alberta, in 1976, 1977 and 1978. Under field conditions, virus sprays caused forest tent caterpillar larvae to die. The virus infection persisted for several years, and defoliation was reduced to a negligible amount.

3. *Parasites and predators*

For many years, parasites and predators have been used as control agents against harmful insect pests, such as the winter moth and the larch sawfly. Current research on spruce budworm control includes the protozoan parasite *Nosema fumiferanae* and the predator *Formica lugubris*.

Nosema fumiferanae is the most common parasite of the spruce budworm. It diminishes vigour in the larva and pupa and reduces longevity and fecundity in the adult budworm. It may be very effective against the spruce budworm if methods can be developed to increase artificially the level of parasitism or to enhance its virulence through strain selection. Current Canadian research is concentrating on a complete biological understanding of this pathogen, methods for mass producing it for field release and means to apply it to foliage.

In Quebec *Formica lugubris*, a red wood ant from Central Europe, has proved to be a desirable predator against the spruce budworm. Scientists at the Laurentian Forest Research Centre in Ste. Foy first released the ants in 1971 in a forested area at Valcartier, about 25 km north of Quebec City. The ant colony, which started within an area of about 2 ha, increased steadily in size. By 1975 it consisted of six nests.

The first occasion for the ants to prey on a spruce budworm population came in 1973. In 1972, preliminary laboratory tests had indicated that *F. lugubris* was highly aggressive in searching for and attacking fourth-, fifth-, and sixth-instar budworm larvae, as well as papae and adults. (Because young larvae are concealed in the foliage, predation was light on the first three instars.)

Defoliation measurements taken in the area of the nests have indicated a reduction of spruce budworm damage by as much as 20 per cent during the early years of infestation. While *F. lugubris* appears to be an important control factor, further studies will be required to determine the ecological and environmental impact of introducing it into Canadian forests.

Mature larvae of the forest tent caterpillar.

4. *Pheromones*

Pheromones are chemical messengers excreted by special glands of female moths when they are ready to mate. Detected by the male's special sensory organs, the pheromones or sex attractants guide the male to the female. (Males also produce pheromones in some species.) Artificially-released synthetic pheromones can disrupt normal communication between male and female, interfere with mating and thus significantly reduce larval populations. They are also used to attract insects in order to monitor their populations.

Canadian and United States researchers at the Great Lakes Forest Research Centre in Sault Ste. Marie, Ontario, the Forest Pest Management Institute and Cornell University in Ithaca, New York, have successfully isolated and chemically identified the pheromones of a number of important pests, including the spruce budworm and associated species. They have also synthesized a number of pheromones. The pheromones of the spruce budworm are now available commercially and are used in surveying and monitoring forest pest populations.

5. *Insect growth regulators (IGRs)—hormones*

As insects grow from egg to larva to pupa to adult, the transformations are controlled by hormones. An orderly succession is essential to the survival of the insect.

In the past few decades, insect physiologists have identified a variety of hormonal compounds, known as insect growth regulators (IGRs) that are capable of altering the rate of development or modifying metabolic processes to the detriment of the insect. Applied in the smallest quantity, IGRs produe larvae that cannot pupate normally, pupae that retain larval structures or adults incapable of flying or mating. They have altered the developmental rate in some insects so that a life stage appears in a season when it cannot survive. IGR compounds are highly specific and safe. Scientists are working to identify, evaluate and develop compounds that affect a broad range of Canadian forest pest species. They are also field testing the compounds to determine under what conditions they are most effective and produce the fewest side effects.

In the Gaspé, Quebec, for example, compounds capable of preventing adult females from producing eggs and of stopping embryonic development have been tested on the balsam wooly aphid. On Anticosti Island, Quebec, in 1973, a field trial of an IGR that affects metamorphosis found the hemlock looper to be the most sensitive species tested. Non-economic levels of IGRs had to be used to achieve the desired results in the spruce budworm, the least responsive species.

In 1976 scientists at the Great lakes Forest Research Centre tested the effect of IGRs and fertilizers applied as foliar sprays during the egg stage of the sawfly. The results indicated that the ovicidal activity of IGRs might be useful in preventing defoliation, especially for ornamental and Christmas trees which receive relatively intensive care.