number of larval motoneurons that do not persist through metamorphosis (for example, MN6) can be seen to be degenerating. But no degenerating cells were seen in the region of MN1 at this time. We conclude that at least in the case of MN1, a single neuron persists through metamorphosis from larva to adult.

In pharate adult *Manduca*, the portion of the dorsal nerve beyond the second branch extends past the spiracle and supplies the dorsal internal longitudinal muscles and the dorsal external muscles. The former muscles are innervated by motoneurons whose cell bodies are located in the next, more anterior ganglion (*8*). Therefore, MN1 probably controls one of the dorsal external muscle groups. These muscles are not present in the larva or the pupa but differentiate during the course of adult development. Knowledge of the exact target of MN1 in the larva and the adult must await electrophysiological examination of the nerve and the muscle groups.

Figure 1 gives an example of the dendritic morphology of MN1 in the larva, the diapausing pupa, and the pharate adult of *Manduca sexta*. In all stages the initial process extended posteriorly from the cell body, then made a 90° turn and crossed the dorsal neuropil to the opposite side of the ganglion. A primary branch extended from the initial process posteriorly through the dorsal neuropil on the side contralateral to the neuron cell body. In the larva, ten secondary dendritic branches could be identified in fills of MN1 (*i* to *x* in Fig. 2, A to C). The amount of third- and fourth-order branching was modest and less than that seen in some other larval neurons (for example, MN6). The initial process leading from the cell body was bare except for a few thin processes ipsilateral to the soma. In some larval preparations, extension of the neuropil a short distance into the posterior connective caused a distortion in the dendritic tree of MN1 (Fig. 2C). But the typical pattern of secondary branching of this cell could nevertheless be resolved.

The morphology of MN1 changed markedly in the diapausing pupa (Fig. 2, D to F). Cobalt filling of the neuron revealed only the primary and secondary branches. Typically, the branches consisted of occasional swollen areas joined together by very thin processes. The swellings were consistently found in pupal material and appeared at relatively characteristic sites along the initial process and primary dendrite of the pupa. Similar swellings were only rarely observed in larval or adult material. The number of secondary branches in the pupa was relatively constant and the branches appeared to be homologous with those found in the larva.

After adult development, MN1 showed a marked branching and subbranching. Secondary branches that were apparently homologous to those of the larva persisted into the pharate adult stage, with the possible exception of branch *iii*. Branch *iv* extended dorsally in the adult (as it did in the larva), but minor changes in the orientation of the ganglion during sectioning resulted in this branch appearing either to the right (Fig. 2H) or to the left (Fig. 2, G and I) of the primary dendrite in the reconstruction. The neuron showed extensive third- and fourth-order branching, and processes extended throughout the dorsal neuropil on the side of the ganglion contralateral to the cell body. The most striking change in the adult MN1 was the development of a second dendritic field. A number of dendritic branches left the initial segment and extended through the dorsal neuropil ipsilateral to the cell body. This new dendritic area presumably grew out from the thin processes that were undeveloped in the larva and the pupa. It is possible that the complete dendritic pattern seen in the adult was present in the larva and pupa, but that the processes were very thin and were not penetrated by the cobalt. We feel that this possibility is unlikely, but it can be excluded only through an electron microscopic study.

During metamorphosis of the peripheral nervous system in the silkmoth *Antheraea polyphemus*, the distal portions of the motor axons degenerate and new processes are sent out to supply the myoblasts of the adult muscle (*9*). Events in the central nervous system seem to be analogous. In *Manduca* during the transition from larva to pupa, most of the larval dendritic branches appear to degenerate or to be resorbed, leaving only the primary and secondary branches at the pupal stage. The extensive swollen areas consistently observed in the pupal neurons may represent accumulations of resorbed axoplasm. With the advent of adult development, extensive outgrowth then occurs from the secondary branches. Also, additional areas of the neuropil are invaded by new branches formed by the metamorphosing neuron. Thus, in this instance the construction of the adult neuron is accomplished by using the "skeleton" of the larval neuron as well as by the development of branches that are unique to the adult.

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Human Babesiosis: Reservoir of Infection on Nantucket Island

Abstract. *Examination of blood films from six species of rodents and lagomorphs on Nantucket Island disclosed infections with* Babesia microti *in all of five* Microtus pennsylvanicus *(field mice) and 31 of 39* Peromyscus leucopus *(white-footed or deer mice). Six human cases of clinical babesiosis have recently been diagnosed on the island.*

Human babesiosis presents two distinct epidemiological patterns: (i) isolated cases in persons who had previously undergone splenectomy and (ii) cases in a group of persons with intact spleens who live on a small island. Of the four reports concerning patients who had splenectomies, two originated from Yugoslavia in 1957 (*1*) and 1969 (*2*), one from Ireland in 1967 (*3*), and one from California in 1966 (*4*). Each case was ascribed to infection with one or another *Babesia* species known to parasitize ungulates. The reports involving persons with intact spleens are limited to residents of Nantucket Island (*5, 6*), located in the Atlantic Ocean approximately 50 km south of Cape Cod, Massachusetts. All seven of the Nantucket cases diagnosed to date were due to a piroplasm of rodents, *Babesia microti* (*7*), which was isolated in hamsters in all seven cases

and in monkeys in the first case (*5*). An additional asymptomatic infection with an unknown species of *Babesia* has been diagnosed in a resident of Georgia with an intact spleen by examination of Giemsa-stained thick and thin blood films (*8*).

In humans, the disease is malaria-like, being characterized by chills, fever, headache, lethargy, and myalgia (*5, 6*). Diagnosis depends on recognition of trophozoites of *Babesia* in Giemsa-stained blood films. The trophozoites may resemble those of malaria. However, the absence of pigment in the parasitized cell as schizogony begins distinguishes *Babesia* from *Plasmodium* species.

The reservoir of *B. microti* includes various rodent and lagomorph hosts (*9–12*). The primary objective of the study on Nantucket Island was to record the prevalence of *B. microti* in these hosts and thus demonstrate the local reservoir of infection. In addition to humans, the domestic fauna of Nantucket consists largely of dogs, cats, rabbits, and horses. White-tailed deer (*Odocoileus virginianus*) are said to number 300 on this 128-km^2 island (*13*). Jackrabbits (*Lepus californicus*) and the varying hare (*Lepus americanus*) are found in some localities, and cottontail rabbits (*Sylvilagus transitionalis*) are abundant throughout the island. Field mice (*Microtus pennsylvanicus*) and white-footed or deer mice (*Peromyscus leucopus*) are abundant, as are the house mouse (*Mus musculus*), the short-tailed shrew (*Blarina brevicauda compacta*), and the common shrew (*Sorex cinereus*). One jumping mouse (*Zapus hudsonicus*) was seen. The Norway rat (*Rattus norvegicus*) is present. Rodents were live-trapped and brought to the laboratory. Each was exsanguinated by cardiac puncture while under ether anesthesia. The last drop of blood thus obtained was used to make a standard thick and thin film, which was dried and Giemsa-stained. Rabbits were shot, and blood films were prepared from heart blood within a few minutes after death.

White-footed mice were captured during two study periods and in two locations on Nantucket Island. Twenty-five were taken during May 1974, 12 with traps set on the premises of the University of Massachusetts field station in Quaise and 13 with traps set in Polpis near the residence of the first person known to be infected with *B. microti* (*5*). The 14 remaining mice were taken early in September 1974 from the field station site. The remaining rodents and the cottontail rabbit were collected on the field station property, and the jackrabbits were taken on the runways of Nantucket Airport. Of the 45 mice studied, 36 harbored parasites (Table 1) with apparent *B. microti* morphology (*9*). No sporozoans were found in rabbits or rats.

Table 1. *Babesia microti* infections in rodents and lagomorphs on Nantucket Island, Massachusetts.

Species	Number	
	Examined	Positive for *B. microti*
Microtus pennsylvanicus	5	5
Peromyscus leucopus	39	31
Zapus hudsonicus	1	0
Lepus californicus	4	0
Sylvilagus transitionalis	1	0
Rattus norvegicus	3	0
Totals	53	36

The islet of Muskeget provided a control population for our Nantucket observations. Although two buildings are present on the island, only a few persons occasionally reside there. Deer are absent and dogs are rarely present. Twenty-four *Microtus breweri* were collected (*14*) during the spring of 1974, and blood samples were prepared as described. None were found to contain sporozoan parasites.

Before this study began, two human babesiosis infections had been recognized on Nantucket in 1969 (*5*) and 1973 (*6*). Both were severe infections, with extreme clinical manifestations of the disease and with an abundance of infected erythrocytes seen in Giemsa-stained blood films. Beginning in the summer of 1974, we visited local physicians on numerous occasions and requested that the blood of patients with chills and fever, lethargy, myalgia, and headache be examined microscopically. During July and August 1975, five patients with this spectrum of symptoms proved to have circulating parasites that were consistent in appearance with *B. microti*. Only one was so debilitated as to require prolonged hospitalization. Blood from each of these patients was inoculated into hamsters, and each produced a patent infection. A detailed clinical report of these infections will be published (*15*).

Early in October 1975, two additional cases came to our attention. A summer resident of the nearby island of Martha's Vineyard was found to be infected with *B. microti* while residing in Washington, D.C. (*16*). He had been ill for several months. A week later, another infection in a resident of Nantucket was diagnosed (*17*). He, too, had been ill for some time and may have become infected during 1974.

Babesia microti infection in wild mammals has been recognized in several locations in the United States and Europe. Populations of white-footed mice on Martha's Vineyard, 24 km west of Nantucket, were found to be infected in 1937 (*11*). Rodents of this species were infected with similar parasites around Ithaca, New York (*10*), and various small rodents and rabbits carried the infection in California (*9*) and in England (*12*). Thus, this parasite seems to be widespread, and this renders problematic the peculiar frequency of human infection on Nantucket Island. However, the prevalence of infection in mice is very high on the island, greatly exceeding that reported from other locations, and this may be causally related to infection in humans.

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