MICROSPORIDIAN PARASITES OF MOSQUITOES

Theodore G. Andreadis
The Connecticut Agricultural Experiment Station, 123 Huntington Street,
P. O. Box 1106 New Haven, CT 06511

KEY WORDS Microsporidia, ssRNA, transovarial transmission, copepods, invertebrate parasites

INTRODUCTION

The Microsporidia are a large diverse group of obligate, intracellular parasites. They are single-celled eukaryotic microorganisms that have small genomes in the size range of prokaryotic cells and are now thought to be highly evolved fungi (Keeling and Fast 2002). They are exclusive parasites of other eukaryotes and possess a unique and highly specialized mechanism for invading host cells via infectious spores. Spores are the only stage that can exist outside a living host cell and they are the primary vehicles for horizontal transmission between hosts (peroral) and vertical transmission (transovarial) within the host. Spores are diagnostic, especially at the ultrastructural level (Fig. 1), and are distinguished by their small size (2–20 μm), thick walls (consisting of an endospore and exospore), and presence of a unique set of organelles that function as an extrusion apparatus. These include a tightly coiled polar filament (tube) that is attached to an anchoring disc at the anterior pole of the spore, a membranous polaroplast, and a posterior vacuole which collectively function to explosively inoculate the spore content or "sporoplasm" through the polar filament into a host cell to initiate infection.

Microsporidia are ubiquitous in nature and exhibit a very broad host range within the animal kingdom. They have been described as parasites in all classes of vertebrates, including humans, and most invertebrates, but are particularly common to arthropods and fish.

Microsporidia represent one of the largest and most diverse groups of parasitic organisms associated with mosquito populations in nature. They have been described from 14 different genera worldwide, and it is quite likely that all mosquitoes serve as hosts for one or more of these parasites. The group currently includes a heterogeneous assemblage of over 150 described species from 23 recognized genera, 15 of which are monotypic (only one species is known) (Table 1).

Members of these genera exhibit extensive variation in their development and life cycles but generally fall into 2 broad categories. The first includes the monomorphic forms such as *Anncaliia* (formerly *Nosema* and then *Brachiola*) (Franzen et al. 2006) and *Vavraia*. These microsporidia have comparatively simple life cycles involving only one sporogonic sequence (Fig. 2). They develop asexually (merogony or schizogony) and produce a single spore type that is orally infectious to mosquito larvae. Vertical transmission may additionally occur via oral ingestion of spores on contaminated eggs (transovum), but there is no separate developmental sequence leading to ovarian infection in female hosts. These microsporidia have a very broad host range and are mildly pathogenic to mosquitoes, generally producing low larval mortality. Other genera from which only one developmental sequence has been described include *Aedispora*, *Crepidulospora*, *Polydispyrenia*, *Senoma*, *Trichotosporea*, and *Tricornia*. However, the complete life cycles and modes of transmission of members of these genera have yet to be resolved and they may be polymorphic.

The second group includes the true polymorphic forms. These parasites are more common in nature and exhibit some of the most complex life cycles yet described for any microsporidia (Fig. 2). These include elements of asexual (schizogony, merogony, and sporogony) and sexual (karyogamy, gametogenesis, and plasmogamy) reproduction; the formation of multiple spore types in various stages of the host; host sex- and tissue-dependent development; and separate developmental sequences leading to vertical (transovarial) and horizontal transmission. Many species, such as *Edhazardia aedis*, require two successive host generations to complete their life cycle, and at least 4 genera, *Amblyospora*, *Duboscqia*, *Hyalinocysta* and *Parathelohania* require obligatory development in an intermediate copepod host. These microsporidia generally exhibit higher levels of host specificity and although they do not cause any acute mortality or detectable morbidity in adult female hosts that go on to transmit infections transovarially, they have at least one phase of development that typically kills larval hosts during the last stadium. Mortality in larvae results from destruction of various host tissues and subsequent depletion of essential energy reserves necessary for pupation. The production of entomopathogenic toxins has never been documented.