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The development of the microsporidium *Paranosema* (*Nosema*) *locustae* for grasshopper control: John Henry's innovation with worldwide lasting impacts.*

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In this issue of "Protistology" we bring a tribute to the Society for Invertebrate Pathology (SIP) that this year celebrated its 50th anniversary (Fig. 1). The SIP have been always playing an important and global role in studies on unicellular eukaryotic symbionts of invertebrates, in particular on microsporidia. The Microsporidia Division was established in 1970 (see the Table 1) as the first official division of the SIP, and most of researchers in the field of Microsporidiology have been SIP members and published in the Journal of Invertebrate Pathology, an official publishing organ of the Society. Beneath we provide a table with some major landmarks of the SIP history. In this issue we also publish the paper prepared by Dr. John Henry (Fig. 2), an outstanding scholar in the fields of insect pathology, microbiological control, and microsporidia research, who developed the only one commercially successful biological insecticide based on microsporidian spores. His paper includes the materials presented at the Microsporidia Division symposium "The past and future frontiers in microsporidiology" at the 50th Annual Golden Jubilee Meeting of the Society for Invertebrate Pathology that was held in August of this 2017 year in San Diego, CA, USA <http://www.sipweb.org/pastmtg.html>. Besides John Henry, many other outstanding microsporidiologists, such as James Becnel, Ann Cali, Joseph Maddox, Emily Troemel, Charles Vossbrinck, Louis Weiss (Fig. 3), shared their memories, ideas and research achievements at this symposium. In the following preamble to Dr. Henry's paper co-authored by Dr. Carlos Lange (Argentina), John's junior friend and colleague, we explain in more depth the importance of the impact of John's research to the problem of microbiological control of insect pests, the problem that gave rise to extensive microsporidia research all over the World.

At a time when chemical control of noxious insects was seeing as close to a panacea (early 1960s) few had the foresight to look for viable alternatives. Among those few was John who not only appreciated the environmental problems posed by chemical insecticides, but also put his hands on finding ways to keep grasshoppers at bay without relying on synthetic insecticides. After years of meticulous field observations on grasshopper communities and their natural enemies in northwestern USA and laboratory experiments at the USDA Rangeland Insect Laboratory at Montana State University in Bozeman, he and collaborators opted among several other candidates discovered for a microorganism to be developed as a biocontrol agent for the long-term management of grasshopper populations. *Paranosema* (*Nosema*) *locustae* is indeed an exceptional microbial within a quite unique group of fungal-affiliated, spore-

* A preamble to Dr. John Henry's "The path to registration of a microbial pesticide" in this issue of "Protistology".

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Fig. 1. Logo of the Society for Invertebrate Pathology and the one of the 50th Annual Meeting and Golden Jubilee Celebration of the SIP <http://www.sipweb.org/>.

forming intracellular parasites of animals and some protists, the Microsporidia. It infects primarily the cells of the host's adipose (fat) tissue causing depletion of energy reserves and alterations in intermediate metabolism. Uniqueness of *P. locustae*, conferred by a set of attributes, was unraveled by Henry during his studies and exploited to its maximum in order to end up with a useful tool for grasshopper management. Few if any of the approximate 1300 known species of Microsporidia show the combination of attributes of *P. locustae*: (i) extremely wide host range among acridomorphs (at least 123 species worldwide are susceptible to infection) which allows use against a variety of pest grasshopper species, (ii) efficient horizontal and vertical transmission that facilitates long-term field persistence, (iii) intermediate virulence permitting heavy spore loads per individual host, (iv) and good tolerance to freezing that enables storage for extended periods (years). Two drawbacks, the apparent impossibility of in vitro production and the low viability of spores under field conditions were cleverly circumvented by establishment of protocols for in vivo production in grasshopper colonies and the use of baits for field delivery, respectively.

The narrative that follows, "The path to registration of a microbial pesticide" by Henry himself, is a concise account of the reasoning and work that lead to the development and registration (1980) of *P. locustae* which holds the distinctions as both the only microsporidium to reach that status, and the first organism that become available as a biocontrol agent of grasshoppers. Henry's work and approach was not only innovative (especially at its time) and lasting but also truly international in scope and repercussion. It was innovative because it departed from the environmentally disrupting application of indiscriminate, fast-killing chemical insecticides. International because it prompted interest and programs worldwide (notably China, West Africa, India, Argentina, Australia, Canada) (Fig. 4) not only about the use of *P. locustae* itself but also about the discovery of other pathogens and on environmental friendly initiatives based on his approach that disease-causing microorganisms would be useful for grasshopper management. In the words of acridologist J.A. Lockwood: "Research,

Table 1. Some major historical landmarks of the Society for Invertebrate Pathology (SIP).

1945	Edward Steinhaus (1914-1969) established the Laboratory of Insect Pathology at the University of California, Berkeley.
1958	The First International Conference on Insect Pathology and Biological Control organized by Jaroslav Weiser, and held in Prague, Czechoslovakia.
1959	The first issue of the Journal of Insect Pathology (Journal of Invertebrate Pathology from 1965) is published, edited by Edward Steinhaus.
1967	Edward Steinhaus proposed the formation of a new Society for Invertebrate Pathology (SIP).
1967 (May)	The founding meeting of the SIP in Seattle, Washington. Edward Steinhaus was elected first President, and Albert K. Sparks - first Vice president.
1967 (Dec)	The first issue of the SIP Newsletter was published.
1968	The first annual meeting of the SIP, hosted by John Briggs, was held in Columbus, Ohio with the annual meeting of the American Institute of Biological Sciences.
1970	The first Division of the SIP, Microsporidia, was officially established at the annual meeting in College Park, Maryland.
1996	Two divisions of the SIP, the Bacteria Division and the Virus Division, were officially established at the annual meeting in Cordoba, Spain.
1999	The Division of Diseases of Beneficial Invertebrates was officially established at the annual meeting in Park City, Utah.
2000	The Nematode Division of the SIP was officially established at the annual meeting in Guanajuato, Mexico.

Fig. 2. John Henry, Joe Maddox and Ann Cali at the Microsporidia Symposium at the 50th Annual Meeting of the Society for Invertebrate Pathology at UC San Diego, August, 15, 2017 (photo by YS).

development, and marketing of biological control strategies for acridid pests have been and will be affected by the history of *P. locustae*". In fact, the development of a second biocontrol agent during the late 1980s and early 1990s, the fungus *Metarhizium acridum*, widely used in Australia, was greatly inspired and influenced by Henry's pioneering work. In recent years there has been a resurgence of interest in *P. locustae* due mainly to work in China, where it is produced in large quantities and used extensively, and Argentina where its long-term persistence seems to reduce the frequency and intensity of grasshopper outbreaks.

We hope the reader enjoys the narrative by J. Henry and appreciates the innovative and pioneering work performed on a very unusual microorganism.

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Fig. 3. Participants of Microsporidia Division sessions at the SIP meeting in San Diego, August 2017 (Photo by Julie Hopper, University of California, Berkeley, USA). From left to right, upper row: George Kyei-Poku, Carlos Lange, Pattana Jaroenlak, Wei-Fone Huang, Louis Weiss, Jimmy Becnel, Sebastian Gisder; second row: Joseph Maddox, Ann Cali, Bettina Vossbrinck, Jonathan Snow, Charles Vossbrinck; lower row: Kelly Bateman, Julie Hopper, Emily Troemel, Sarah Biganski, Yuliya Sokolova, Leellen Solter.

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Fig. 4. Carlos Lange, Mae, John's wife, John, Francisco Delgado (of Cape Verde Plant Protection, the outstanding local liaison), and John Evans (creator and owner of the private company producing *P. locustae* at the time, Evans BioControl) in 1989 in Cape Verde while conducting field trials with *P. locustae*. A photo from collection of CL.

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