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Authors: Beaulieu, Frédéric, and Behan-pelletier, Valerie

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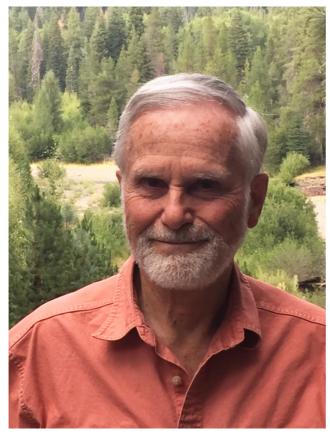
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# **Evert E. Lindquist's approach to the taxonomic impediment in Acarology: Diversity in specialization through 60 years of systematics research and beyond**

# FRÉDÉRIC BEAULIEU<sup>1,2</sup> & VALERIE BEHAN-PELLETIER<sup>1</sup>

<sup>1</sup>Agriculture and Agri-Food Canada, Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, Ontario, K1A0C6, Canada

<sup>2</sup>Corresponding author; email: frederic.beaulieu@agr.gc.ca



Born precisely 72 years after Antonio Berlese, on 26 June 1935, Evert Esplin Lindquist continues to have a profound influence on acarology globally. His ~60-year career significantly strengthened the foundations of acarology through his skills as a systematist, his exceptional attention to detail, his broad curiosity as a biologist, and his dedication to sharing his knowledge through enlightening publications and keen mentoring. Evert Lindquist is also much more than the sum of his acarological career. He is a friend and colleague to most of us, an altruistic scientist, and a cherished collaborator.

# Systematics research on Acari

Lindquist is the world's most renowned authority on Ascidae *sensu lato* (now divided into Ascidae, Melicharidae and Blattisociidae), as well as a world expert on Heterostigmata, especially Tarsonemidae. This broad expertise began developing over 60 years ago, when he was a student at the

University of California, Berkeley, from which he later graduated (B.Sc. 1957, M.Sc. 1959, Ph.D. 1963). He attributes his interest in acarology to his involvement in an undergraduate project on an analysis of soil invertebrate samples from Barrow, Alaska, where he was "exposed to the entire diversity of free-living mites from the Barrow area, took the acarology course presented by A. Earl Pritchard, and became fascinated with Acari" (E. E. Lindquist, pers. comm. 2011). This led to his first publication in 1961, on the taxonomy and biology of *Arctoseius* (Ascidae) from Barrow<sup>1</sup>, followed in the same year by a publication on the taxonomy and biology of *Tarsonemoides* (Tarsonemidae) parasitizing bark beetle eggs<sup>2</sup>. In these publications on two contrasting acarine

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groups, he focussed on both the taxonomy *and* biology of each group—a double-double penchant that has persisted throughout his career. Lindquist's Ph.D. thesis<sup>7</sup> on the systematics of "Blattisocinae" propelled him further into the world of mesostigmatic mites, especially those currently recognized as Blattisociidae (Phytoseioidea), Ascidae and Melicharidae (Ascoidea). Subsequently, he coauthored a pivotal paper with G.O. Evans on the idiosomal chaetotaxy of Gamasina<sup>11</sup>, which is perhaps the most cited publication on the taxonomy of Mesostigmata in the world, with over 400 citations (Web of Science, 2018). In parallel, his paper on "The world genera of Tarsonemidae[...]with a reclassification of family-group taxa in Heterostigmata<sup>246</sup> is probably the most cited (>240 citations) publication on the Tarsonemidae and the Heterostigmata: at over 500 pages, some of us refer to it as the bible of Tarsonemidae.

His later publications on the systematics of Ascidae *sensu lato*  $(34 \text{ publications})^{1, 3, 4, 8, 10-12, 19, 22}$ , 55, 56, 60, 63, 66, 68, 78, 79, 88, 93, 99, 102, 103, 105-108, 112, 113, 116, 117, 120, 123, 124, 127, on the idiosomal chaetotaxy of Mesostigmata<sup>64, 84</sup>, on Tarsonemidae  $(17)^{2}$ , 6, 13-15, 18, 21, 24, 33, 34, 40, 45, 46, 80, 90, 94, 129 and related Heterostigmata (>10)<sup>30, 32, 39, 41, 48, 57, 65, 76, 91, 125</sup> have set a solid phylogenetic footing and terminological basis for future research on these groups.

Throughout his career, Evert has published over 125 scientific articles<sup>1-129</sup>, representing 96 peerreviewed publications, 10 book chapters<sup>42, 43, 69-73, 100, 101, 104</sup>, two books<sup>74, 122</sup>, and over a dozen miscellaneous publications on mites. In total, he has published over 4100 pages. Of his peerreviewed publications, 39% are single-authored, and he is the lead author in nearly half of his coauthored publications. He has published with over 80 coauthors, most frequently Marilo Moraza (13 coauthored publications), Dave Walter (12), and Jerry Krantz (5). Retired in 2000, Evert's productivity has not abated, with publications since 2010 surpassing numbers in previous decades (see all publications at the end).

Lindquist's research contributions extend well beyond Ascidae *sensu lato* and Heterostigmata. He (with various coauthors) has published on the systematics of at least 13 other unrelated families or superfamilies of Mesostigmata<sup>9, 28, 50, 62, 84, 85, 96</sup>, Prostigmata<sup>20, 51, 74, 89, 119, 128</sup> and Endeostigmata<sup>59</sup>. In addition, he has been involved in several ecological papers focussed on mite communities or their behavior, some with high impact in soil or canopy ecology<sup>56, 68, 92, 95, 111</sup>, and published influential papers on the evolution of phytophagy in mites<sup>35, 81</sup> and on mite symbioses with insects<sup>17, 26, 65</sup>. Some of his reviews on the feeding habits and biology of the subject taxa have remained among the key references for these taxa<sup>46, 65</sup>. He has published on the use of mites against agricultural and forestry pests<sup>16, 37</sup>, and on Ixodida<sup>86</sup>, including an invaluable handbook to the ticks of Canada<sup>122</sup> that covers the diagnosis, biology and pathogens transmitted by tick species in the country.

In collaboration with E.A. Sidorchuk, Evert published significant articles on Cretaceous and Triassic amber fossils of Heterostigmata and Tetrapodili, respectively<sup>121, 125</sup>. These publications on fossilized ancient relatives of eriophyoids were a nicely expanded sequel to the initial stunning discovery of these Triassic fossils<sup>114</sup>. Evert's involvement on these studies undoubtedly stemmed from his previous work on Eriophyoidea, particularly his 1996's publication<sup>69</sup> where he standardized morphological terminology for eriophyoids, based on putative homologies with other mite groups. Evert was lead editor of this volume<sup>74</sup> and wrote four other chapters dealing with the systematics, diagnosis, phylogenetic relationships, and evolution of eriophyoids in relation to their hosts<sup>70-73</sup>. This key publication significantly strengthened the foundation of systematics research on Eriophyoidea. Similarly, Lindquist published two book chapters on Tetranychidae<sup>42, 43</sup>, in which he standardized terminology for their external anatomy and reviewed the phylogenetic relationships of spider mites and related tetranychoid families. As with his publications on eriophyoids, this placed the systematics research on tetranychoids into a stronger framework.

Another pivotal publication is Lindquist's morphology-based test of monophyly of Acari<sup>38</sup>. In a tribute to Lindquist in 2011 when he received the Acarological Society of America Award, Gerd

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Alberti wrote "Besides his impressive and most competent taxonomic studies, in particular on Heterostigmatina, Eriophyoidea and Mesostigmata, his thoughtful review on *Current Theories on the Evolution of Major Groups of Acari and on their Relationships with other Groups of Arachnida, with Consequent Implications for their Classification*—has fascinated me. For me, it still stands as *the* admirable in-depth state-of-the-art study on this difficult topic."

Evert's broad knowledge of the taxonomy and biology of Mesostigmata and Prostigmata resulted in his involvement in three chapters of the third edition of the 'Krantz and Walter' Manual (2009)<sup>100, 101, 104</sup>.

During his career, Evert has described nine new families and redescribed or rediagnosed 15; described 37 new genera and rediagnosed >90; and described 132 new species or subspecies and rediagnosed ~90. Just this year, he and coauthors described a new family of Raphignathina that consists of subelytral parasites of dytiscid water beetles<sup>128</sup> and a new tribe of Tarsonemidae that are parasites of tetrigid grasshoppers<sup>129</sup>. His publications include 33 keys to >170 species; 13 keys to >165 genera; and contributions to two family keys in the Manual of Acarology (2009).

Evert's keen eye for homologizing structures and distinguishing apomorphies from plesiomorphies through broad taxonomic comparisons has been central to his improving the taxonomy of many acarine groups. In particular, he pays attention to ontogeny and immatures stages, recognizing that they contain information that can help elucidate homologies and phylogenetic relationships<sup>11, 84, 93, 117, 119, 129</sup>: nearly half of his systematics papers include descriptions of one or more immature stages. Furthermore, Lindquist consistently puts his findings into a broader context, including phylogenetic, evolutionary and ecological. His curiosity and his clear analytical mind led him to many hypotheses and speculations—often with supporting data—on the nature of host associations, feeding habits and structural functions, many of which he published in Remarks or Discussion sections of his publications. His series of papers coauthored with M. Moraza (2008–2018) on flower-, fungus-, and hispine-associated gamasines is one source of examples<sup>99, 105, 108, 113, 117, 120, 123, 127</sup>, but any earlier publication will reveal similar scientific richness.

With his strong understanding of the International Code of Zoological Nomenclature, Lindquist has worked on resolving nomenclature issues<sup>11, 25, 28, 39, 70, 96, 118</sup>, including a major one on Eriophyoidea<sup>27, 31, 49</sup>.

# His work at Agriculture and Agri-Food Canada

Lindquist was employed for nearly 40 years (1961–2000) at the Research Branch of Agriculture and Agri-Food Canada (AAFC), Ottawa, where he remains affiliated as an Honorary Research Associate. As Research Scientist, he built the Acari section of the Canadian National Collection of Insects, Arachnids and Nematodes (CNC) from scratch, through collecting trips for mites throughout North America, Mexico and Central America, and with the help of colleagues and subsequent acarologists at AAFC that he helped hire (I.M. Smith, V. Behan-Pelletier, F. Beaulieu, W. Knee, M. Schwarzfeld). Since 1961 he has mentored not only colleagues at AAFC and Canadian and international universities, but also provided his expertise to other government agencies (e.g., Health Canada, Canadian Food Inspection Agency, Environment Canada) and the public through species identifications and advice.

## Training of acarologists

Among Lindquist's greatest contributions to acarology is his training of a generation of acarologists, as lecturer at the Acarology Summer Program of The Ohio State University during 1972–1988. Students included: J. H. Camin, J. Kethley, R.A. Norton, C.E. Yunker (1972); N. Fashing, L. Goff, L. Lundquist, G. Mullen, G. Oldfield, A. Paschoal, D. Wrensch (1973); D. Ide, I.M. Smith, D.E. Soneshine, S. Swift (1974); L. B. Coons, B. McDaniel, J. McMurtry, J.A. Yoder (1975/

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1976); C. Bowman, J. Hoy, G. de Moraes, L. Watrous, R. Thomas (1978); C. Cramer, G. Nuzzaci, J. Palacios (1979); V. Behan-Pelletier, J. Morales-Malacara, D. Walter (1980/1981); C. Childers, E. de Lillo, H. Klompen, M. Moraza (1983–1987); J. Amrine, M. Kaliszewski, M. Sabelis (1988). As Jim McMurtry said (pers. comm. 2011): "my knowledge of acarine taxonomy was essentially nil. I took the two weeks of agricultural acarology taught solely by Evert. I learned a lot of acarology, and with Evert's encouragement, decided that maybe I could do a bit of taxonomy myself. As one of Evert's successors in the agricultural acarology class, my involvement in teaching for only a few days (phytoseiids and tetranychids) made me appreciate even more the great extent of his knowledge and efforts".

### Professional recognition and current research

In addition to teaching acarology at The Ohio State University (1972–1988), he was a visiting lecturer at three institutions in Mexico (Universidad Nacional Autónoma de México, Instituto Politécnico Nacional, and Colegio de Postgraduados) (1983 and 1987), and a collaborator and visiting instructor for the Arthropods of La Selva Project in Costa Rica (1992–1999). He was a member of the International Executive Committee for the Congress of Acarology (1990–1998), and an adjunct professor at Carleton University, Ottawa (1971–1983).

Evert has been honoured through many awards, including: twice by The Ohio State University for outstanding work on the systematics of Acari (1974) and outstanding contributions to agricultural acarology (1988); at the International Congress of Acarology (ICA, 2002), when he became a Honorary Lifetime Member in recognition of outstanding contributions to systematics, phylogenetics, morphology and biodiversity of Acari; by the Latin-American Society of Acarology (2002), in recognition of exceptional contributions to supporting the development of acarology in Latin American countries; and at the Acarological Society of America Annual Meeting in Reno (2011) for his outstanding contributions to acarology. He was also the Keynote speaker for the 10<sup>th</sup> ICA in Canberra (1998), for which he has published a rich plenary address in the ICA Proceedings<sup>87</sup> that shows again how thoughtful and visionary Evert Lindquist is.

Evert is currently involved in several taxonomic projects, including one recently submitted for publication, in which he has the anchor role as last author of 14: a revisit of Lindquist *et al.*'s  $(1979)^{36}$  'Acari of Canada', which reviews the diversity of the acarofauna in the country and taxonomic progress since 1979.

The impact of Evert Lindquist's publications, teaching and mentoring will influence generations to come. He has our admiration and highest respect, and he well deserves the James A. McMurtry Award.

### Acknowledgements

We thank Enrico de Lillo, Carl Childers, as well as the recently deceased Gerd Alberti, Jim McMurtry and Gwilym Evans for having shared earlier (2011) their opinions of Evert, which we either quoted in the text, or were a source of inspiration; David E. Walter for editorial comments; Hans Klompen and Orlando Cómbita-Heredia for information about past students at the acarology workshops; and Zhi-Qiang Zhang for the invitation to write this article on our esteemed colleague.

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