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Progress and Prioritizing Needs for Future Research on Testate Amoebae: A Meeting Report on the International Symposium on Testate Amoebae, Antwerp, Belgium, September 12—14, 2006

An international group of 44 scientists from 16 countries assembled at the University of Antwerpen to share experiences and assess current research progress concerning testate amoebae. It had been 23 years since the last testate amoebae workshop was held in Aachen, Germany and 30 years since the first testate amoebae workshop before it was organized in 1976 in Sofia, Bulgaria. Interest in testate amoebae has accelerated greatly in recent years. Thus a meeting of testate amoebae specialists from around the world was long overdue.

More than 50 oral and poster presentations were given during the 3-day meeting. Topics included morphology, taxonomy, phylogeny, biogeography, ecology and paleoecology of testate amoebae. In opening comments, L. Beyens expressed the wish that this meeting would encourage more testate amoebae research and greater involvement in major research consortia in the future. The workshop featured three keynote lectures. Each presentation was an overview aimed to highlight three important areas where testate amoebae research has made major advances since the last meeting in Germany.

Phylogeny and Classification

Modern morphological studies and new molecular techniques developed in the last decade or so have had a profound influence on the thinking about the traditional systematic schemes for testate amoebae. This coincides with a new overall classification involving all eukaryotes, where it is proposed that most testate amoebae fall within a new group called Amoebozoa. The meeting began with Dr. R. Meisterfeld of RWTH Aachen, Germany speaking on "Phylogeny, classification and distribution of euglyphid filose testate amoebae (Euglyphida)". He used the example of the Euglyphida group to show the advantages of molecular phylogeny approaches in refining systematics and clarifying evolutionary relationships. Dr. Meisterfeld along with a paper by E. Lara and coauthors (Switzerland) showed that some old taxonomic relationships are confused. Related taxa once assumed to be close are not and relationships of more divergent taxa are probably closer than previously thought. The future of testate amoebae systematics clearly lies in much more work on molecular characteristics if we are to clarify and refine taxonomy, phylogeny and the classification relationships. This kind of work has far-reaching implications for testate amoebae-based work. Traditional hierarchical classification of testate amoebae will remain in a somewhat state of uncertainty until more molecular work can be completed. Much needs to be done to address issues around "morphological taxa" and concerns over cryptic and phenotypic plasticity within the testate amoebae.

A. Kudryavtsev (Russia) reported on some fascinating new taxa from desert soils of Kazakhstan as did J. Yang (China) from Lake Mulan in Central China. It would be interesting to see what molecular information might reveal about these morphologically distinct taxa from new geographic regions.

Ecology and Palaeoecology

Testate amoebae are abundant in moist soils and aquatic habitats around the world and have the

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added attribute that upon dying, their shells are preserved in abundance as fossils in wetland and lake sediments. Their ecology was explored in presentations that featured sandy beaches on the Bulgarian Sea coast (Todorov and Golemanski, Bulgaria) to lake bottoms in France (Gilbert and co-authors, France) to peatlands on Amsterdam Island in the Indian Ocean (Heger and co-authors, Belgium). Ecological studies around the world are showing close relationships between testate amoebae and soil moisture, soil organic matter content, and dissolved oxygen which underscores the value of testate amoebae as strong bio-indicators and environmental proxies. Drs. B.G. Warner of the University of Waterloo, Canada and E. Mitchell of the Swiss Federal Research Institute, Switzerland reviewed the "Progress and future needs of testate amoebae research in Quaternary palaeoecology". Despite an early start in the late 19th century, testate amoebae were essentially ignored in paleoecology research until the late 1980s, after which time there has been resurgence in the use of testate amoebae as paleoenvironmental proxy indicators. The qualitative analyses of the early days have been replaced by quantitative approaches. The extent to which testate amoebae can be used for paleoenvironmental reconstructions is directly dependant upon the level of knowledge about environmental controls on extant communities. Much effort in recent years has contributed to development of sophisticated transfer functions which indicate that testate amoebae are important indicators of site water conditions. A. Geary (UK) reported on his efforts aimed to explore the possibility that testate amoebae can be used as hydrochemical indicators and P. Rae (UK) investigated relationships with precipitation and temperature on bogs in Britain also. Most of the paleoecological work has focused on *Sphagnum*-dominated habitats in the Northern Hemisphere because such habitats are where testate amoebae tend to be most diverse and best preserved in fossil deposits. Warner and Mitchell emphasized that significant new insights will be gained from studies of fossil testate amoebae in wetland and lake habitats other than those dominated by *Sphagnum*. Also, great potential exists for the use of testate amoebae proxy indicators from sites at middle and southern latitudes; a presentation by I. Flett (Australia) on testate amoebae from the Galapagos Islands demonstrated this. Also, much of the work has been at the mesoscale, however, there is need for future research on testate amoebae at the microscale. This point was emphasized by a presentation on microhabitat characteristics by A. Bobrov (Russia), Y. Mazei, and A. Tsyganov (Russia). Indeed, microscale studies have been largely overlooked by peatland ecologists collectively and so the potential exists for considerable synergy between vegetation and testate amoebae ecologists to work more closely together.

A. Wall and co-authors (France) and F. McCarthy and co-authors (Canada) presented examples where fossil testate amoebae studies are being extended to lakes. New revelations about past environments might come to light the day that it is possible to make comparisons of testate amoebae records from tandem lake and wetland sites.

Much remains to be learned about the ecology of testate amoebae. In what might be assumed to be biologically sterile environments, testate amoebae were shown by M. Wanner and W.E.R. Xylander (Germany) to be rapid colonizers, diverse, and abundant in dune soils. They were able to differentiate "newcomers" from "residents" and confirm how low-order organisms in soils clearly operate differently from higher-order organisms that live above or on the soil. This study is an elegant example illustrating how testate amoebae are powerful biomonitors of change in a wide array of soil conditions, be they natural or human-altered.

A number of ecological studies were presented from regions both far and near, but noteworthy were studies from little-known regions such as the Antarctic Islands (L. Beyens and co-authors, Belgium), Hungary (Török, Hungary), Ecuador (V. Kraskevskaya, Germany), Thailand (P. Wangsomnuk, Thailand), Tibet (J. Yang et al., China), and Japan (Y. Aoki, Japan).

Finally, papers by Nguyen-Viet et al. (France) and Shimano et al. (Japan) demonstrated some new and novel applications of testate amoebae as bioindicators. Further, W. De Smet (Belgium) reported an odd presumed parasite—host relationship between rotifers and the shells of testate amoebae which they inhabit.

Testate Amoebae in Global Change Research

At a time when global environmental issues are front and centre in the minds of many people, the third plenary speaker, Dr. D.J. Charman, University of Plymouth, UK, asked why testate amoebae research has ignored large scale questions. He reiterated that testate amoebae are ideal environmental indicators because they: (a) are ubiquitous

and abundant in soils and aquatic habitats around the world, (b) have distributions closely controlled by water and moisture variables in natural and man-made habitats, (c) contain shells that are preserved after death allowing living and dead populations to be studied together, and (d) have short-lived generations and rapid reproduction rates which makes them sensitive to environmental changes. Testate amoebae-based paleoclimate reconstructions hold much promise for characterizing recent and predicting future climate. Ecological and paleoecological research is showing that testate amoebae respond to seasonal changes which lead to the possibility of extending historical climatic data bases farther back in time than what is available from instrumental records. S. Müller and A. Bobrov (Russia) presented a detailed post-glacial climatic record from Cape Mamontovy Klyk based on testate amoebae. Similarly, testate amoebae can be used to trace sea level histories or predict high-risk coastal zones. UVB radiation from ozone layer thinning, eutrophication of aquatic ecosystems and atmospheric pollution are other global environmental problems which testate amoebae have much to contribute and as yet, little has been done. Beyens and collaborators (Belgium) have done experimental warming experiments in Greenland to model the response of testate amoebae to the warming of the highly sensitive arctic ecosystem. For global scale issues to be addressed, international teams of specialists will need to work together.

Biogeography

Testate amoebae have existed for at least 220 million years (Schmidt et al. Germany). A long history, as well as their position near the base of the food chain, makes testate amoebae ideal indicators to test and develop new theories concerning the biogeography of all living organisms. H.G. Smith and D. Wilkinson (UK) contributed new thinking on ongoing debates of cosmopolitanism versus endemism in testate amoebae biogeography. They caution even though testate amoebae may exhibit more tendencies towards cosmopolitanism than most multicellular taxa, "everything is not everywhere" or cosmopolitanism cannot be assumed for all testate amoebae. Taxa smaller than 100—150 μm in size are more likely to be cosmopolitan in distribution than the larger taxa. In contrast, the contribution by W. Foissner and M. Kreutz (Austria) on small *Sphagnum* ponds in Germany showed how there can be a high degree of endemism in small geographic "hotspots". Clearly we have more work to do particularly outside the Northern Hemisphere where there has been a longer tradition of research.

The symposium was an outstanding success. The participants congratulated L. Beyens and coworkers for hosting this important meeting. Much was learned and there is much to do. It is expected that testate amoebae specialists will not wait for another 23 years to pass before the next symposium. Drs. Mitchell (Switzerland) and D. Gilbert (France) have extended an invitation to convene the forth International Symposium on Testate Amoebae.

Further details are available on: http://www.ua.ac.be/ista.

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