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EDITORIAL

Introduction to the Special Issue: Bland J. Finlay: Uncovering the Unseen World of Microbes

Microbes, organisms defined by their small size, comprise prokaryotes, such as archaea and bacteria, and eukaryotes, such as protozoa, fungi, and algae. These include some of the earliest organisms to have evolved on Earth and form the base of the tree of life. Microbes are globally ubiquitous, present in astronomical numbers and underpin the major global biogeochemical cycles. Although small, microbes can be complex with the ability to detect and respond to their environmental conditions, including gravity. Some microbes have unique or unusual biological features such as: the ability to thrive in anoxic conditions, use nitrate as a terminal electron acceptor in respiration, oxidise methane as a source of energy and establish symbiotic relations with other microbes. Bland J. Finlay undertook ground-breaking research in all the areas outlined above (Fenchel, Protist 173[5]:125906). Despite their ubiquity, the known number of species in many microbial groups appears to be surprisingly small and Bland and collaborators argued that microbes lack a biogeography and that the 'environment selects' where microorganisms thrive. This idea was controversial and provocative, but Bland argued his case cogently with a brilliantly clear writing style (rather reminiscent of another Scot, Robert Louis Stevenson) and excellent illustrations as outlined in this issue by his son (Finlay 2022, Protist 173 [5]:125907).

Bland was very fond of PROTIST and was proud to have been on the journal's editorial board since Prof. Michael Melkonian founded it 25 years ago. We thus are very thankful to Michael for the brilliant idea of dedicating a special issue to Bland's memory – it is an excellent tribute to him and his lengthy career in protistology. This Special Issue honours Bland's scientific legacy in 14 articles contributed by 51 authors from 12 countries, covering a wide range of topics including taxonomy, phylogeny and cell ultrastructure; diversity and ecological interactions; and methods to culture and preserve protists. These articles were written by his family, former colleagues, students and collaborators who interacted directly with him; and other scientists who were influenced by his research. One of these, Ulrike-G. Berninger, describes her experience of working with Bland as a young student (Berninger 2022, Protist 173 [6]:125910).

Taxonomy, Phylogeny and Ultrastructure

Taxonomy underpins almost all aspects of biology. Carr and Leadbeater (2022, Protist 173 [6]:125924) re-evaluated the taxonomy and phylogeny of a group of loricate choanoflagellates from the order Acanthoecida that contains species that are designated as either 'tectiform' or 'nudiform', depending on their division pattern. A phylogeny based on 14 genes showed that the tectiform Acanthoecida is paraphyletic with another order, the Stephanoecidae. In a sister paper, these authors (Leadbeater and Carr 2022, Protist 173 [6]:125923) showed that the tectiform *Stephanoeca diplocostata* also has nudiform properties as does a newly-discovered genus, *Enibas*, that might have evolved from a *Stephanoeca*-like ancestor. Another

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protist, *Legendrea loyezae*, is an extremely rare ciliate that thrives in anoxic freshwater sediments. Weiss et al (2022, Protist 173 [6]:125912) describe previously unknown morphology and behaviour as well as the 18S rRNA phylogeny of this ciliate for the first time; the authors argue that, based on their observations, another species, *Thysanomorpha bellepheron*, should be moved under the *Legendrea* genus due to their shared morphological and behavioural characteristics. Since *L. loyezae* has only been detected six times in over a century, it underlines that the true diversity of microbial species and communities is underestimated and requires further research.

Diversity, Communities, and Ecological Interactions

Microbes are key components of ecosystems, and their metabolism and diversity can control ecosystem structure and function. Maberly et al (2022, Protist 173 [6]: 125925) analysed long-term data on phytoplankton from lakes in the UK and reported a consistent pattern of seasonal variation of taxon richness with the greatest numbers of taxa, as well as functional groups, in the summer. An analysis of environmental conditions suggested that higher water temperature in the summer promoted a more rapid turnover of taxa and functional groups. Competition was also evident, since the number of taxa sharing a unit of chlorophyll *a* was low when phytoplankton were abundant. Microbial communities can be affected by other environmental filters. Dumack et al (2022, Protist 173 [6]:125913) analysed Cercozoa communities from different types of soil, crops and bacterial microbiomes. They found that different plant species supported different Cercozoa communities. Although the rhizosphere bacterial communities were controlled by bottom-up factors via root exudates, they were strongly affected by top-down control exerted by grazing protists that formed a 'protist microbiome' with a strong effect on bacterial composition and function. In another ecosystem, biological soil crusts in a semi-arid Mediterranean system, Pérez-Uz et al (2023, Protist 174 [1]: 125929) found that ciliates and testate amoebae had a lower species richness than in other soil environments. In a field experiment, artificial nitrogen deposition caused an even greater reduction in species richness and a shift in protist community composition, with some species increasing in abundance at the expense of others.

In areas with glaciers, meltwater carries small rock particles, glacial flour, into the coastal ocean where autotrophic microplankton form the base of the marine food-web. A comparison of four fjords in Greenland (Maselli et al 2023 Protist 174 [1]: 125928) showed that the abundance of autotrophic microplankton is affected by the reduced light penetration and nutrient availability, while heterotrophic and mixotrophic protists appeared to be unaffected (Maselli et al 2023 Protist 174 [1]: 125928). Laboratory experiments confirmed that mixotrophic protists were unaffected by glacial flour up to high concentrations of 50 mg/L. The flagellate microalga, *Prymnesium parvum,* can produce toxins. Caron et al (2022, Protist 173 [6]:125927) performed growth experiments on this haptophyte to determine the effect of pH and salinity on its growth rate and toxin production. They showed that reduced pH decreases toxicity as does reduced salinity although to a lesser extent. Reductions in both environmental conditions reduced toxicity but also reduced growth rate. Since ocean acidification is causing pH to decline this will potentially have ecological consequences, especially in areas receiving inputs of freshwater.

Culture and Preservation Methods

The ability to grow, enumerate and analyse protist cultures is central to studies on their biology and has commercial applications. The ciliate *Loxodes* has numerous unusual physiological characteristics (see Fenchel 2022, Protist 173 [5]:125906) but is hard to culture and preserve for fluorescence microscopy. Seah et al (Protist 173 [5]: 125905) devised methods to grow *Loxodes* in bulk and preserve it effectively, opening the door to a range of modern cell biology investigations in the future. Some microalgae produce biochemicals of commercial value such as the eustigmatophyte *Nannochloropsis oculata*. Tran et al (2022, Protist 173 [6]:125914) developed a novel 'angled twin-layer porous substrate photobioreactor' for this species that allowed high growth rates producing biomass, lipids and vitamin E with potential commercial applications. Many laboratory studies rely on cultures isolated by the research community over decades. This valuable scientific resource depends on the ability to maintain cultures, ideally without genetic drift, and one technique to ensure this while also reducing the cost of regular sub-culturing is to use cryopreservation. Day et al (2022,

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Protist 173 [6]:125915) describe the failure of refrigeration in a cryostat holding >600 strains of cyanobacteria and microalgae and a strategic approach to assess their viability immediately and after 10 years. This has led to the production of advice for emergency, restorative and ongoing remedial actions following refrigeration failure.

The articles in this Special Issue demonstrate how protists continue to provide an endless source of research topics and discoveries - all that is required, as Bland used to say, is a microscope and some imagination. Microbial diversity, phylogeny and metagenomics, descriptive biology, taxonomy, ecological interactions, industrial applications and other scientific enquiries on protists, will continue to further our knowledge and understanding of life and how ecosystems function on Earth.

Genoveva F. Esteban
Bournemouth University, Department of Life and Environmental Sciences, Talbot Campus, Poole, Dorset BH12 5BB, UK
e-mail gesteban@bournemouth.ac.uk

Stephen C. Maberly
Lake Ecosystems Group, UK Centre for Ecology & Hydrology, Lancaster Environment Centre, Library Avenue, Bailrigg, Lancaster LA1 4AP, UK
e-mail scm@ceh.ac.uk

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