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EDITORIAL

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Protistology today: advances in the microbial eukaryotic world

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In September 2000, we organized the 3rd meeting of the Protistology Group of the Spanish Society for Microbiology (SEM). This Group has been very active since 1996, when it was set up as a part of SEM. From the 2000 meeting, the idea of preparing a monographic issue of *International Microbiology*[1] grew in my mind. Why prepare a monographic issue on protistology? In Spain, very few scientists are involved in protistological research. Although I will not analyze here the reasons behind this state of affairs, it is in any case a good reason to promote knowledge of protists among microbiologists.

According to the various definitions given by Ernst Haeckel, the taxon Protista contains many – but not exclusively – unicellular eukaryotic organisms. In the modern view, protists are eukaryotic organisms of cellular organization. Therefore, the term embraces classical protozoa, unicellular autotrophic organisms and also lower unicellular fungi. This monographic issue comprises reviews related to both protozoa and unicellular autotrophic organisms, but not to fungi.

Some of the most discussed topics in protistology are those related to protist systematics, evolution and biodiversity. Classification systems for protists are continually changing, and experts cannot agree a unifying concept of how to do their job. Some authors think that the only way to do systematics is to carry out phylogenetic systematics. Indeed, both approaches (taxonomy and phylogeny) are artificial views of the real word, but both are absolutely necessary. So we will continue to follow a long, heavy and tortuous path towards better protist classification for at least the next 10 or 20 years. Christian F. Bardele believes that comparative ultrastructure and comparative genomics will some day tell us how entire genomes have evolved over time through lateral gene transfer from all sorts of temporary guests in host cells, and through differential loss or rearrangements of genes. After finishing several prokaryotic and eukaryotic genome projects, support for this idea may well become quickly evident.

Protist biodiversity is presently a passionate point of controversy among several protistologists. The first review of this monographic issue is a contribution by B.J. Finlay and G.F. Esteban about a basic and important topic on the abundance and biodiversity of protozoa. Simultaneously, this paper constitutes a brief tribute to the "father of protozoology (protistology)", Antonie van Leeuwenhoek (1632–1732), who was probably the first human to see microorganisms (including protists). Finlay and Esteban argue that, in general, protozoan morphospecies are ubiquitous and apparently cosmopolitan; global abundance does influence local abundance and an emerging conclusion is that there is no correlation between geography and genotype. They illustrate their assertions with very good examples. Since the last European Congress on Protistology (Helsingor, Denmark, 1999), we know that W. Foissner's interpretation differs from that of Finlay, mainly on the number of protistological species and their cosmopolitan character. Thus, important questions such as "What is a

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species?'', ''How many species are there?'', ''Are there limits to the geographical distributions of species?'', among others, are still without a convincing answer.

A. Serrano's research group reviews the role of inorganic pyrophosphate (PPi), a simple energy-rich molecule, in protist (microalgae and protozoa) bioenergetics. These authors report the ubiquitous character of the inorganic pyrophosphatases among protists; their widespread occurrence among evolutionary-divergent protists supports the ancestral character of bioenergetics based on PPi. In addition, this molecule may play an important role for microbial survival under environmental stress conditions. Again, enzymology has proved to be a good tool for eukaryotic molecular microbial phylogeny.

Over the last 10 years, microbial ecologists and medical microbiologists have demonstrated that these two fields of microbiology are interrelated. Some of their research projects have made dramatic progress in the understanding of how bacteria grow in nature, as well as the importance of biofilms, cell-to-cell interactions, quorum sensing and molecular mechanisms for adapting to starvation or other stress conditions. Other projects have studied the mechanisms by which bacteria are able to adhere to tissues, invade, survive and multiply in their hosts. Among protozoa, amoebas and ciliates are frequently colonized by bacteria, and thus are interesting models to study eukaryotic–prokaryotic microbial interactions. For medical microbiologists this is really important, because bacterial pathogens can also be involved in such interactions with protozoa. An important difference between mammalian and protozoan hosts seems to be the ability of some protozoa to expel membrane-bound vesicles that contain large numbers of living infectious bacteria. In addition, the encystment capacity of several protozoan hosts constitutes a protective and propagation system for these pathogenic bacteria.

H.-D. Görtz describes, in an excellent review, diverse types of intracellular bacteria in ciliates, operating as symbionts, infectious bacteria and symbiotic methanogens, and discusses their ecological significance. Concerned with microbial ecology and cell adaptation to starvation, Gutiérrez's group reviews ciliate cryptobiosis, which is a strategy to overcome several environmental stresses. The authors outline five main features of the ciliate resting cyst formation, or encystment, process: cell dehydration and autophagy, resting cyst wall fabrication, and high chromatin condensation involving gene inactivation and mRNA accumulation. The authors hope that the application of genomic and proteomic methodologies will considerably increase the molecular and cellular knowledge of this microbial eukaryotic differentiation process in the near future.

Among parasitic protists, several important models (*Trypanosoma*, *Leishmania*, *Giardia*, *Plasmodium*) were profusely studied during the 20th century. The reason for this is obvious: their influence on humans. The review by S. Castanys and F. Gamarro's research group is a good example of this kind of study, and represents the forefront of current Spanish protist parasitology. The ATP-binding cassette (ABC) transporters are a large and diverse group of membrane proteins involved in the ATP-dependent transport of different solutes across intracellular, or cellular surface, biological membranes. ABC transporters have been identified in many microorganisms, both prokaryotes and eukaryotes, and are involved in processes such as the extrusion of noxious compounds and toxins, the uptake of nutrients, the transport of ions and peptides, and cell signaling. In addition, they have been implicated in many phenomena of biomedical importance, including cystic fibrosis, adrenoleukodystrophy, multidrug resistance to chemotherapy and multidrug resistance in bacteria, yeasts and parasites. The review focuses on ABC transporters in the protozoan parasite *Leishmania*, paying special attention to their relationship with drug resistance, and is therefore of interest to both microbiologists and parasitologists.

In ciliatology (protozoological studies involving ciliates), one of the most classical topics is related to ciliate cortical structure analysis. It is the second distinctive feature of ciliated protozoa and the one responsible for the name of the phylum. The ciliary unit or kinetid is a complex assembly of membranous and fibrillar elements, which are obviously involved in cell motion. An example of ciliate cortical anatomy is shown in the figure that illustrates this editorial (Fig. 1). Universal cytoskeletal elements are: microtubules (composed of tubulin), actin

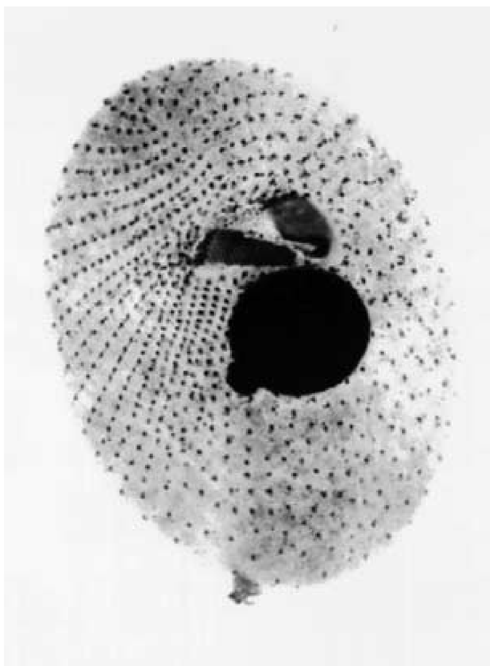

Fig. 1 Nuclear and infraciliature features of the ciliated protozoa *Colpoda cucullus*, observed by silver carbonate impregnation. This strain was isolated from a soil sample from Bogor, Indonesia. Courtesy of Carmen Jareño and Ana Martín-González, University Complutense of Madrid, Spain. (magnification, ca. 1,000×)

microfilaments, intermediate filaments, and calcium-binding proteins. Ciliates appear not to have made extensive use of actin in the construction of their cytoskeleton, contrary to other protists. However, actin has been studied in several ciliates, and it is encoded by highly divergent genes. Its only definitively established function is food vacuole formation, although it could be involved in other, still unknown, functions.

Several Spanish protistological research groups have a long tradition of involvement in ciliate cortical structure studies. Among them, the group led by A. Torres has, over the last few years, addressed research projects aimed at a molecular approach to this topic. Closing this issue, the unusual characteristics of ciliate actins are discussed by Torres and collaborators. This expert review on this unconventional protein in ciliates is prettily illustrated with computer-simulated three-dimensional schematic representations of this interesting molecule.

Finally, I hope that this monographic issue of *International Microbiology*, dedicated to show us only some aspects of current protistology, may be a useful tool to provide better knowledge of protists in the microbial eukaryotic world. As Santiago Ramón y Cajal expressed it: ‘‘In Science as in life achievement is the offspring of love’’, our love for the wonderful world of protists will become real with our daily research work. Also, I hope that this issue will be useful to young research students and to increase interest in these eukaryotic microorganisms among microbiologists.

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