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ORIGINAL PAPERS

Changes in Taxonomy from Linné to Cavalier-Smith; Case Study – Testacean Protists

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Abstract

Starting with Linné and up to nowadays taxonomy has been developing constantly and it has appealed to almost all of the domains of biologic sciences. However, during the last 100 years it has made an extraordinary leap, as a consequence of the broad changes which occurred in electronic microscopy, biochemistry, genetics, ecology and the mathematical processing of populational data. This evolution is most obvious at the level of microscopic organisms. As an example I have shown the qualitative and quantitative leap achieved at the level of unicellular eukaryotes – protoctists, which I have highlighted with examples from the study of testacean rhizopods. The cultures of the various species have proven to be highly useful, as well at the variability data at the level of the populations and those obtained from paleontology.

Keywords: species, correlations bwetween taxonomy and other domains of biology, genetic phylogeny, testaceans.

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Introduction

Carolus Linnaeus is considered the founder of taxonomy, and the exact date is the publishing of the10-th edition of his book entitled*”Sistema naturae”*, i.e. the year 1759 (*http://en.wikipedia.org/wiki/10th_edition_of_Systema_Naturae).*

Taxonomic research had been undertaken before him, but Linné's merit consists in the development of a unitary system which he applied rigorously for many years and which is still observed nowadays by all the biologists. Initially, the name of a new species was given according to the will of the person who had made the discovery, whereas Linné introduced the system of unitary name, the binary system – name and first name, which he called genus and species. This system was initially based only on descriptive elements regarding the morphology of the respective organism. At the basis of the system there was a single specimen, the so-called holotype, and if there were several specimens, the others were called paratypes.

At the same time with the setting up of biology as a field of research of living organisms, its various branches appeared, diversified and evolved more or less independently. Unlike these, taxonomy has had to constantly take into account, like it or not, the discoveries of the other domains of biology. Moreover, the other domains, which are included nowadays in the category of natural science: chemistry, physics, geography, geology, paleontology, climatology, have played a major role in the development of biology. To all these we must add the continuous improvement of the equipment used in scientific research, and, more recently, certain aspects undertaken by sciences which belong to other domains which are not part of the natural science, such as mathematics, sociology, etc.

Consciously or unconsciously, this evolution of biology has constantly been based on taxonomy. If you do not know exactly what organism you are working with, the results of the work of anatomy, histology, cytology, physiology do not have any value. This situation is still maintained today, even in much younger domains, such as biochemistry, biophysics, ethology, genetics, ecology, etc.

The ascending course of biological knowledge has progressed in a relatively uniform manner for approximately 200 years (i.e. until the middle of the 20th century), after which, concurrently with the explosion of information in all the fields, it accelerated. At present, biological research is obviously on an ascending course (Hagen, 2012, Doniţă et a., 2017). A particular leap was determined by Cavalier-Smith (Cavalier-Smith et. at., 1993, 2015) who proceeded to the analysis of the phylogeny of the living world based on the data obtained from the studies of molecular genetics (DNA or parts of DNA) which enabled the more in-depth study of the origin of the different species on genetic bases. He began his work in the 8-th decade of the 20th century and, ever since, these have had consequences on the study of all the groups of organisms, and after 2000 even on the study of microscopic organisms.

Another aspect which should be emphasized is the gradual passage from individual research to research conducted by ever larger teams of specialists, either in the same work place, or in research or higher education centres from the same country or even from different countries. (see Adl. et al., 2019). The effect of this new type of research is very important since the ideas expanded and the published papers obviously became more complex.

The Development of Taxonomy

In taxonomy we can easily notice all the stages scientific research in biology has been through, as well as the manner in which it is developing at present. Initially, taxonomic research was conducted only on morphological bases. Subsequently, cytological, physiological elements were used, and later on the approach of finer aspects became necessary, such as, for instance, data from cell biology, biochemistry, ethology, and, more recently, elements from genetics and ecology. Furthermore, if initially the description of a species was made based on a single specimen, or several more at the most, which were mandatorily preserved in a museum or in a special collection, now the research extends to as many specimens as possible from the same population (or, if they belong to different populations, this fact must be explicitely specified) using statistical data and ever more complicated mathematical processing.

The collaboration with other natural sciences showed that every species has a certain (larger or smaller) geographical area where every population of the given species is subjected to particular influences which depend, directly of indirectly, on the local environmental factors and which determine, at the level of every population, small differences which become genetically stable and must be taken into account. These differences may be relatively well known and have led to the nuancing of the description of some relatively well delimited subunits in the area of the given species, such subunits having initially been called „variety" (or if they had finesse they were called „forms") and which now have been elevated to the rank of „subspecies".

Concurrently with the extension and increase of the complexity of the aspects dealt with in taxonomic research, codes of the botanical, zoological or microbiological nomenclature appeared. These codes are constantly updated and have to be taken into account unconditionally, irrespective of the satisfaction or dissatisfaction of certain taxonomists. Their role is to keep in check the desire of many taxonomists to detail and to create, more or less objectively, more and more taxonomic units, and, consequently, to induce a kind of chaos in taxonomy.

In parallel with descriptive taxonomic research, it became necessary to order supraspecific and subspecific taxons, which made taxonomy even more complicated (Table 1). The classification systems evolve, they constantly become more complex and at the same time they determine new phylogenetic concerns (they cause repositionings of the manner in which the living world has evolved or regressed during the geological eras).

In the middle of the 20th century, Bertalanffy, an Austrian researcher, came up with the idea of the existence of organized hierarchical systems which in biology proved to be extremely useful in order to understand the ways in which life evolved on this planet during the eons. It was later on proved that Bertalanffy's theory was also useful in order to understand many processes which take place in chemistry, physics or sociology.

Table 1. The evolution of the classification systems of the living world

Linné (1759)	Haeckel (1894)	Whittaker (1969)	Woerse (1977)	Cavalier-Smith (2004)
Animal Vegetal Mineral	Animal Vegetal	Animal Vegetal Fungi	Animal Vegetal Fungi Protiste Eubacterii Arheobacterii	Eukariote Animal Vegetal Chromiste Protiste Procariote Eubacterii Arheobacterii

Romanian academician Nicolae Botnariuc from the University of Bucharest was a great supporter of the systemic theory in biology and he emphasized the role and specific functions of every hierarchical level of this theory (Fig. 1). (Botnariuc, 1976).

Genetics created a new system for understanding phylogeny and for the functioning of information at the level of the populations, and ecology emphasized the importance of the diversity of the intrapopulational and interpopulational factors which determine the survival of any species (Table 2), the role of the variability and diversity of the factors acting on the population and explaining the dynamics and evolution of the species (Gomaa et a., 2012, Kosakian et.a., 2016 a,b, Lahr, et.s., 2019, Olendzeski et a. 2018). At present taxonomy requires information from the other natural sciences, i.e. from geography, climatology, paleontology, chemistry and physics (the development of taxonomy after it started to be based on ecological thinking can be noticed, and in Table 3 the spectrum of modern approaches in taxonomy from the point of view of ecological diversity is presented). The tracking for a period of time (a longer or a shorter one, according to the life span of the studied species) in order to see its peculiarities during the individual life of the representatives of the respective species should be added to this information. This is why in order to do taxonomy at present, in any group you might be working, it is necessary to know morphology, anatomy, physiology, ethology, biogeography, biochemistry, genetics, paleontology, etc.

In the Fig.1 is presenting the role and specific functions of every hierarchical level of this theory (Botnariuc, 1976).

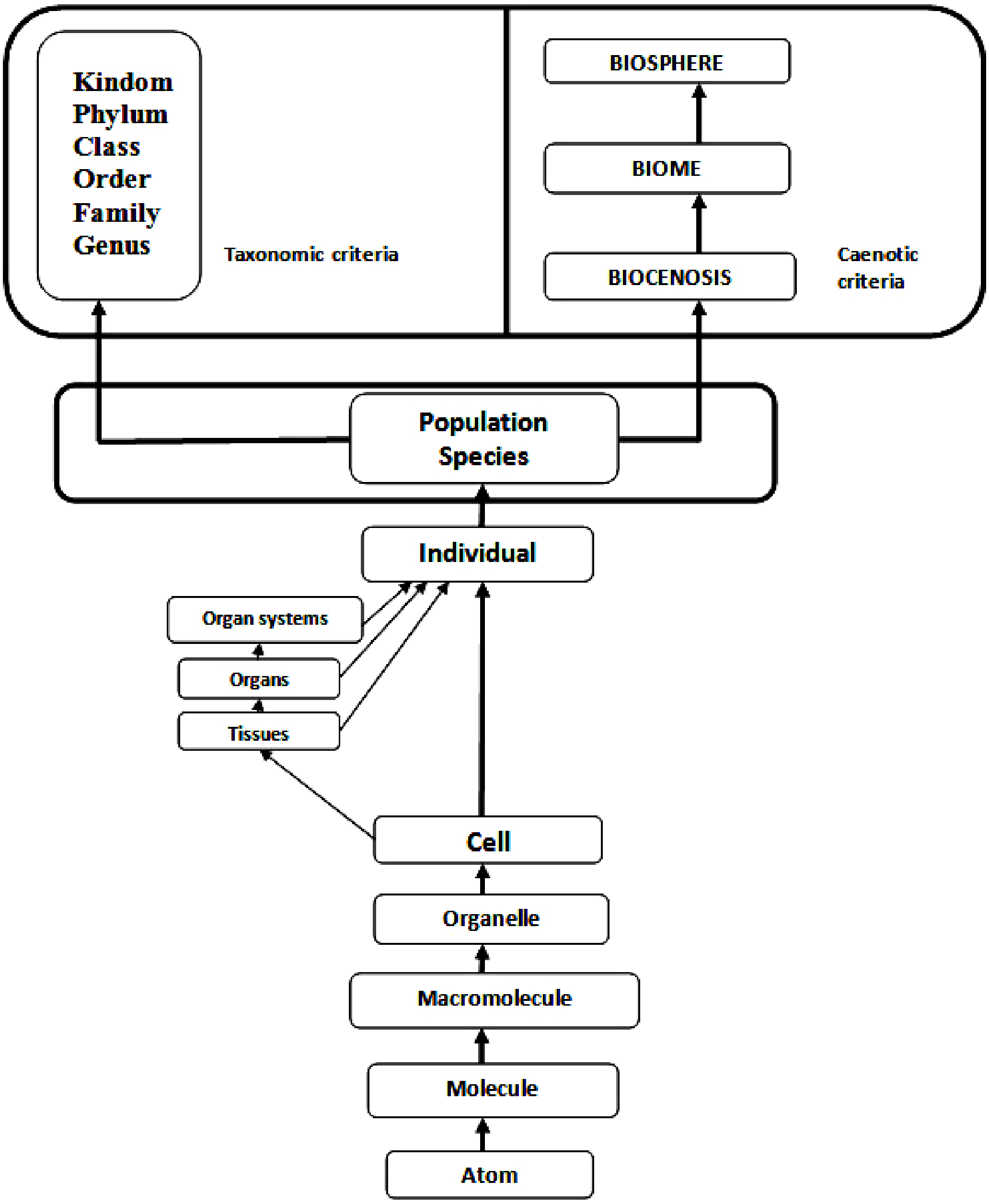

Figure 1. The role and specific functions of every hierarchical level of this theory (Botnariuc, 1976).

Table 2. Interpopulational and intrapopulational factors which must be taken into account in taxonomy (Bavaru et a., 2007)

Morphological
Ecological
Intrapopulational
Under the influence of climate factors
Geographical
Ethological
Genetic
Sexual

Table 3. Factors on which the diversity of a population depends (Chardez (1961, 1973, Mazei et a., 2017, Luketa, 2017)

Size of the population
Its history
Living environment
Response to the action of the biotic and abiotic factors
Trophic spectra
Behaviour (ethology of the species)
Reproduction capacity and number of viable descendents
Development cycle and infant mortality
Mobility
Forms of resistance
Distribution according to life stages
Spatial distribution
Functional role in the ecological system/systems to which it belongs

From Linné and up to nowadays the species has acquired new values; it has remained the basic unit in taxonomy, even if its meaning has become more complex and diversified as a means of understanding the variety of forms in the living world.

Case Study – Testacean Protists

In figure 2 we present the phylogenetic tree of the living world drawn up by Lynn Margulis before and soon after the year 2000 (Margulis et a., 1997, 2009), and in figure 3 the phylogenetic tree of the living world drawn up by Adl (Adl et a. 2019)! From this figures we can notice that the first living organisms were the prokaryotes (which have cells without a nucleus), then the eukaryotes appeared (whose cells always have a nucleus where most of the genetic material which ensures the storage of the information of the respective species accumulates). According to Margulis the basic criteria are the structure and the manner in which the nucleus appears and becomes complex and the manner in which the sexual reproductive system has improved. Prokaryotes are simple unicellular organisms (represented by unicellular organisms or disposed in clusters or in rows of identical specimens of the same species)((Margulis et a., 2009).

The simplest eukaryotes are represented by unicellular organisms which make up a special kingdom, Protista. Without going into details, mention should be made that the evolution of the eukaryotes took place through the biochemical diversification of the functional relations of microscopic prokaryotes .

In eukaryotes the appearance of the nucleus triggered an explosion of means in which the living world developed and diversified, first at the unicellular level, then, later on, multicellular organisms appeared, in which the various vital functions became ensured by groups of specialized cell, forming certain tissues or organs.

Protists are a good example of this evolution. Initially they were differentiated according to the manner of obtaining food, into autotrophic, heterotrophic and saprophytic, which are now grouped into a rather large number of branches/ phylums, with distinct characters. From them the evolution continued to pluricellular eukaryotes in three large directions: autotrophic protoctists produced plants, heterotrophic protoctists produced animals and saprophytic protoctists produced fungi. (Figure 2)

To better explain the manner in which the concept and manner of work in taxonomy have changed, we shall illustrate these by the example of the study of very primitive heterotrophic protoctists, lacking a membrane (i.e. organisms which lack a formation to protect the living cytoplasm from their living environment, but which otherwise behave like any other living organism). These are the Rhizopods.

In order to live, their cellular mass (cytoplasm) emits a series of projections (pseudopods) with which it moves, touches and analyzes the nearby environment and with which it acquires the necessary food (mainly prokaryotes and decomposing organic material, and, more rarely, even some unicellular or pluricellular eukaryotes). These pseudopods form a vacuole around the food which incorporates them and which, subsequently, secretes digestive substances (which they decompose into simple organic compounds with which ameobas self-regenerate/feed).

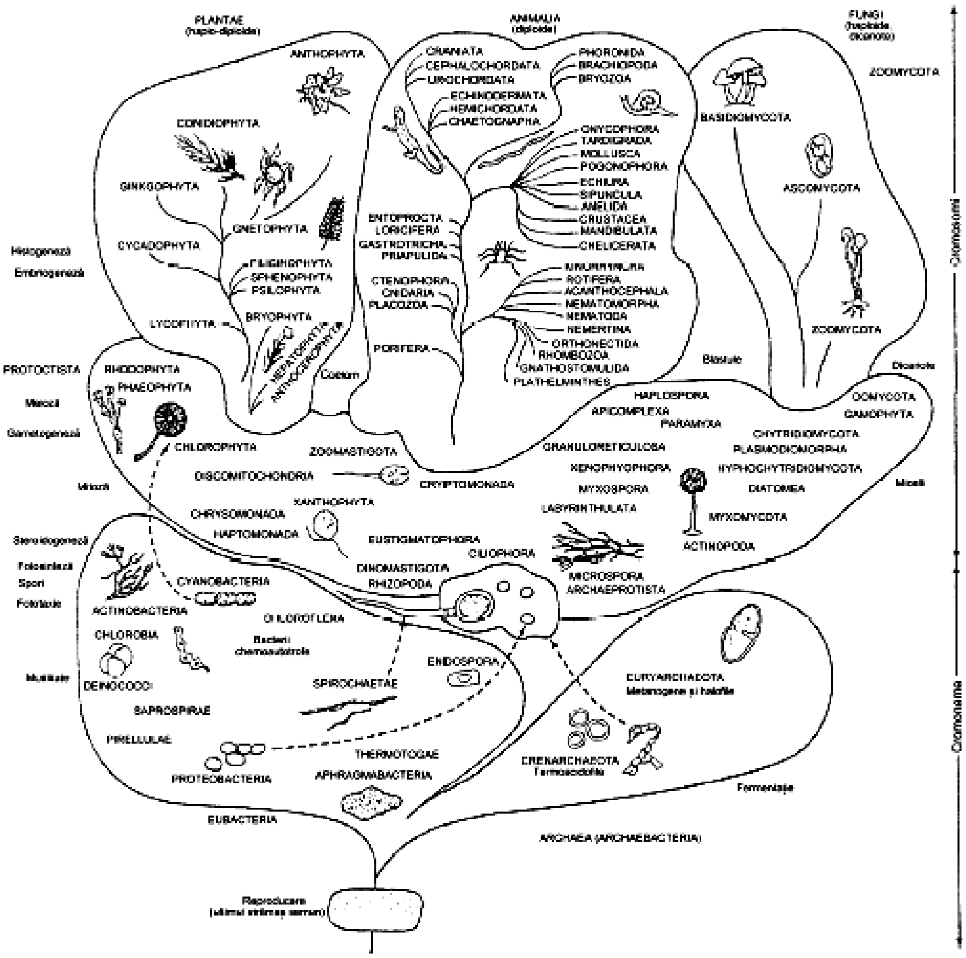

Fig.2. Classification of the Living World (Margulis et al., 2009)

During the evolution of amoebas/rhizopods three types of pseudopods were differentiated: lobopods, phyllopods and actinopods (Figure 4). In each of these three types of amoebas evolution followed two courses: some of them remained with a free protoplasmic body (Euamoebida) and others created a protective cover for the cytoplasm made up of allochtonous or autochthonous material (Testacea). The protection material with which the amoeba makes its shelter may be of exogenous origin (and it is called xenosome) or it is secreted by the amoeba (and it is called idiosome – being made up of calcium or silicium salts extracted from the environment by the amoeba).

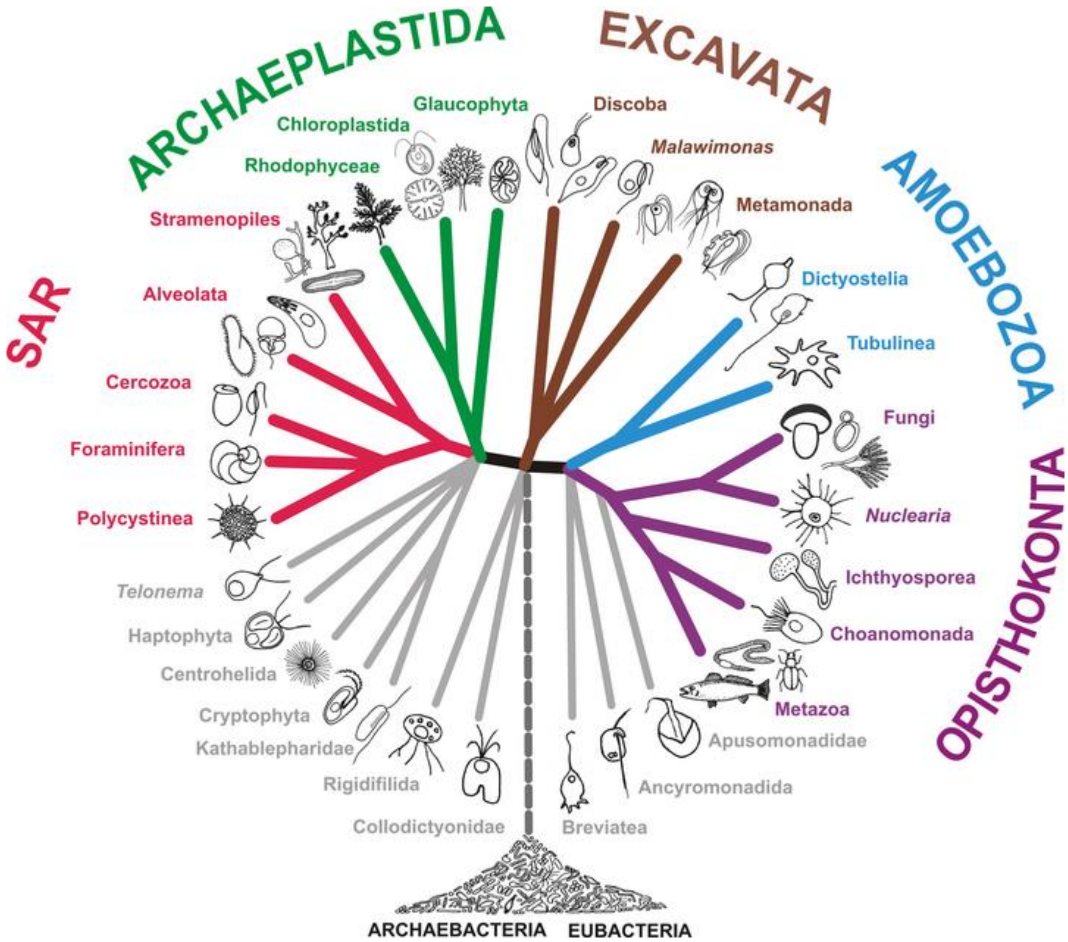

Fig.3. A view of eukaryote phylogeny reflecting the modern classification (Adl.et al., 2019) presented herein

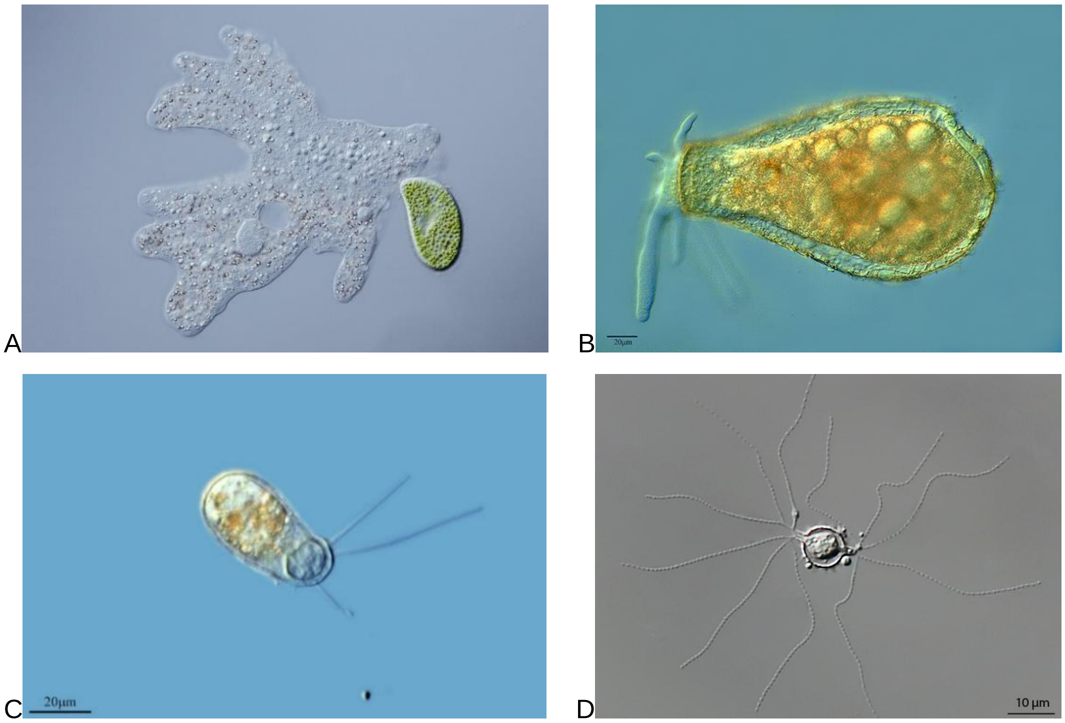

Fig.4. Naked amoeba (A), tecamibe with lobopods (B), with phyllopods (C) and granulopods (D) (http://microworld.nd/2020)

The taxonomy of naked amoebas (Euamoebina) is based on the shape and cytoplasmic and nuclear composition, on the manner of locomotion and feeding of the amoeba. More recently, the structure of some parts of the DNA of the amoeba has been also taken into account (Gomaa et a., 2012, Kosakian et.a., 2016 a,b, Lahr, et.s., 2019).

The taxonomy of the amoebas enclosed in a hard shell (Testacea) was based until the year 2000 almost always on the analysis of the shape and structure of the protecting shell (the sheath) (Figure 5). For almost 3 decades now, the geneticians have been tackling the study of some of the components of their cell DNA, which has profoundly altered the systematic character and taxonomy of these amoebas.

If we think that in the past the taxonomy of primitive protoctists was based only on morphological characters, and the shape of the pseudopods and other physiological, cytological and biochemical characters were analyzed randomly, now, an ever increasing role is played by genetics which can explain the phylogenetic evolution ot testaceans. (Fig.6). Besides this, at present, a very important role is played by ecology, which enables us to understand their huge adaptative variability, their eurioicyty, their physiology and even the ethology of these primitive eukaryotes. An important part in the changes occurring now in the taxonomy of Testaceans is the result of the conquests from the domain of the cultivation techniques and observation under more performing microscopes (Fig.7), as well as by the information coming from various domains, such as paleontology, biogeography, etc.

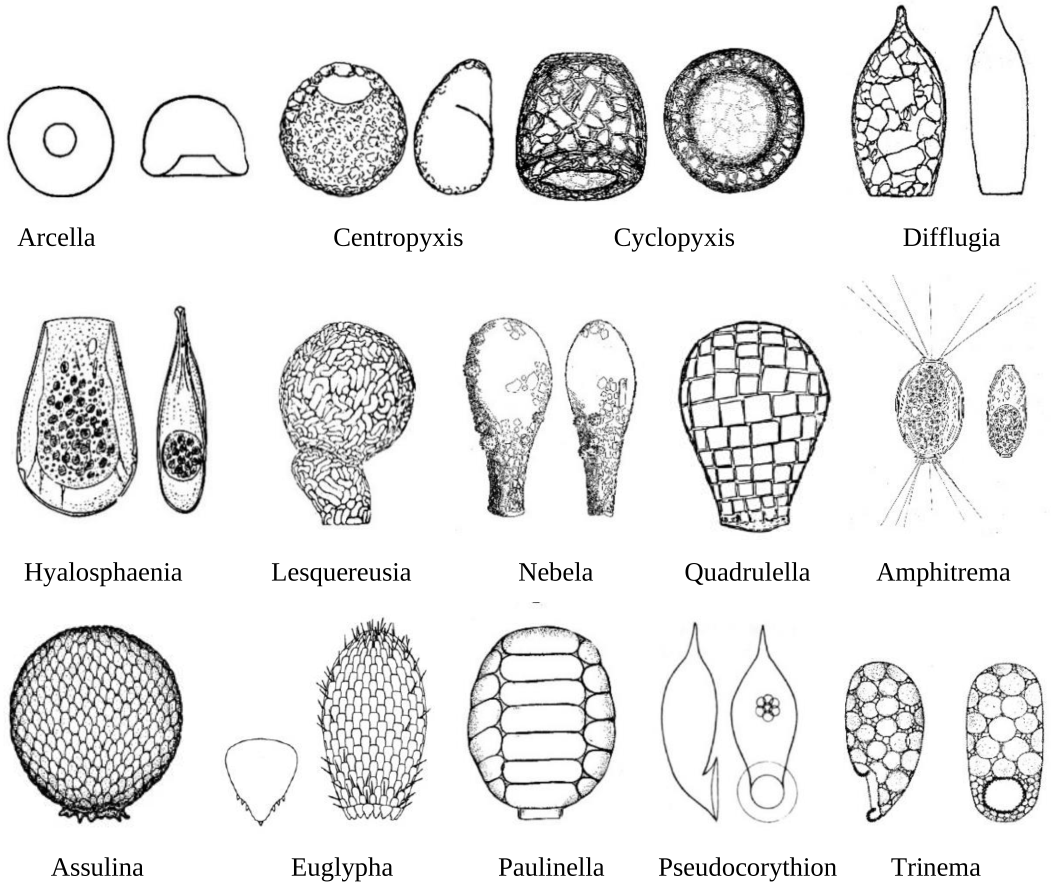

Fig.5. Images made by testaceology specialists before 1980

Besides the above mentioned, we must emphasize one more important point: for the daily taxonomic activity, the morphological, cytological, ethological and ecological aspects remain a priority; for the matters related to phylogeny, biogeography and the use of modern microscopy techniques, the genetic aspects are the most important. Thus, throughout the taxonomic research of unicellular eukaryotes (protoctists) more and more domains of natural sciences work together, every one of them on its specific level.

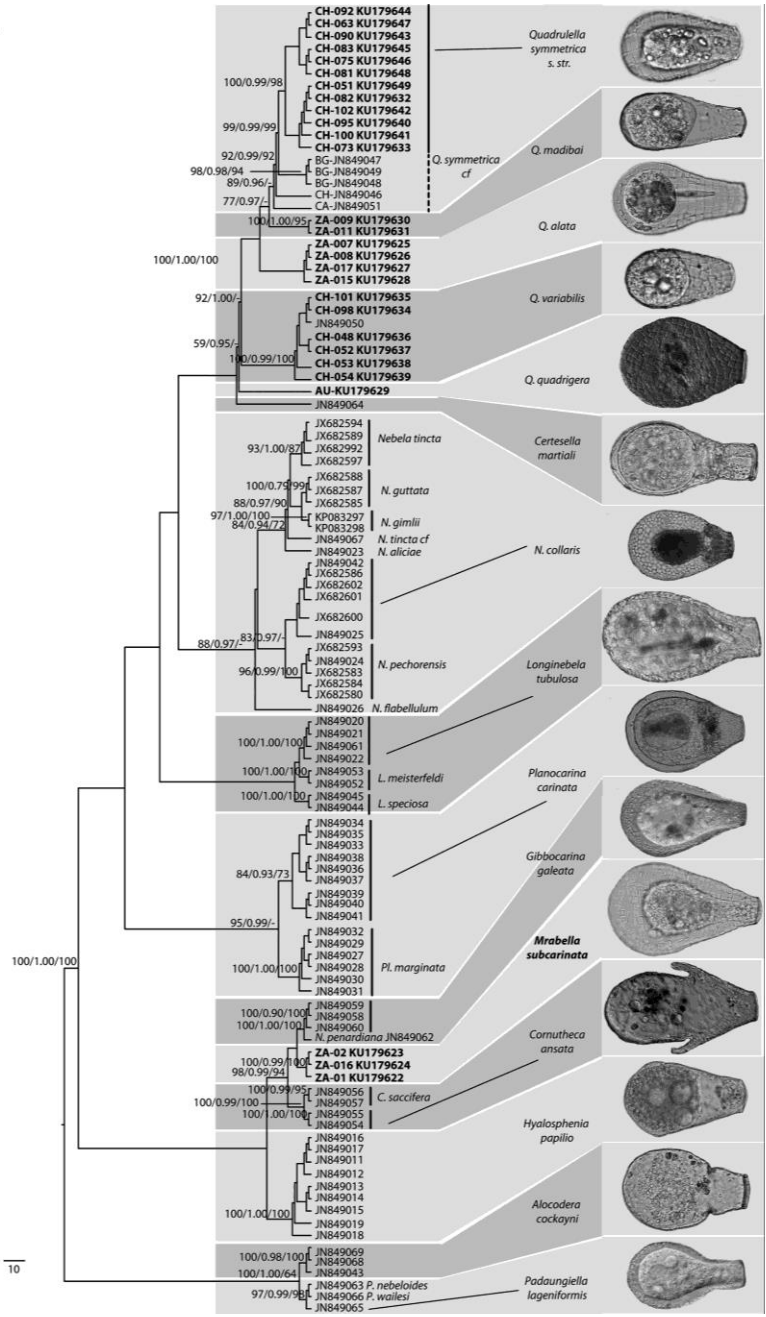

Fig.6. Phylogeny established based on molecular genetics (Kosakian et al., 2016)

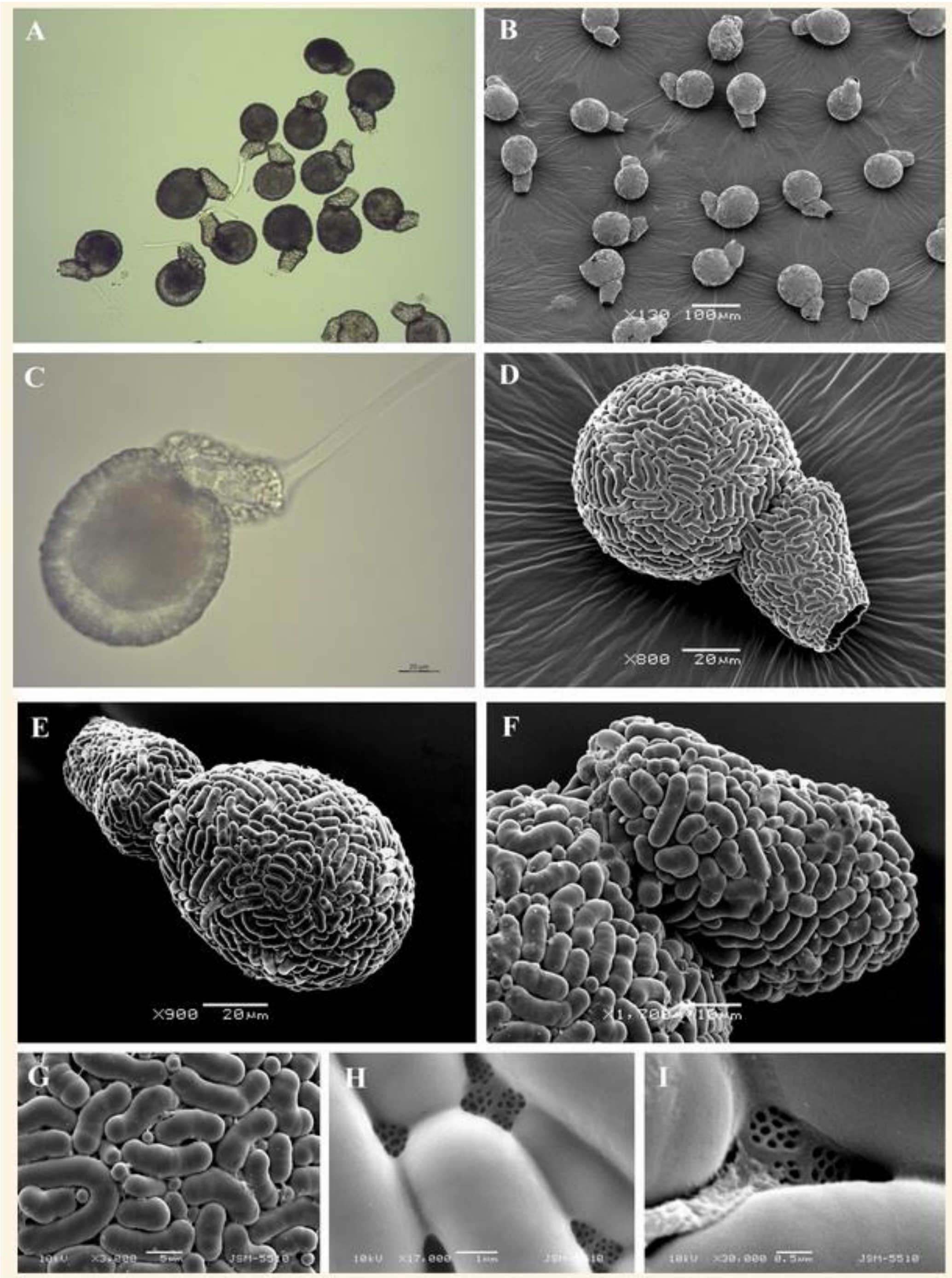

Fig.7. Manners of research on testacea (a species of Lesquereusia) at present (Todorov & Bankov, 2019)

Conclusions

Taxonomy lies at the basis of all the research in the domain of biology.

Although it is the oldest domain of biology, it is constantly evolving, based on the latest knowledge acquired in all the branches of biology, natural sciences and even in certain domains of social sciences. In order to carry out taxonomy it is necessary to be up to date with everything that has recently been obtained in biology, to extract what is important for taxonomy, to make known to everybody all the changes taxonomy is constantly going through and to apply these changes.

To demonstrate this I have taken the case of the simplest eukaryotes, a group of protists, testacean amoebas, with which I have demonstrated the above.

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