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Protozoology from the Perspective of Science Theory: History and Concept of a Biological Discipline

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A b s t r a c t : In order to understand protozoology from the perspective of science theory and biophilosophy, the history and the concept of protozoology have been analysed. To this end, almost 40 protozoologists were taken into consideration and correlated with distinct phases in the evolution of the discipline. Names, lifespans and events were combined into one picture to identify individuals representative of each step in the genesis of protozoology. On the basis of who could have known whom and who could have known what, their different concepts have been interpreted. The evolving terminology, in particular, has generated a species-concept for taxonomy, systematics and classification which is new for almost all protozoologists and therefore of special interest for modern protozoology. Additionally, by the analysis of protozoological congresses a general – qualitative and quantitative – profile of the history and concept of traditional and modern protozoology has been developed and here presented and discussed.

K e y w o r d s : cladistics, Eukaryota, protozoological congresses, species-concept, systematics.

Introduction

Biology is a very young science. Its sub-disciplines are therefore even younger; and, due to the quantity of organisms still to be discovered, the question about the history of biology has not often been asked. Almost 100 biological sub-disciplines are listed in only five different encyclopedias (BROCKHAUS 1998; HERDER 1992; KORFF 1998; MEYERS 1998; MITTELSTRAß 1995). There is not any generally valid structure of biology, even if MAYR gave his 1997-book the title "This is biology". Protozoology plays – if at all – only a subordinate role, traditional observation of nature and biology as science are mixed, relations to the history of civilization and ontological prerequisites of a discipline genesis are being neglected. Obvious contradictions between theory and practice within biology led to this article, viz, protozoology from the perspective of science theory. This article analyzes function and role of a biological sub-discipline in a complete scientific context. History and concept are inseparable in this. On the one hand, a protozoologist can focus his attention on cells or on evolution; on the other hand, an evolutionist or cell biologist can concentrate his studies on protozoa. This example clarifies the following question on the right of existence or on the willingness of various disciplines (or rather of the scientists involved) to demonstrate cooperation. The hypotheses of this work are: (1) protozoology is a scientific discipline that shares ontological prerequisites with all other scientific disciplines; (2) protozoology has continuously passed through all the phases of a discipline genesis; (3) the extensive evolution of terminology within protozoology clarifies the transition of a traditional consideration of "Nature" to a modern natural science; (4) protozoology has a theoretical basis with regard to the objects investigated; and (5) the biological complexion (image, profile) of protozoology compared to other disciplines is complete.

What is science in the context of protozoology and who are the scientists taking part? Which phases are part of a discipline genesis and how are they characterized in the context of protozoology? What are the concepts with which protozoologists work regarding the objects investigated, and do these fit into the context of fundamental biological theories such as cell theory and theory of evolution? In the end the question arises, how far can one make a profile of protozoology or whether history and concept of protozoology can be quantified. The latter leads to the trial of coding of thematic focal points of protozoological congresses with a consecutive analysis that shall, at the same time, grant insights into and outlooks for protozoology.

Science, Biology, Protozoology

Why there cannot be protozoology

"No academic has the right to present as true ideas [ones] that he cannot justify in terms of either reason or experience. Every academic body has the duty to adopt and enforce the most rigorous known standards of scholarship and learning" (BUNGE 1996). For BUNGE the different sciences share a number of ontological prerequisites. The reality exists independently of the human consciousness, and nature is subject to objective legitimacies (HÜGLI & LÜBCKE 1998): protists have not come into existence with the invention of the microscope. According to evolutionary epistemology, we are able to recognize such legitimacies of the real world since our cognitive structures match our world because they themselves have formed in customization to those (VOLLMER 1994). To MAHNER & BUNGE (1996a, b, 1997), science can be characterized by a 10-tuple, that follows in abbreviated form:

s [science] = ‹C,S,D,G,F,B,P,K,A,M›, where at any given moment, (i) C is the research community, (ii) S is the society, (iii) D is the domain or universe of discourse, (iv) G is the general outlook or philosophical background, (v) F is the formal background, (vi) B is the specific background, (vii) P are the problematics, (viii) K is the fund of knowledge, (ix) A is the collection of aims, (x) M are the methodics and (xi) s has strong permanent links with other scientific disciplines.

For the past 100 years or so, the concept "biology" popularized by Lamarck (coined by Burdach in 1800) indicates and characterizes an independent science. Lamarck marked the growing number of fields of science which examine respectively the various life-forms by this concept. Following Lamarck, the idea of the homogeneity of such fields of science received large impetus. Huxley, e.g., represented the view that the conventional subdivision into zoology and botany is intellectually without meaning and that one should study living beings under uniform points of view, a view which is today even more obvious than at his time because today it is clearer that many living beings are neither animal nor plant (ENCARTA 1998). – To the history of an idea of a third kingdom see RAGAN (1997). – According to the HERDER encyclopedia of biology of 1985, biology is a science. Zoology is still one of its branches and protozoology in turn a branch of zoology. How does it have to be understood now in view of the 10-tuple and in view of the encyclopedically entries that CAVALIER-SMITH (1993), who cannot share aversions to poly- and paraphyletic groups still today wrote that there can be neither botany nor zoology for an "ultrastrict cladist"? Science is not a question of faith but a process of reasoning, refutation and improvement in hypotheses to find checkable explanations for the conditions of the world (SUDHAUS & REHFELD 1992). Neither is cladistics a question of faith; it describes a method which is either better or worse than another. If using a method means to do first this, second that and so on, then what is an ultrastrict cladist? Does he allow for all steps of the method while the not quite so strict cladist simply omits one or another point? If the cladist reaches the end of a method which is better (or worse) than another and therefore finds there cannot be such a thing as botany and zoology, one may criticize the method but not the one using it, according to the rules of science. So Cavalier-Smith is right, however he forgets that neither protophytology nor protozoology can exist for cladists nor for every biologist, or in general for every scientist, neither botany nor zoology, as long as there is not any better method. Corresponding systems and the disciplines based on them have merely to be compared with more or less well sorted coin collections as long as there is no autapomorphy for animals or plants.

Why there can be protozoology

"..., if a discipline makes no contact with other disciplines then it is not a science" (MAHNER & BUNGE 1996a). Natural science, which is modern, experimental and as mathematical as possible took its begin approximately at 1600. Natural philosophy question impulses and skilled craftmanship were connected in a way to alter nature in favor of human needs (SEIFERT & RADNITZKY 1994). Religion was a forerunner of science, alchemy the forerunner of chemistry, astrology the forerunner of astronomy, and magic the forerunner of modern technology (MAHNER & BUNGE 1996a, b). All scientific disciplines have, so to speak, their teething troubles which only win in significance if they break out once more in adult age. Science is a process and one cannot reproach scientists that they do not take the state of knowledge of future research into account in their present hypotheses. Scientific disciplines have traditions from which their cognition arises. We need a traditional protozoology or protozoologists to recognize that protozoans do not form any descent community. Nevertheless the objects investigated that a protozoologist has dealt or deals with are real biological systems. Even if corrections are made and one scientist calls himself, e.g., a ciliatologist, biology is and remains decisive. Protozoology is not autonomous like every other science, and GRELL (1956) was completely right when he wrote more than 40 years ago, that protozoology is not a specific science, but only the combination of knowledge we have of a definite animal group, the protozoa, the unicellular organisms. It is therefore nothing more than a part of special zoology. Being part of the cognition that there are not any common characteristics for all protozoa, this changes nothing at the level of zoology. If animals have no characteristics common to all, this changes nothing at the level of biology. A biologist examines neither animals nor protozoa but organisms. If CORLISS (1986a) regards protozoology or protistology as a respectable interdisciplinary area of modern biology, then one only can underline this. It is the organisms examined in traditional protozoology – and still being examined – which are gathering more and more meaning. Also KUZNICKI & HONIGBERG (1984) and CAVALIER-SMITH (1993) stress the strong international cooperation of protozoologists. In protozoology they see a large discipline with a promising future. For cell biology, developmental biology, biochemistry or evolutionary biology, single-celled organisms are excellent model organisms, and one will need biologists who are familiar with these organisms. SCHALLER (1992) writes in his thoughts on the disintegration of biology, that definitely the youngest biologist off-spring requires integral teaching events, early meetings with whole organisms – in short, a whole biology. Nobody wants to be only a biologist. The questionable habit of biologists emphasizing their prefix always and everywhere (i.e., one is a mycologist, lepidopterologist, protozoologist, cell biologist, evolutionary biologist, etc.) asks for an integration, that is, a common language within biology. Depending on their job, protozoologists are always cell or evolutionary biologists, just like an evolutionary biologist should always be a protozoologist. How much protozoology can contribute to a promotion of an integrated and interdisciplinary biology is a component of the following and the final chapter concerning the history of and the progress in protozoology as a branch of biology.

To the history of protozoology as a branch of biology

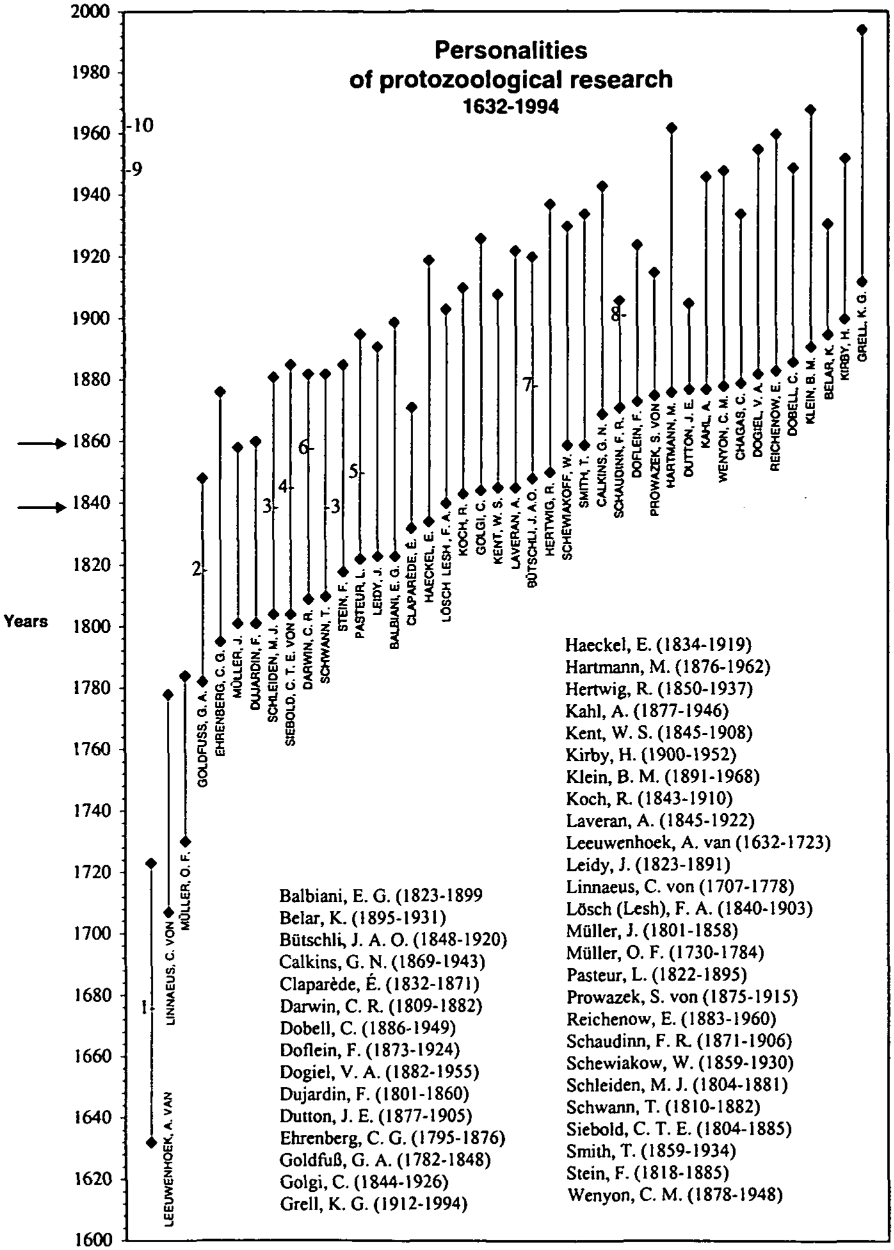
One combines historical and systematic questions to understand the beginning and nature of scientific disciplines and to make the aspects of origins of various disciplines comparable. Disciplines are self-reproducing, self-evolving and object-oriented systems of scientific work, and they are also social institutions whose genesis can be subdivided in single steps (stages) as a defined historical process (Table 1).

Tab. 1: Course of stages in the genesis of the protozoological discipline.

Stage of the discipline genesis	Time period
Past history: discovery, description, naming	1565–837
Early history and initial phase: cell-theory, descendent-hypothesis	1838–1877
Constitution phase: program, institutionalization	1878–1901
Phase of establishing: periodicals, societies, congresses, research departments, institutes, textbooks	1902–1961
Phase of consolidation: integration, technical terminology, specific methods, secondary disciplines	from 1962

The table assigns the data of the history of protozoology to the known phases of the genesis of a scientific discipline. Besides this, events are mentioned which are specific for the respective phases.

Fig. 1: Persons, decisive for protozoological research (1632-1998). The illustration shows persons important for protozoological research in alphabetical order. According to additionally registered life data, it is possible to correlate the life spans of scientists to each other. In the lower box major scientific events are mentioned which can be assigned to corresponding scientists (marked in the respective life span by a number). The arrows outside the time axis mark the establishment of the cell theory (1838/39) and of the theory of evolution (1859).



1: Microscopic analysis of single-celled living beings; 2: Concept "Protozoa" is coined; 3: Cell-theory is established; 4: "Protozoa" are single-celled organisms; 5: Abiogenesis is disproved; 6: "Origin of species" appeared; 7: First protozoological institute is founded (Heidelberg, Germany); 8: First protozoological journal is founded (Archiv für Protistenkunde, Jena, Germany); 9: Society of Protozoologists is founded (Chicago, USA); 10: First International Congress of Protozoology is held (Prague, Czechoslovakia).

In the context of a more precise discipline concept, social mechanisms play a role just as the traditional opinion of science, the emergence of a new quality of cognition, institutionalization, conditions for the temporal-spatial existence, a concrete structure or measure determination and the underlying type of the discipline formation process (GUNTAU & LAITKO 1987). A discipline is more than a field of knowledge, i.e., about a system of concepts, facts, laws and theories; it is always bound to the intellectual and practical work of scientists, too. By this, a science concept arises for the discipline understanding, and it puts cognitive work, social powers and social relations into the center of attention. Beyond this, one needs a cognitive minimum which absolutely must be given as conditio sine qua non of a discipline, i.e., a common attitude of its representatives (GUNTAU & LAITKO 1987). Decisive is the standardization of the term used here, i.e., the use of terms according to uniform points of view. On the other hand, one has to make sure that without fluent concepts no development of knowledge can be given. According to GUNTAU & LAITKO (1987), the beginning of object-orientated communications networks, the strengthening of the corresponding cognitive attitude of its participants, the emergence of fragments of an own reproduction mechanism and, of course, the emergence of institutions for the specification and safeguarding of such performances are serving as reliable indicators for discipline-formation processes. The problem arises of referring to the discipline genesis at first as a past history, secondly as the real discipline genesis and, thirdly and last, as the development of the discipline on its own basis. The latter has to be subdivided into initiation, constitution and establishment. "Protozoology in a nutshell" (Fig. 1) may very well be the adequate paraphrase for the trial which is made in the following. Names, life spans, events and phases of the discipline genesis are visualised. The picture realized through this serves both science- and historico-cultural coherences on the one hand and a way in the discipline as a criterion of assessment on the other hand.

The history of zoology itself reads as collection of major names in the history of science: Plinius, Gesner, Galen, Harvey, Magnus, da Vinci, Vesalius, Linné, Ray, Buffon, Cuvier, Hooke, Schwann, Schleiden, Mendel, Darwin, Baer, Watson and Crick are individuals representative of a long and still continuing discipline genesis to mention only some since Aristotle (ENCARTA 1998). Such a list can be made also for the most essential personalities of protozoological research, and it clarifies how many single researchers were involved in a discipline genesis.

The single steps of a stage-defined discipline genesis as a part of the ontological prerequisites of all scientific disciplines can be defined by specific events (GUNTAU & LAITKO 1987); the integrated technical terminology, specific methods and secondary disciplines also are part of this besides periodicals, societies, conventions, research departments, chairs, institutes and textbooks. In the course of the events mentioned protozoology has continuously passed through all phases of a discipline genesis. Part of this is the past history, the early history, the initial phase, the constitution phase, the phase of establishing, the institutionalization and the phase of consolidation. Almost 300 essential personalities of protozoological research stand out in the 300-year-old history of protozoology (WOLF 1999). The life data clarify the continuity for a protozoological-oriented work on this within biology. A confrontation of persons, topics and phase history makes it possible to filter individuals representative of the sections defined above out of this continuum (Table 1 and Fig. 1): Leeuwenhoek for the past history, Ehrenberg for the early history and initial phase, Bütschli for the constitution phase and Hartmann for the phases of establishment and consolidation (for Hartmann see also HESSE 1941). The overall picture ("protozoology in a nutshell") clarifies beyond this who could have known whose theories at a given time and which other personalities have decisively contributed to the formation of the discipline. From such a picture, the strategies underlying protozoology can be deduced and understood. Certain aspects must be taken into account separately, e.g., the evolution of terminology within protozoology can be assigned only problematically to such an overall picture.

[Additionally, at the end of this article, a timetable gives details about the history of protozoology (Table 5).]

Evolution of terminology in protozoology

Description and naming of the organisms and their possible incorporation into an order already existing is the first step in the process of organizing (SCHMITT 1994). This principle (description and naming) is essentially based on the application of a classic logical definition, i.e., a definition refers to the next general term and the specific difference was used in biology for the first time by Linné (SCHMITT 1994). Also the concepts found in the context of protozoology as involving (only) single-celled organisms try to define, describe, and name them. With the descriptions becoming better and better, the concepts change just as the allocation into the order already existing. Things to be described are renamed or newly defined. Not only the things but also the concepts assigned to them therefore have a history, i.e., they pass through a genesis which is characteristic for them. The evolution of terminology within protozoology is in full progress and superfluously hardly to be overlooked; e.g., consider the questionable reintroduction of the concept "protoctista" (MARGULIS & SCHWARTZ 1998; MARGULIS et al. 1990).

In the following considerations, the concepts between Animalcula and Protozoa are put in relation to each other, that is, to start a theoretical consideration and to understand it in the complete historical context beyond this. The questions are: Are there generic terms and specific differences for the used concepts? Are there characteristics or qualities genuine for the named things? What exactly was described and named? Can we define things consistently?

Within 300 years evolution of terminology within protozoology, more than 30 terms have become established to describe, characterize and define single-celled organisms (Fig. 2; for details see WOLF 1999). The history of protozoological nomenclature has always paralleled the history of engineering and the natural sciences. The invention of the microscope allowed laypersons like scientists an insight into the world of the microcosm. Between "Animalcula" and "Protozoa", between nature consideration and science, from Leeuwenhoek to Haeckel, a babylonian language confusion arose whose conceptualities tried to answer the basic questions of biology. The concepts "Animalcula", "Monaden" and "Infusoria" ("infusion little animal") determined the time between 1600 and 1700. The transitions mark the begin of modern natural science, which between 1800 and 1900 generated a variety of further concepts. The time of the reintroduction or renaming of con-

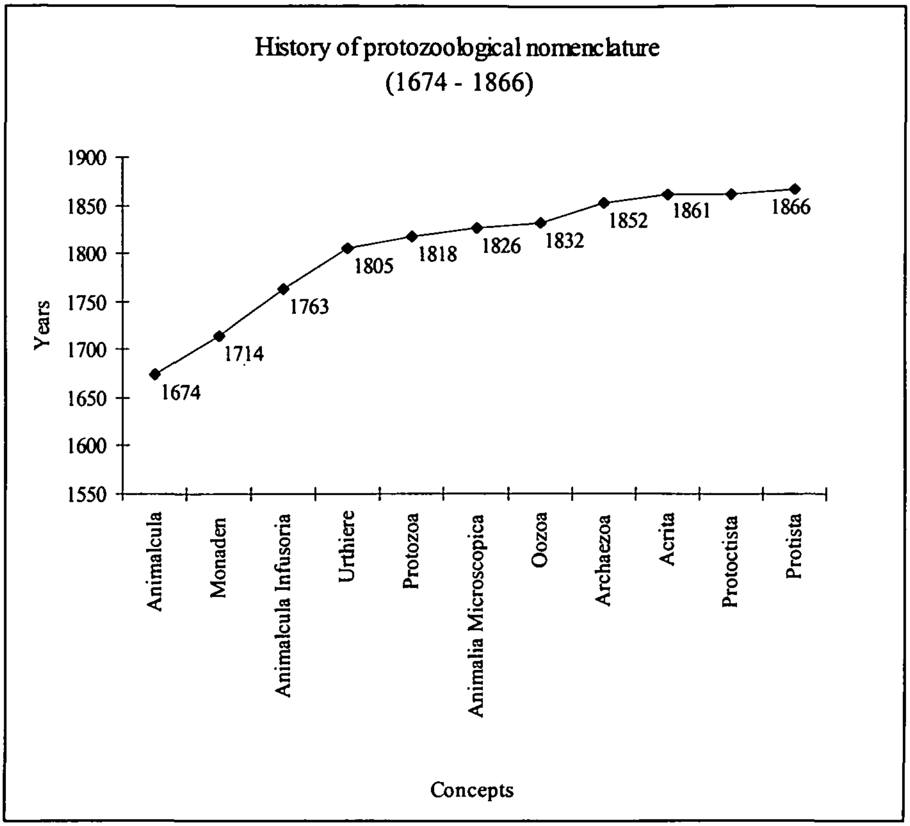


Fig. 2: History of protozoological nomenclature (1674-1866). The illustration represents the starting dates of the most essential concepts for the single-celled organisms between 1674 and 1866. The steeper the curve of the evolution of terminology, the longer it lasted till a new term and by this a new concept was introduced. The concepts Monaden, Infusoria, Protozoa, Archezoa, Protoctista and Protista -- although not always in their original sense – are still in use.

cepts already existing starts with the 20th century. "Protozoa", "protoctista" and "protista" are still determining the zoological, "algae" and "protophyta" the botanical discussions. With regard to a discipline genesis, the demarcation against the traditional fields zoology and botany have played a large role, though the cell theory (1838/39) and the theory of evolution (1859) suggested very early the unnatural junction of "animals", "plants" or "protista" (RAGAN 1997). Conceptualities like "single-celled Eukaryota" determine the present horizon of knowledge, although a translation adequate for textbooks is often carried out only in isolation due to a missing theoretical basis.

Species, evolution and taxonomy in protozoology, or why the natural kind *Amoeba proteus* does not evolve

Bio- and agamospecies

According to the biospecies concept agreement rules, that species are the real supraorganismic entities of evolution (notwithstanding agamously propagating haploid organisms), species are understood as closed propagation communities or as populations reproductively isolated from each other.

Agamous organisms nevertheless do evolve and by that they contradict the biospecies concept in a certain sense, for para- or agamospecies are not biological species: "Only that which have the propensity for speciation, says Ghiselin, deserves to be called species, and this does not include asexual entities. ... Although by descent they have continuity in time within the clone, they lack the internal cohesion characterizing a gene pool. Therefore they are classes and not individualspopulations" (MAYR 1988). Due to the obvious contradiction with practical and everyday work of a protozoologist, one may wonder how the eukaryotes have arisen in view of a so curious denial of the ability for speciation of mono- or asexual organisms; but it cannot astonish one that a species concept was and is a topic in protozoological research. The discussion between Sonneborn and representatives of the biospecies concept is in an excellent way, represented by SCHLOEGEL (1999) "'What I meant to protest against,' Sonneborn explained to another critic, 'was what seemed to me an authoritarian point of view dominated by Mayr, Dobzhansky, Simpson and Darlington, a point of view which seems to me to argue in circles and to mistake definitions for facts of nature'" (SCHLOEGEL 1999). Any theoretical generalization within taxonomy must, for the common textbook opinion, start with a species concept based on the assumption that species are the most essential generalization units to be distinguished clearly from others within biology. POLJANSKI, e.g., tried again and again to verify the reality of asexual species. In his numerous publications (1957, 1958, 1959, 1976, 1977, 1982a,b, 1986 and 1992), he not only criticized the biospecies concept by the fact that he diagnosed it as an insufficient definition, but simultaneously he noticed the reality of asexual species and their stable "genofund". The reality of the species-category is here justified with an intraspecific distinctive differentiation of geographical and ecological separate groupings (biotypes, forms, races and subspecies). For Poljanski species are a natural phenomenon, a universal form of life whose essence can be determined with various criteria. Although by the criticism of the biospecies concept, the aspects of a morphospecies, ecospecies or evolutionary line become more concrete and the results also find entrance in textbooks of general biology – for example SUDHAUS & REHFELD (1992) write that there would be good reasons not only to treat agamospecies "like species" but "as species" – the problem has to be sought in another place in the end. There is no specific protozoological species problem. Just as little as the kind of *Amoeba proteus* evolves, neither does any other species evolve. Following a hypothetical realism, it is not about cavilling but about a uniform, realistic and practicable definition of the species-category. At this the biospecies strategy (species as individuals), however, raises a problem which does not appear at all if the concept is species as classes (MAHNER 1998).

Species as classes

If Poljanski also has criticized the weaknesses of the biospecies strategy, he still worked with supraorganismic entities or species as individuals. This species concept prevailing in protozoology (comparable to general biology) is based on the following hypothesis: (1) "All eukaryotic organisms are descendants of one single common ancestral species [and] this species is lost by splitting up into two succeeding daughter species" (HÜLSMANN & HAUSMANN 1994). But species-as-class concepts also can be found in the protozoological literature: (2) "The taxa, whether real (individuals) or conceptual (species to kingdoms), label territories of a presumed phylogeny" (PATTERSON 1994). The logic distinguishes between "real individuals " mentioned in (2) (= things) as concrete systems of nature by the composition from parts (components), and the "conceptual species" (classes) as constructs of man in the composition from members (elements). Things are material objects which exist in the real world whereas conceptual classes are invented without reality to bring certain things together (AX 1995).

The facts represented in (1) would have the following consequences: If classes are invented and do not arise, then the arisen species-as-individuals must be new things. Evolutionary novelties are characteristics of the species-as-individuals and such species-as-individuals would be classified as elements of quantities (MAHNER 1998; MAHNER & BUNGE 1997). If we now would like to classify Antony van Leeuwenhoek, for example, and his reality as individual (material object or thing) is undoubted, a problem arises. If the basic set is the quantity of all sorts (species), i.e., species are the elements and all subordinated taxa are subsets, Antony van Leeuwenhoek then stands merely as a part whole in connection with the elements (species) of the basic set. However, his excellent eyes, his heart, his lungs are also a part whole and we certainly do not want to classify these. Only if he becomes the element of a basic set of all organisms, can he be classified. However, this presupposes a subordinated subset and this one cannot simultaneously be an element. The organism is real, the species is a logically preconnected class which makes general statements about its elements and the qualities possible in the first place (MAHNER 1998; MAHNER & BUNGE 1997). That gives rise to the following species definition: „A species is a biospecies if, and only if (1) it is a natural kind (rather than an arbitrary collection); (2) all of its members are organisms (present, past, or future); (3) it "descends" from some other natural kind (biotic or prebiotic)" (MAHNER 1993; MAHNER & BUNGE 1997). That also means, that species can not be the unit of selection (HULL 1988; MAHNER & BUNGE 1997; for other species-concepts see GRANT 1994; PETERS 1998).

Organisms and populations as material units of evolution and the question of selection

Of course, Antony van Leeuwenhoek as an element of the basic set of all organisms is a carrier of evolutionary novelties, he is a unit of classification and an essential unit of evolutionary change and, nevertheless, he alone is not able to aquire as many new qualities as it is required in biological evolution. In a population, evolutive novelties of different organisms of different generations sum up (MAHNER 1998). Of course, such a population can represent a material system with definite relationships. Of course, a propagation community is also a material system. With regard to a classification we must not make the mistake to equate such a propagation community (which is merely an indicator for the equality of organisms) with a species. If one analyzes the logical structure of a classification it can be seen that propagation communities or populations as real systems do not play any role in systematics. They will not become a component of the classification and they are not represented by species-taxa (BACHMANN 1998; MAHNER 1998). According to MAHNER (1994), definite organisms can be part of propagation communities only because they have certain qualities which allow a mating. These qualities precede a population formation and make a way for species as natural kinds: "Das heißt, zwei Organismen gehören deshalb zur gleichen Art (im Sinne einer natürlichen Äquivalenzklasse), weil sie diese Eigenschaften besitzen, und nicht, weil sie sich miteinander fortpflanzen oder Teile der selben Fortpflanzungsgemeinschaft sind. Teil der selben Fortpflanzungsgemeinschaft zu sein, ist lediglich ein Indikator für die Zugehörigkeit zur selben Art. ... Zwei Organismen gehören nicht deshalb zu einer Art, weil sie sich (erfolgreich) verpaaren, sondern können sich nur deshalb miteinander verpaaren, weil sie zu einer Art gehören" (MAHNER 1994).

Of course, we need a material system (population) for evolutionary biological reasons. On the one hand, composition, environment and structure show definite relationships, on the other hand such a population is logically post-connected to species-as-classes (MAHNER 1994). Organisms living in a definite population at the same time form a material system. No longer living organisms – e.g., Antony van Leeuwenhoek – cannot be part of such a system, though they can be part of a class *Homo sapiens*, to follow the example. The same is valid for allopatric populations. They certainly can belong to the same species (class), but they do not form any material system due to a missing definite relationship (AX 1995). Bio-populations may evolve, but what we classify is and remains the organism. To evolve means the emergence of qualitative novelty, i.e., the origin of the variants promoted or eliminated by selection. Selection explains merely the distribution and frequencies of variants within populations as well as the conspicuous fit of the organisms. It is the individuum-environment-interaction which results in differential propagation (see also HULL 1980, 1988). The emergence of a qualitative novelty (evolution) is an ontogenetic (organismic) process and an object of research of developmental biology (MAHNER 1994, 1998).

In the context of protozoology, it may be said that all "protists" are organisms but not all "protists" – as "single cells" – are elementary biological systems. Endosymbiont-hypothesis, general endocytobiology, the question for the origin of the first eukaryote or titles as "ciliates: cells as organisms" (HAUSMANN & BRADBURY 1996), "the protozoon and the cell" (CORLISS 1989) and, somewhat questionable, "... the organism as cell " (MARGULIS et al. 1984) cause a distinction in "elementary" and "composite biological system". Also in this context the organism, whether as "elementary" or "composite biological system", as the largest unit of life, evolves. It is the organism which is classified or systematized.

Cladistics

Empires (regna or domains) exist in the heads of people, but not in living nature (AX 1995). The method for the reconstruction of phylogenetic trees developed by HENNIG (1950) essentially consists of five steps: (1) Collecting characteristics that are regarded as homologous, (2) judging alternative characteristics about an outgroup comparison (reading direction), (3) checking the taxa for monophyly by well-founded aut- and synapomorphies, (4) forming a hypothesis concerning sister-taxa relations with a well-founded phylogenetic tree, and (5) checking the phylogenetic tree with further characteristics. There is no doubt among evolutionary biologists about the fact that a phylogenetic tree as basis of any phylogenetic statement can be made only according to Hennig's method (SUDHAUS & REHFELD 1992). Hennig's phylogenetic systematics (cladistics) – whose superiority over others (evolutionary and phenetic systematics) also within protozoology has been shown repeatedly (CORLISS 1998a; HAUSMANN & HÜLSMANN 1996a, b, 1999; HÜLSMANN & HAUSMANN 1994; LEIPE 1996; LEIPE & HAUSMANN 1993; LIPSCOMB 1984; PATTERSON 1994; PHILIPPE & ADOUTTE 1996; SCHLEGEL 1994, 1998; SOGIN 1991; SOGIN & GUNDERSON 1987; SOGIN & SILBERMAN 1998; SOGIN et al. 1989) – tries to systematize the organisms or supraspecific descent communities classified according to their natural equivalence. The concept of such a system is oriented strictly – with regard to the taxa – at the conditions of nature. So one can try to work out the most natural equivalent classes from the composition of all living beings and with the help of Hennig's method. Such equivalent classes (in the case of species 'binominal', in the case of descent communities according to a well-founded autapomorphy nominally) are named and taken into a system (AX 1995; PATTERSON 1994). A taxonomy examines the logical and methodological principles of the classification, i.e., its operations aligned with an aim (classification and systematization) (AX 1995; MAHNER & BUNGE 1997).

Development of a system

A consistently phylogenetic system can be developed only by dropping all taxonomic categories. Categories are merely etiquettes for the units of the system to indicate the rank in a hierarchy of classifications. They are useless for systematics that is evolution-oriented.

Of course, this also applies to the species-category which is objective as long the species category refers just to the taxon; however, only sister species share the same ranking. Beyond this, there is neither any serviceable definition for a higher category nor a liability in its assignment. If based on the dichotomy-principle according to the parsimony explanation a logical problem arises in addition, i.e., at supraspecific units within a monophylum only two equally ranked taxa can stand in the system (AX 1995). As pointed out by Ax, the uselessness of Linné's categories can be easily demonstrated with a textbook comparison: in Kaestner's "Lehrbuch der Speziellen Zoologie", GRUNER (1993) subdivides the "empire" of the animals into 25 phyla. The sub-empire "Protozoa" is represented by one phylum Protozoa. In Wurmbach/Siewing's "Lehrbuch der Zoologie" (1985), the sub-empire Protozoa, on the other hand, is subdivided into seven, the sub-kingdom Metazoa into five phyla.

If the large structure of living beings is also problematic, then the solution for certain is not in the number of useless categories which still find use in today's university lectures with the badly chosen titles "animal" or "plant kingdom".

It is rather decisive that even heterotrophy and autotrophy are unsuitable qualities for the grounds of phylogenetic units – no matter which categorical rank one gives them. Neither animals nor plants as descent communities with stem species befitting only them exist in nature, i.e., as artificial groupings they do not have any place in the system of real organisms. Since there is no empire based on autapomorphies of animals, logically there is not any equivalent subdivision of "Protozoa" and Metazoa, either (AX 1995). Heterotrophic single-celled organisms are rejected as an unit of the phylogenetic system. Being single-celled is the plesiomorphy of the alternative being a multi-celled metazoon. "Protozoa" are a paraphyletic group of primarily single-celled heterotrophic Eukaryota (AX 1995).

To this, also categorical classifications such as "user-friendly", or being based on "conventions", or putatively "didactic" or being based on "five or more empires", – again and again suggested, for example, by CAVALIER-SMITH (1993, 1998, 1999), CORLISS (1994, 1998a, b), LEE et al. (1985), LEVINE et al. (1980), MARGULIS (1996), or MARGULIS & SCHWARTZ (1998) – change nothing.

Single-celled eukaryotes: the (present textbook) system

The system of the Eukaryota (HAUSMANN & HÜLSMANN 1996a, b, 1999; HÜLSMANN & HAUSMANN 1994; LEIPE & HAUSMANN 1993; PATTERSON 1994) represented here and proposed parallelly with those of CAVALIER-SMITH (1993) and CORLISS (1994, 1998a,b) is worldwide the only one which was set up consistently following phylogenetic criteria. In "Protozoology" and "Einzellige Eukaryota" (HAUSMANN & HÜLSMANN 1996a,b), it has found a textbook-adequate translation.

The logic of phylogenetic reconstruction, electron microscopy, traditional protistology, endosymbiont hypothesis and the catalog enlarged by molecular data of morphological characteristics form the corner pillars of this systematics whose development has been taking place during the last 50 years (see LEIPE & HAUSMANN 1993; PATTERSON 1994). The system justifies the relative conditions regarding single-celled organisms essentially by the following autapomorphies (HAUSMANN & HÜLSMANN 1996b):

(1) Nucleus, mitosis, meiosis, microtubules, microfilaments, phagocytosis and amoeboid movement for all Eukaryota. (2) Flagella (9 x 2 + 2-pattern), microtubules in connection with the nucleus proceeding from singular kinetosomes, 80S-ribosomes and endosymbiogenesis with bacteria for the avoidance of oxygen-poisoning for all Mastigota. (3) Primarily two flagella for all Dimastigota. (4) Primarily four flagella for all Tetramastigota. (5) Transformation of endosymbiontic bacteria into mitochondria, anagenesis of typical dictyosomes and mastigonemes for all Metakaryota.

Without referring to the sub-taxa of the Tetramastigota and Metakaryota more closely, one can say that a system has arisen which supplies hypotheses which, in the future above all will make it possible to check the phylogenetic tree by further characteristics, i.e., the ground structure of the system will independently have the groups incertae sedis (e.g., *Amoeba proteus*) stock unlike the systems based on conventions.

Amitochondriate eukaryotes, metakaryotes and hydrogen hypothesis

Study of nuclear genes of eubacterial origin in amitochondriate eukaryotes has already delivered evidence for a cryptic – perhaps ephemeral – endosymbiosis of putatively pre-symbiontic organisms (e.g., HENZE et al. 1995). The research of Müller on hydrogenosomes and the energy-metabolism of ancestral eukaryota (MÜLLER 1980, 1988, 1992, 1993, 1996, 1998), or the comparison of hydrogenosomal with mitochondrial proteins, led to suspecting a common eubacterial origin of hydrogenosomes and mitochondria (see also BUI, BRADLEY & JOHNSEN 1996). The protein transport also shows similarities which in addition support a common origin of hydrogenosomes and mitochondria (BRADLEY et al. 1997). Latest studies show that symbionts that were able to become a mitochondrion or a hydrogenosome were already available in the first eukaryote, i.e., that all eukaryotes are united in the origin of their mitochondrial endosymbiontic progenitor. Mitochondrial genes (particularly chaperones, like *cpn* 60 and genes of the *HSP*-family) were prove to be present in almost all taxa of amitochondrial eukaryotes [Microspora, Tetramastigota (Retortamonada)] (e.g., DOOLITTLE 1998; GERMOT et al. 1996, 1997; HIRT et al. 1997; MARTIN & MÜLLER 1998; PEYRETAILLADE et al. 1998; ROGER et al. 1996; ROGER et al. 1998; SOGIN 1997a, b; VELLAI et al. 1998; VOGEL 1997, 1998). With that, the mitochondria or their precusor(s) have been an autapomorphy for the Eukaryota, while representing a plesiomorphic state for the taxon Metakaryota. How much other characteristics justifying the phylogenetic tree are affected by this, only further examination will show (see also EMBLEY & MARTIN 1998). For the Archamoeba corresponding data are missing. Other results still speak for a basal position at least for the Tetramastigota (LANG et al. 1997; MORIYA, OHKUMA & KUDO 1998; SANCHEZ et al. 1996), whereas the Microspora are regarded as related to the Fungi (CAVALIER-SMITH 1998; MÜLLER 1997; VOGEL 1997). The hydrogen hypothesis of MARTIN & MÜLLER (1998) supplies an explanation for the origin of the first eukaryote and, simultaneously, for mitochondrial genes within amitochondriate eukaryotes. Eukaryota resulted from a symbiontic relation of two bacteria [archaeon (host) and eubacterium (symbiont)]. If the composite cell remains in an anerobic habitat the symbiont becomes a hydrogenosome or is lost; otherwise it develops into a mitochondrion in an oxygen-containing environment (MARTIN & MÜLLER 1998).

The evolution of terminology within protozoology and biological taxonomy are in direct coherence. The material units of evolution (the emergence of qualitatively new characteristics) and selection (the individuum-environment-interaction) are organisms and populations. Biospecies, on the contrary, are defined as natural equivalent classes. A system of the Eukaryota based on these strategies – also in the context of textbook adequate translations – needs neither protozoa nor categorical ranks. Developed with the help of the phylogenetic method (cladistics), it gives evolutionists the possibility of giving up "thinking in empires" and to reject poly- as well as paraphyletic groups. The limits of such a system – particularly with a view to dichotomy – are pointed out by the latest insights about ancestral and amitochondriate Eukaryota and the different statements of the endosymbiont and hydrogen hypothesis sensu MARTIN & MÜLLER (1998).

Progress in protozoology: a profile of the discipline – congresses between 1961 and 1997

"The aims of the Society shall be the association of workers for the presentation and discussion of new or important facts and problems in protozoology and for the adoption of such measures as will tend to advance protozoological science" (Society of Protozoologists, Constitution, Article I., Section 2. 1954). The "modern age" of the history of protozoology starts 1947 after the Second World War, first in the USA with – at that time – still the "American Society of Protozoologists" (CORLISS 1998c).

In 1951, renamed as the "Society of Protozoologists", it marked the first step in direction of an international organization and to a cooperation among protozoologists everywhere.

Its constitution allowed its own publication organ, the "Journal of Protozoology", which was launched in 1954. Since then, the intensified internationality of both the society and the journal made possible international congresses taking place every four years, since 1961. In the context of the conventions, an "International Commission on Protozoology" was established at the second congress held in 1965 in London, to coordinate supporting and adhering societies arising in other countries and to prepare further conventions, too. The number of submitted abstracts to respective congresses and the number of authors involved are represented in Table 4 (see also KUZNICKI & HONIGBERG 1984). Beyond this, the number of symposia and the number of plenary lectures held are also represented (Table 2 – 4). To derive or make a profile of the discipline the latter have been coded and visualised with regard to their respective topic focal points. Since the main focal points shifted within biology in the course of time, and correspondingly its branches were modified and newly organized, the limits of biology cannot be marked obviously. Notwithstanding a traditional subdivision of biology into botany, zoology, protozoology (protistology), human biology and microbiology the most extensive structure level of a modern and general biology (which in a similar manner deals with molecules, cells, individuals and populations) is the subdivision carried out here according to the elementary process (evolution) and the elementary unit (cell). Such a subdivision makes it possible to filter main topic focal points within the traditional biological disciplines, although all topics of biological research cannot be covered by these two fields. An often carried out theoretical sub-structure into function and role biology (SUDHAUS & REHFELD 1992) plays a rather subordinate role here. It is represented in a similar manner respectively in the two fields cell and evolution research.

Tab. 2: Plenary lectures of I-X International Congress of Protozoology, coded.

Congress	Plenary lectures
I Prague	Modern trends in Soviet protozoology (H) Protozoa as models in biological research (T) Protozoology today (H)
II London	The comparative morphology of the Peritrichida ciliates (Ev) Vampire bats as vectors and hosts of equine and bovine trypanosomes (Ec) Morphological regularities of the progressive evolution in protozoa (Ev) Hydrodynamic principles in the locomotion of microorganisms (C) Conjugation in *Spirostomum ambiguum* EHRBG. (C) The project of the establishment of an International Union of Protozoologists (T) The significance of ultrastructure in the taxonomy of protozoa (Ev)
III Leningrad	Organites et appareils de fixation chez les Ciliata (O) The structure and function of the cytostome (= micropyle) in the Sporozoa (C) Sur quelques progrès de nos connaissances relatives à l'ultrastructure des zooflagellés dans ses rapports avec la mitose (C) Evolution of parasitism in Euglenoidina parasite in Copepoda (Ev) The species problem and protozoology (T)
IV Clermont-Ferrand	The problem of physiological adaptations with regard to the forms of variability in free living protozoa (some results and perspectives) (T) Mechanisms of pathogenicity among parasitic protozoa (Ec) *Trichoplax adherens* and the origin of Metazoa (Ev) The present contribution of ciliates in the problem of cell morphogenesis (C)

V New York	An hour with Mr. Henry Oldenburg of the Royal Society of London and Heer Antony van Leeuwenhoek of Delft, Holland (H) ("Play")
VI Warsaw	Recent advances in the in vitro cultivation of parasitic Protozoa and their significance for the control of these parasites (O) Intraspecific variations and species concept in Protozoa (T) Protozoology in Poland: past and present (H) Genetic engineering in *Tetrahymena* (C) Assembly and patterning of microtubular structures (C) Environmental adaptation of *Tetrahymena* membranes: role of membrane lipids (C/Ec/Ev)
VII Nairobi	The cell cortex during ciliate morphogenesis and ciliogenesis (C) The design of new vaccines (O) Functional aspects in calmodulins in Protozoa (C) Protozoa of the digestive tract of herbivorous mammals (Ec) Environmental management for the control of parasitic protozoan diseases (Ec)
VIII Tsukuba	The karyorelictid nuclear apparatus: a model of nuclear differentiation (C) The contribution of hypotrich ciliates to our understanding of molecular biology and evolution of ciliates (C/Ev) Cilia in cell motility: membrane-controlled rotary engines (C) Approaches to the solubilization and partial purification of glycerol-3-phosphate oxidase from mitochondria from trypanosomes (C) Advances in the biology of intestinal Protozoa: *Entamoeba histolytica* and *Giardia lamblia* (Ec) The role of Protozoa in nature in terms of functional properties related to size (Ec)
IX Berlin	Protozoa: evolution and systematics (Ev/T) Cytoskeleton and molecular basis of patterning in ciliates (C) Progammed DNA rearrangements in *Tetrahymena* (C) Progress in some anti-protozoan vaccines against human diseases: leishmaniasis, toxoplasmosis, and malaria (Ec) Opportunistic Protozoa in AIDS (Ec/C) Modern technologies in protozoan research: aims and possibilities (O)
X Sydney	Molecular genetic analysis of invasion and development in *Toxoplasma gondii* (C) Evolution of the Protista from the perspective of molecular systematics (Ev/C) Genetic of host resistance and susceptibility to disease (C) The global diversity of Protozoa and other small species (Ec) Parasites of farmed aquatic animals (Ec)

C = cell biology; Ec = ecology; Ev = evolutionary biology; H = history of biology; T = theoretical biology; O = others.

Tab. 3: Topic focal points of Plenary lectures of I-X International Congress of Protozoology.

Topic focal points of Plenary lectures	# [a]
cell biology (including genetics, physiology, biochemistry, biophysics, molecularbiology, developmental biology and ultrastructural-research)	20
evolutionary biology (including phylogenetics, population-genetics, morphology, taxonomy, systematics, classification and social biology)	9
ecology (including environmental management and parasitology)	11
history of biology	4
theoretical biology	6
others	4

[a] Sum of Plenary lectures held to the respective topic focal points (multiple entries possible).

Tab. 4: Number of abstracts, authors and symposia of the ten International Congresses of Protozoology.

No.	Place and year	Abstracts	Authors	Symposia
I	Prague (1961)	192	230	9
II	London (1965)	374	467	15
III	Leningrad (1969)	492	623	15
IV	Clermont-Ferrand (1973)	479	525	27
V	New York (1977)	478	745	28
VI	Warsaw (1981)	418	866	6
VII	Nairobi (1985)	403	780	16
VIII	Tsukuba (1989)	333	598	16
IX	Berlin (1993)	569	1298	20
X	Sydney (1997)	371	1087	27

In the context of the topic focal points of protozoological congresses to be coded the disciplines ecology (including parasitology), history of biology and theoretical biology become included in the subdivision of biology, i.e., it is tried to take the disciplines, which hardly can be assigned to the fields cell or evolution, into account separately. Further, partly exotic disciplines, become listed as "others". An attempt has been made to abstract a list of almost 100 different biological sub-disciplines or fields mentioned above. To avoid the subjectivity of such an assignment, also several fellow students – naive to the question – have assigned the sub-disciplines and fields. In almost all fields they came to the same results. The same procedure recurred in the context of the classification of the plenary lectures held at the conventions, but into the predefined sub-disciplines cell biology (C), ecology (Ec), evolutionary biology (Ev), history of biology (H), theoretical biology (T) and others (O) (Table 3).

By supplementing the qualitative studies with a strictly quantitative counting of the symposia, abstracts and plenary lectures, a three-dimensional profile of the topics of the conventions, especially, and of modern protozoology in general, may be noted. In the following one is able to recognize and to discuss both temporal and thematic developments and shifts (Table 2, 3 and Fig. 3).

Although KUZNICKI & HONIGBERG (1984), in their quantitative analysis of the international protozoological congresses (Prague, London, Leningrad, Clermont-Ferrand, New York City and Warsaw), could prove increasing numbers of both abstracts submitted (< 200 to > 400) and scientists involved (< 300 to > 800), these numbers judged as indicators of a blossoming protozoology show a trend which is only partly confirmed by subsequent congresses. The number of submitted abstracts on the one hand stagnated after the Warsaw congress at +/-400 or it even slightly sank; on the other hand, the number of authors on all abstracts involved doubled from ca. 700 to ca. 1300, on the average. Considering a constant number of internationally worked on topics, more and more researchers are involved. On the one hand, the teamwork to be originated from this, the larger number to specialists and the interdisciplinarity in the course of the phase of the consolidation could make more specific methods and secondary disciplines possible; on the other hand, the number of the symposia held at the 10 congresses shows a fluctuation at a complete increase around the factor three between < 10 to > 20, by that – in turn with a view to the phase of the consolidation – established subranges or arising secondary disciplines could hardly be recognized. The titles of the symposia as well as the plenary lectures lets to suspect a change between an increasing specialization (particularly in molecular cell biology), the wish for generalization in the context of a general biology and renewed specialization. The coding of 47 plenary lectures reported at all the congresses clearly shows the dominance of cell biological questions opposite these from other fields of a general biology (e.g., evolutionary biology, ecology). Cognition in the context of cell biological questions could on the one hand be benefitial to other fields within the protozoology (e.g., molecular systematics), on the other hand an unbalanced focusing could unnecessarily deteriorate both, i.e., first the image of a science originally orientated at the complete biology of the organisms and second the consolidation. One could derive, from the continuous and strong increase of cell biological topics at simultaneous stagnation or slight rise (e.g., within the ecologically oriented protozoology), the number of wider topic complexes, the numerical doubling of the co-authors, the progressive specialization and the increasing topic variety, i.e., still speak about a thriving protozoology.

Simultaneously, the focal points clarify a general shifting of the profile of protozoology to the profile of cell biology, which then is hardly to be distinguished from a cell biologically oriented protozoology. Today both cell biology and protozoology are methodically oriented meta-disciplines, in which on the one hand the differentiation, and on the other hand, the interdisciplinary cooperation could characterize a protozoology standing between independence and identity loss.

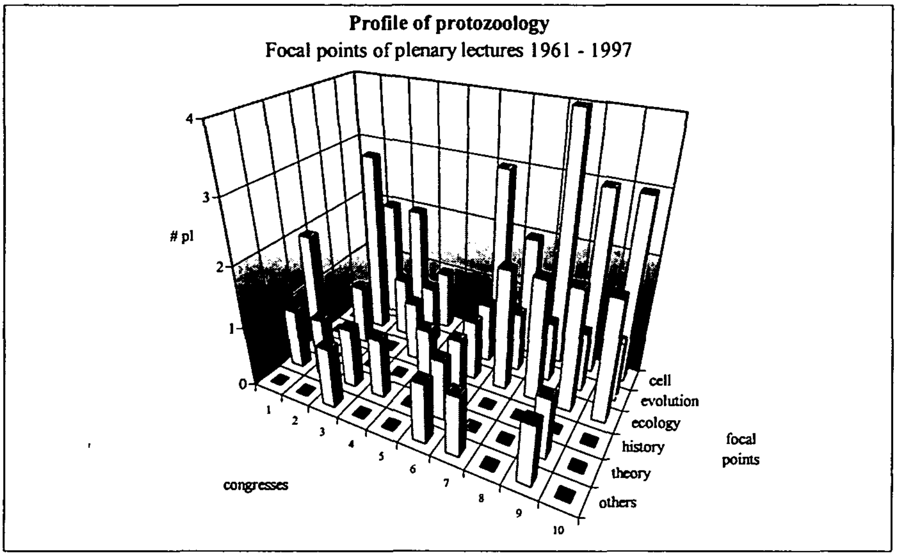


Fig. 3: Profile of protozoology. The illustration shows thematic shiftings of the plenary lectures both along the time and along the topic axis. # pl = number of plenary lectures held at the congresses (example: congress 8 = VIII International Congress of Protozoology in Tsukuba; 4 plenary lectures held about the topic focal point cell, 2 about the topic focal point ecology, 1 about the topic focal point evolution and none about the topic focal points theory, history or others).

Conclusions

A theoretical strategy in the context of science history always has a practical present reference. To understand history is to avoid faults. Genesis, terminology and methodology form the basis of a theoretical science consideration. As a branch of biology, protozoology deals with single-celled organisms. As a meta-discipline of a modern and interdisciplinary science, however, it examines molecules, cells, individuals and populations in the context of a general biology (CAVALIER-SMITH 1995; CORLISS 1986a). Complex biological coherences such as endosymbiogenesis require as well cell biological, evolutionary biological and ecological as historical and theoretical questions in a balanced relationship. The analysis of the international protozoological congresses taking place every four years and the plenary lectures particularly clarifies, on the other hand, another development. More and more often cell biological or molecular biological topics dominate – comparable to a general trend in biology. Evolutionary biology and ecology, even if represented, are constantly second- or third-rate in the context of protozoology, just like history and theory. At a constant number of abstracts submitted to protozoological conventions the number of researchers involved rises, just as does the number of symposia held there. Protozoology, on the one hand, takes an integrated interdisciplinarity, demanded due to increasing specialization and the rising topic variety, into account with regard to specific methods as well as secondary disciplines; on the other hand, it has not fundamentally changed the relationship of its focal points. The chances of a future protozoology lie between independence and identity loss, particularly since the image and consolidation are not yet defined against closely related disciplines.

Single-celled organisms as models with a promising future for general life processes speak for the former, the (for the most part) missing theoretical basis with regard to a taxonomic summary for investigation of objects in protozoology against this, for the latter. Superordinated disciplines of general biology, like, e.g., cell biology or evolutionary biology, additionally impede the image of protozoology that has arisen in the tradition of botany and zoology. Due to the often identical investigative methods, the difference in the attempts is hardly to be seen. The early history and the initial phase of a protozoology just arising take place in the time of a paradigm change within general biology. Cell theory and descent hypothesis cause a reorientation. No more animals and plants but the elementary unit cell and the elementary process evolution are in the center of the interest. The still young protozoology constituted itself contradictorily on the same basis as general biology between the disciplines botany and zoology just having been replaced. In this context, the reactionary beginning explains the peculiarities in the history of protozoology, paralleling the history of natural sciences.

The evolution of terminology performed within protozoology, thus causing the Babylonian language confusion between Animalcula and Protozoa for 300 years, generated more than 30 concepts for the summarizing characterization of single-celled organisms. Thereby these organisms should be neither animals nor plants, and to this day thinking in empires or domains dominates discussion. Many concepts are still in use, additionaly deteriorating a theoretical concept. The same applies to the titles of traditional protozoological journals changed in more recent time.

Arbitrary classifications and often a wrong species-concept are symptomatic in protozoology and, moreover, represent non-uniformity in teaching and in adequate translation in textbooks. Protozoa, just like animals or plants, are not closed descent communities. They do not have any place in a phylogenetic system of the eukaryotes and it is the task of protozoology to teach exactly this. Protozoology can persist as a science only if it is ready to get rid of its own roots to a certain degree.

Protozoology as a scientific discipline shares ontological prerequisites with all other scientific disciplines. In the context of society and the scientific community, the range of its discussions, its general, formal and logical background, its definition problem, its fund of knowledge, its common aims and its methods, it has continuously passed through all the phases of a discipline genesis. The past history, the early history and initial phase, the constitution, the establishment, the institutionalization and the consolidation of the discipline, are all part of this. The single phases in the context of protozoology can be justified well about defined events. Discoveries like the one of the "Animalcula", descriptions like the one of the "Infusionsthierchen als vollkommene Organismen", names like "Protozoa", periodicals like the "Archiv für Protistenkunde", societies like the "Society of Protozoologists", international congresses particularly like the first one in Prague in 1961, the first research departments principally in Berlin, textbooks such as Grell's "Protozoology", chairs and institutes mark respective transitions in this. Almost 300 personalities of protozoological research stand for continuous achievements of the discipline. Leeuwenhoek's discoveries, Ehrenberg's descriptions, Bütschli's classification system (programmatic for the whole of protozoology) and Hartmann's work with protists as models characterize the four individuals representative of the decisive and fundamental beginning (genesis) steps on the way to today's phenotype of protozoology (Table 5).

Risking a look into the future, it is the avoidance of or the care for consistent phylogenetic systematics, that will decide between a superfluous protozoology or the chance for a new beginning.

In favor of the latter, every connotation of the evolution concept presupposes, in the context of protozoology, a species-as-class strategy. Only in such a way – obtained on the natural equivalences of single-celled organisms – can one understand and explain their evolution as the origin of qualitatively new characters and selection as an individuum-environment interaction.

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Tab. 5: Time table of protozoology. [a]

Year	Person	Contribution
1565	Gesner	In the book "De omne rerum fossilium genere", for the first time fossil foraminiferans are described (as molluscs).
1674-1677	Leeuwenhoek	Free-living single-celled organisms are seen and described for the first time; the concept "Animalcula" is coined.
1678	Huygens	Description of ciliates and confirmation of Leeuwenhoek's observations.
1714	Leibniz	The concept "Monaden" is coined.
1718	Joblot	Microscopical observations, e.g. description of contractile vacuoles, are published.
1750	Buffon / Needham	The theory of "generatio spontanea" is formulated.
1753	Linné	"Systema naturae" appears.
1763	Ledermüller	The concept "Animalcula Infusoria" is coined.
1765	Wrisberg	The concept "Infusoria" is coined.
1766	Spallanzani	The theory of "generatio spontanea" is disproved.
1786	Müller	The book "Animalcula infusoria fluviatilia et marina" appears.
1805	Oken	The concept "Urthiere" is coined.
1809	Lamarck	The work "Philosophie zoologique" appears.
1817	Goldfuß	The concept "Protozoa" is coined.
1826	d'Orbingny	Extensive studies about foraminiferans are published.
1826	Bory	The concept "Animalia microscopica" is coined.
1828	Dufour	For the first time Gregarinea are described in beetles; start of a protozoologically oriented parasitology.

1832	Carus	The concept "Oozoa" is coined.
1835	Dujardin	Sarcode-doctrin is formulated.
1838	Ehrenberg	The folio: "Die Infusionsthierchen als vollkommene Organismen" appears.
1838/39	Schwann/ Schleiden/ Purkinje	The cell theory is formulated.
1845	Siebold	Protozoa are recognized as single-celled organisms.
1850	Pasteur	Final experimental refutation of the abiogenesis.
1852	Perty	The concept "Archezoa" is coined.
1859	Darwin	The work "Origin of species" appears.
1861	Owen	The concept "Acrita" is coined.
1861	Hogg	The concept "Protoctista" is coined.
1861	Schultze	Strengthening of the cell theory.
1866	Haeckel	The concept "Protista" is coined.
1874	Fromentel	The concept "Microzoaires" is coined.
1878	Bütschli	The first protozoological institute is founded in Heidelberg;
1880-1890		the first system of Protozoa is established.
1884	Schulze	Founding of a protozoological institute in Berlin, Germany.
1885	Hertwig	Founding of a protozoological institute in Munich, Germany.
1902	Schaudinn	Foundation of the "Archiv für Protistenkunde" (Jena, Germany), the first journal of its kind in the world; 1998 renamed in "Protist".
about 1905	Dogiel	Start of the establishment of an important protozoological school in Russia.
1914	Hartmann	Founding of the Department for Protistology at the Kaiser Wilhelm Institute for Biology in Berlin-Dahlem, Germany.
1947	Founding of the "Society of Protozoologists" in Chicago, USA.	
1950-till now	Phylogenetic method, electron microscopy, endosymbiont-hypothesis, DNA-sequence data, hydrogen-hypothesis.	
1954	Founding of the American "Journal of Protozoology"; 1993 renamed in "Journal of Eukaryotic Microbiology".	
1961	I. International Congress of Protozoology held in Prague.	
1963	Founding of the Polish journal "Acta Protozoologica".	
1965	II. International Congress of Protozoology held in London.	
1968	Founding of the French journal "Protistologica"; 1987 renamed in "European Journal of Protistology".	
1969-1997	III. – X. International Congress of Protozoology.	

[a] Time table according to AESCHT (1994); CORLISS (1978, 1979, 1991); ENTZEROTH (1994); HAUSMANN & HÜLSMANN (1996a).

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