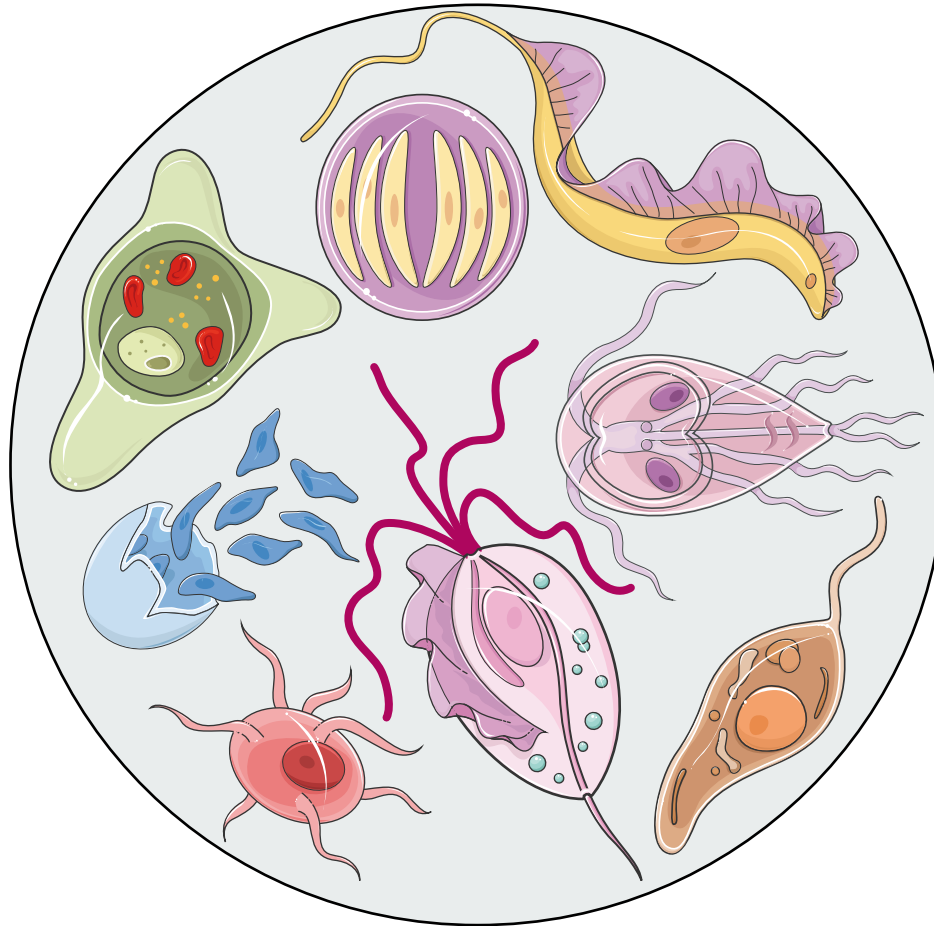


# Biology of parasitic protozoa

## I. Introduction



Andrea Bardůnek Valigurová

[andreav@sci.muni.cz](mailto:andreav@sci.muni.cz)

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## Bi7872 Biologie parazitických protozoí ✨

Přírodovědecká fakulta

podzim 2022

### ▣ Rozsah

3/0/0. 3 kr. (přif plus uk plus > 4). Ukončení: zk.  
Vyučováno online.

### ▣ Vyučující

doc. RNDr. Andrea Bardůnek Valigurová, Ph.D. (přednášející)

### ▣ Garance

prof. RNDr. Andrea Vetešníková Šimková, PhD.

Ústav botaniky a zoologie - Biologická sekce - Přírodovědecká fakulta

Kontaktní osoba: doc. RNDr. Andrea Bardůnek Valigurová, Ph.D.

Dodavatelské pracoviště: Ústav botaniky a zoologie - Biologická sekce - Přírodovědecká fakulta

### ▣ Předpoklady

SOUHLAS

(Mám splněno? →)

### ▣ Omezení zápisu do předmětu

Předmět je nabízen i studentům mimo mateřské obory.

### ▣ Mateřské obory/plány

- Zoologie (program PŘF, N-ZOL)

### ▣ Cíle předmětu

Cílem přednášky je seznámit studenty se základními skupinami parazitických protozoí, jejich taxonomickým zařazením, současnými názory na jejich fylogenezi, buněčnou organizaci, životními cykly, vlivem na hostitele. Studenti budou také stručně seznámeni s nemocemi, které jsou způsobovány parazitickými prvky.

### ▣ Výstupy z učení

Student bude po absolvování předmětu schopen popsat, indentifikovat a zařadit základní skupiny parazitických protozoí z různých hledisek; bude znát nemoci způsobené parazitickými prvky.

### ▣ Osnova

- 1. Definice protozoí a jejich jednobuněčnými eukaryotními organizmy a jejich vývojové vztahy. Buněčná organizace protozoí s důrazem na parazitické formy 2. Euglenozoa 3. Metamonada 4. Oxymonada 5. Parabasala 6. Percolozoa 7. Rhizopoda 8. Alveolata 9. Apicomplexa 10. Ciliophora 11. Protista mimo říši Protozoa: Microspora, Myxozoa, Chromista, Pneumocystis spp. 12. Diskusní seminář Literatura Hausmann, K. and Hülsmann, N. Protozoology. Georg Thieme Verlag, Stuttgart, N. Y. 1996, 338s. Bednář, M., Fraňková, V., Schindler, J., Souček, A., Vávra, J. (Eds.). Lékařská mikrobiologie: bakteriologie, virologie, parazitologie. Marvil, Praha, 1996, 558s. Jírovec, O. a spolupracovníci. Parasitologie pro lékaře. III. vydání. Avicenum/ 1977, 797s. Lee, J. J., Hutner, S. H. a Bovee, E. C. (Eds.). Illustrated Guide to the Protozoa. Society of Protozoologists

### ▣ Literatura

- Doporučená literatura viz osnova přednášky

### ▣ Výukové metody

přednáška

### ▣ Metody hodnocení

ústní zkouška

## Lectures

- Introduction: [BPP 2022 I](#)
- Euglenozoa (Excavata): [BPP 2022 II](#)
- Fornicata / Preaxostyla / Parabasala (Excavata): [BPP 2022 III](#)
- Apicomplexa I (SAR): [BPP 2022 IV](#)
- Apicomplexa II (SAR): [BPP 2022 V](#)
- Amoebae (Excavata, Amoebozoa): [BPP 2022 VI](#)
- Ciliophora, Opalinata (SAR): [BPP 2022 VII](#)

- *Pneumocystis* (Opisthokonta, Fungi): [BPP 2022 VIII](#)
- Microsporidia (Opisthokonta, Fungi): [BPP 2022 IX](#)
- Myxozoa (Opisthokonta, Animalia): [BPP 2022 X](#)

# Recommended sources of information

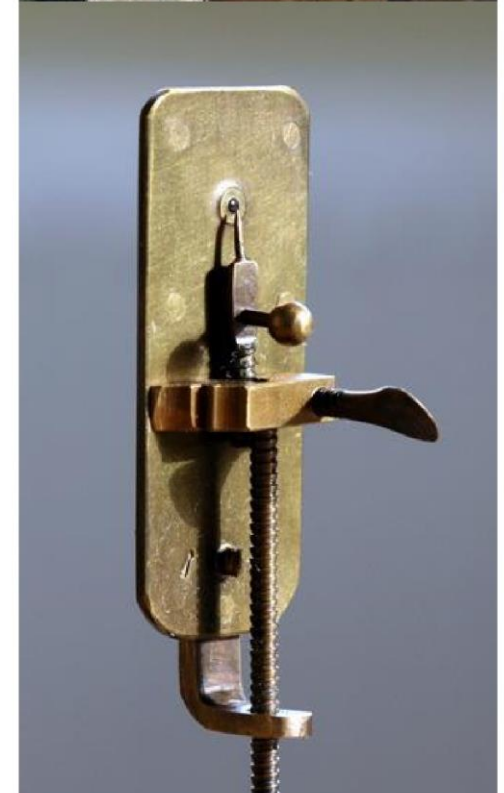
## ❑ lectures

- ❑ Votýpka J, Kolářová I, Horák P et al. (2018): O parazitech a lidech. Triton. ISBN 978-80-7553-350-0
- ❑ Jírovec O et al. (1977): Parasitologie pro lékaře. Avicenum
- ❑ Lee JJ et al. (2000): Illustrated Guide To The Protozoa. Allen Press. ISBN 9781891276224
- ❑ Hausmann K, Hülsmann N (2003): Protozoologie. Academia. ISBN 80-200-0978-7
- ❑ Volf P, Horák P (2007): Paraziti a jejich biologie. Triton. ISBN 978-80-7387-088-9
- ❑ <http://tolweb.org/tree>
- ❑ <https://www.catalogueoflife.org>
- ❑ <http://www.google.com>

# **History of unicellular (single-celled) organisms**

# Antoni van Leeuwenhoek (1632-1723)

- Dutch tradesman and scientist
- "the Father of Microbiology,,
- wrote approximately 560 letters to the Royal Society of London and other scientific institutions over a period of 50 years
- discovery of single-celled organisms
- term **Animalcula** (1676) = little animals
- van Leeuwenhoek's main discoveries:
- Infusoria in 1674
- bacteria (e.g. large selenomonads from the human mouth) in 1676
- spermatozoa in 1677
- *Giardia* in 1681



## Gottfried Wilhelm Leibniz (1646-1716)

- philosophical theory of monads (1714)
- „**monads** are elementary particles“
- historical term for a simple unicellular organism
- original meaning „a single-celled microorganism, especially a flagellate protozoan of the genus *Monas*“

Today the general body type of some algae or flagellates:

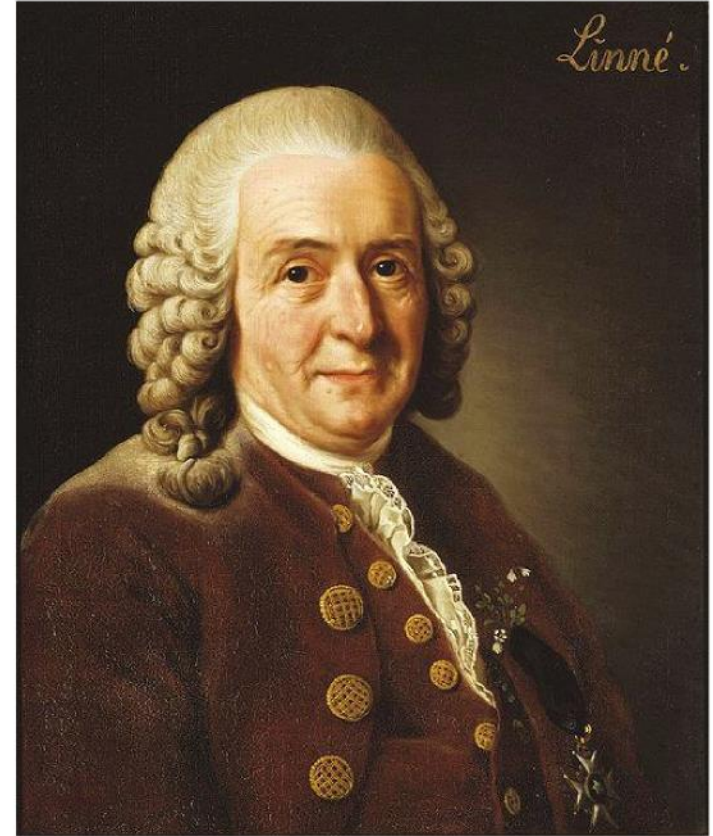
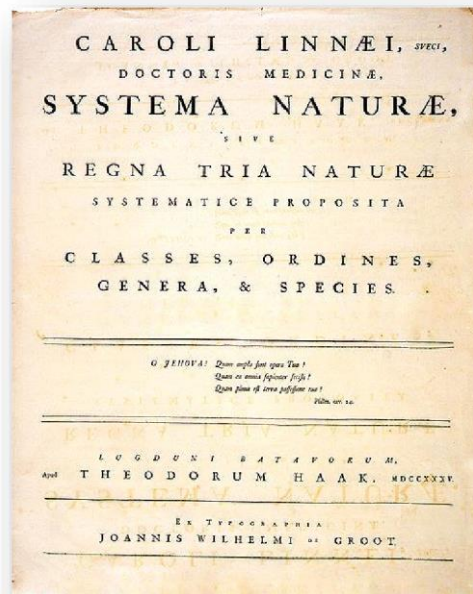
- **cryptomonads**: group of aquatic eukaryotes
- **metamonads**: group of flagellate amitochondriate single-celled organisms





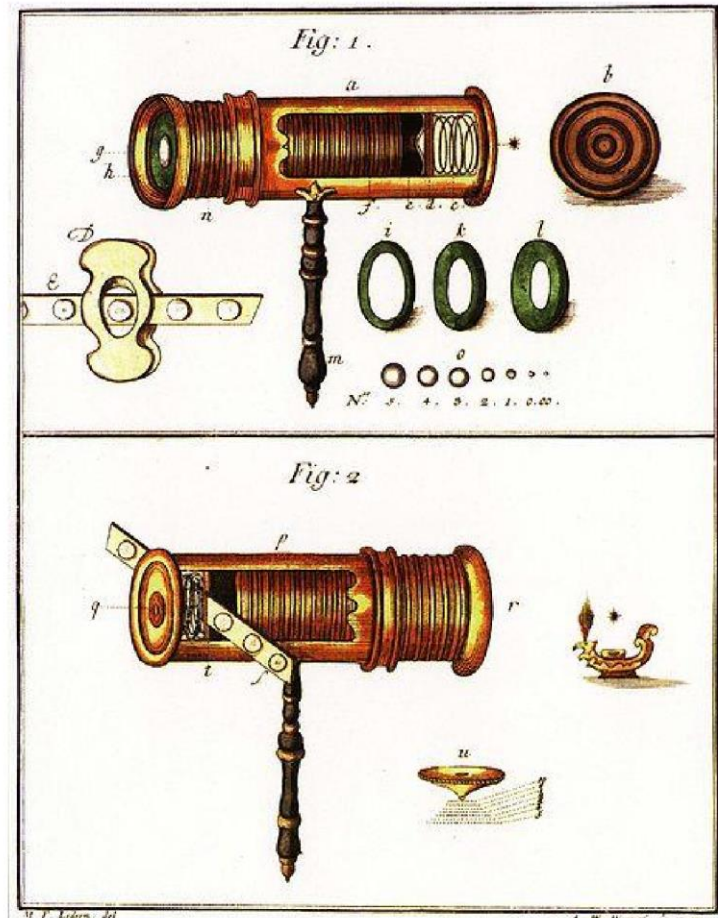
# Carl Linné (1707-1778)

- „god created – Linnaeus arranged“
- *Planta x Animalia* (1735)
- all single-celled organisms → to the genus „**Chaos**“



## Martin Frobenius Ledermüller (1719-1769)

- illustrated a wide range of objects such as various parts of plants and insects, small shells, plankton, the crystallisation of salts in the solution, various kinds of microscopes and optical experiments
- term **Infusoria** (1763) - animals from infusion



## Lorenz von Oken (1779-1851)

- German naturalist, botanist, biologist, and ornithologist
- term **Urthiere** (1805) - German term for single-celled organism
- synonym for Infusoria



## Georg August Goldfuss (1782-1848)

- term **Protozoa** (1818) - Greek equivalent of the German "Urthiere,, = primitive, or original animals
- protozoans defined as single-celled organisms with animal-like behaviours, such as motility and predation
- originally the group included also some "lower" multicellular animals, such as rotifers, corals, sponges, jellyfish, bryozoans and polychaetas



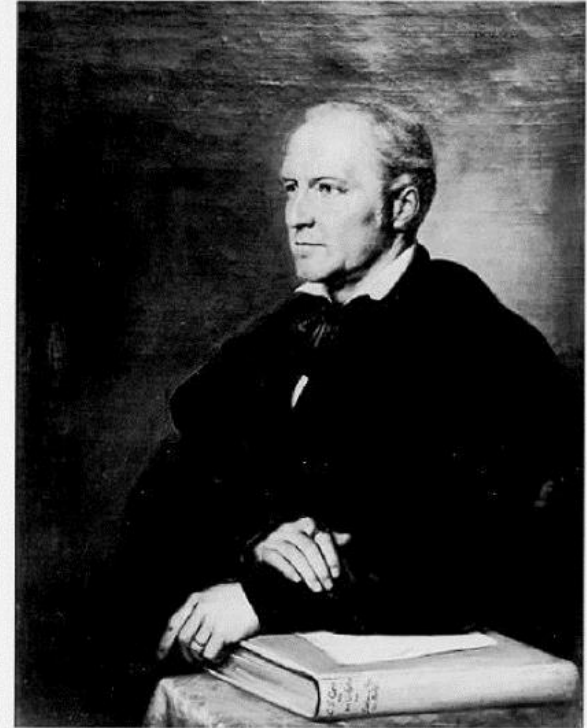
## Jan Svatopluk Presl (1791-1849)

- term **Prvoci** (1821)
- „Tělo sliznaté, měškovité, bez útroob a ústí; povrchem se živící a dýchající. Žádné nervy ani žilstvo. Volní, okem často neviditelní.“  
*(Body slimy, sac-like, without viscera and mouth; superficial feeding and breathing. No nerves or veins. Free, often invisible to the eye.)*
- author of Czech natural science terminology in several fields (botany, chemistry, zoology, mineralogy, geology)



## Carl Gustav Carus (1789-1869)

- **Eithiere** or **Oozoa** (1832)
- synonym for Infusoria and Protozoa (Goldfuss, 1818)



CARL GUSTAV CARUS (1789–1869)

Gemälde von Julius Hübner, 1844  
Privatbesitz, Sächsische Landesbibliothek/Deutsche Fotothek

## Maximilian Perty (1804-1884)

- German naturalist and entomologist
- term **Archaezoa** (1852)
- synonym for Protozoa
- term for eukaryotes that diverged before the origin of mitochondria (1989)
- all these groups are recently known to have developed from mitochondriate ancestors, and trees based on other genes do not support their basal placement
- kingdom **Archaezoa** has therefore been abandoned



## Richard Owen (1804-1892)

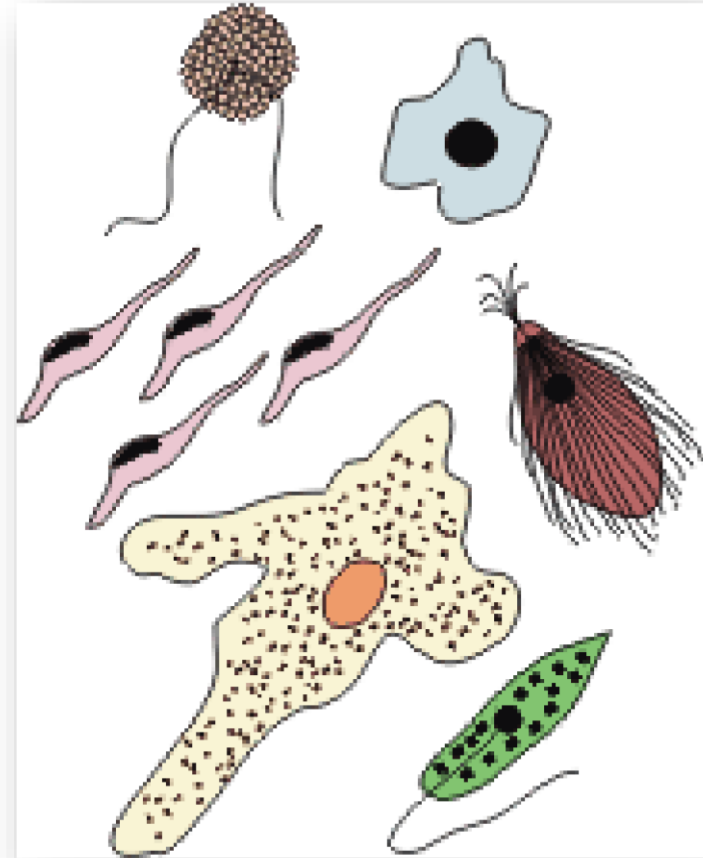
- term **Acrita** (1861)
- „nondifferentiated cells“
- all organisms outside Animalia and Vegetabilia





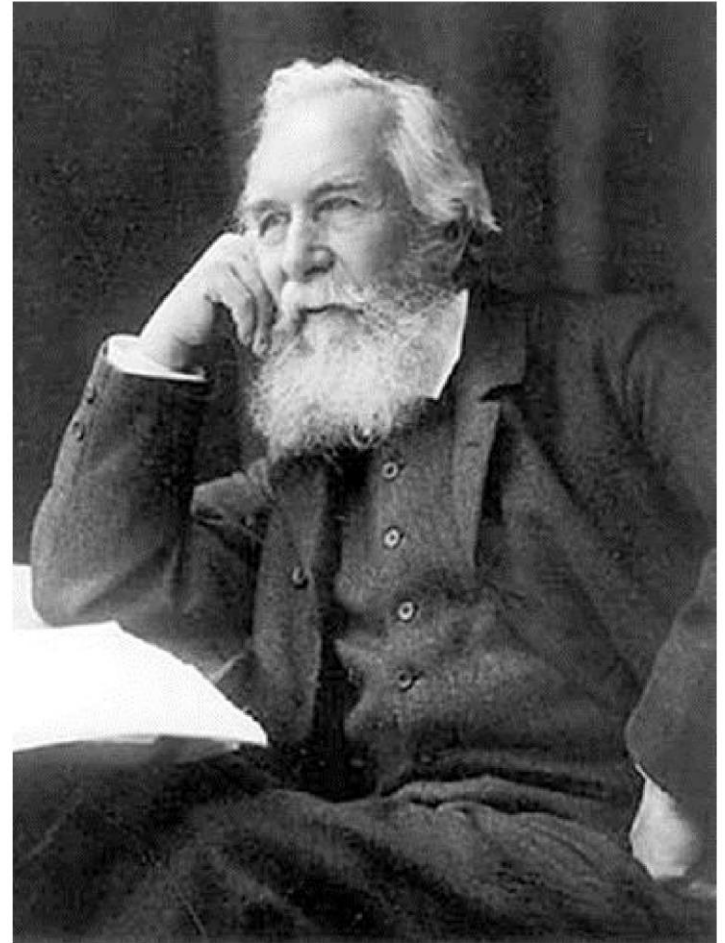
## John Hogg (1800-1869)

- term **Protoctista** (1861)
- eukaryotic organisms which are neither true plants, animals nor fungi
- protists including unicellular algae, slime moulds and amoeba
- some that act like plants and make their own food, and some that are more like animal or fungal cells



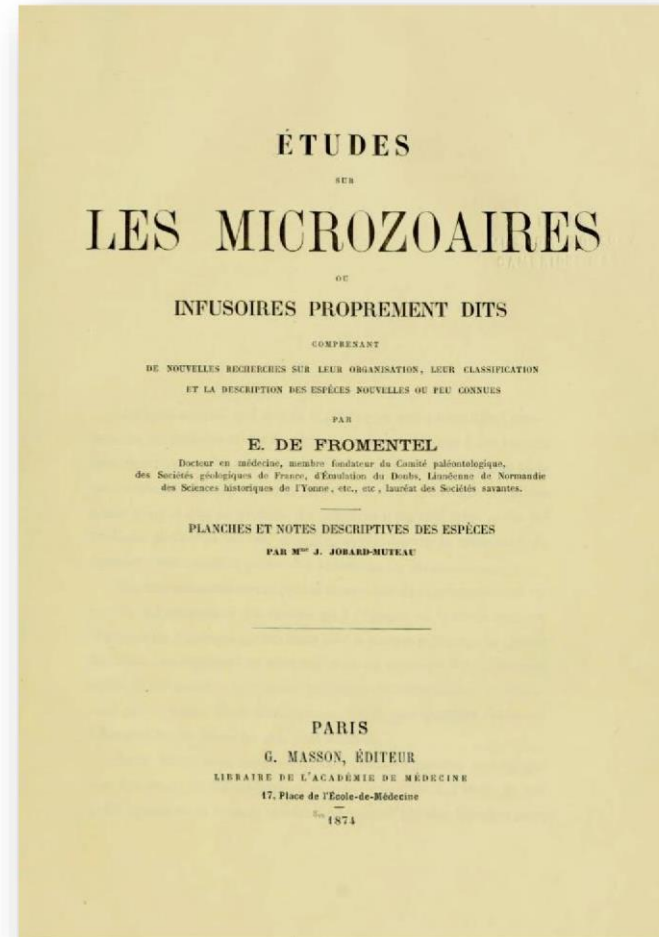
## Ernst Haeckel (1834-1919)

- term **Protista** (1866)
- eukaryotic organisms which are neither true plants, animals, nor fungi



## Emile de Fromentel

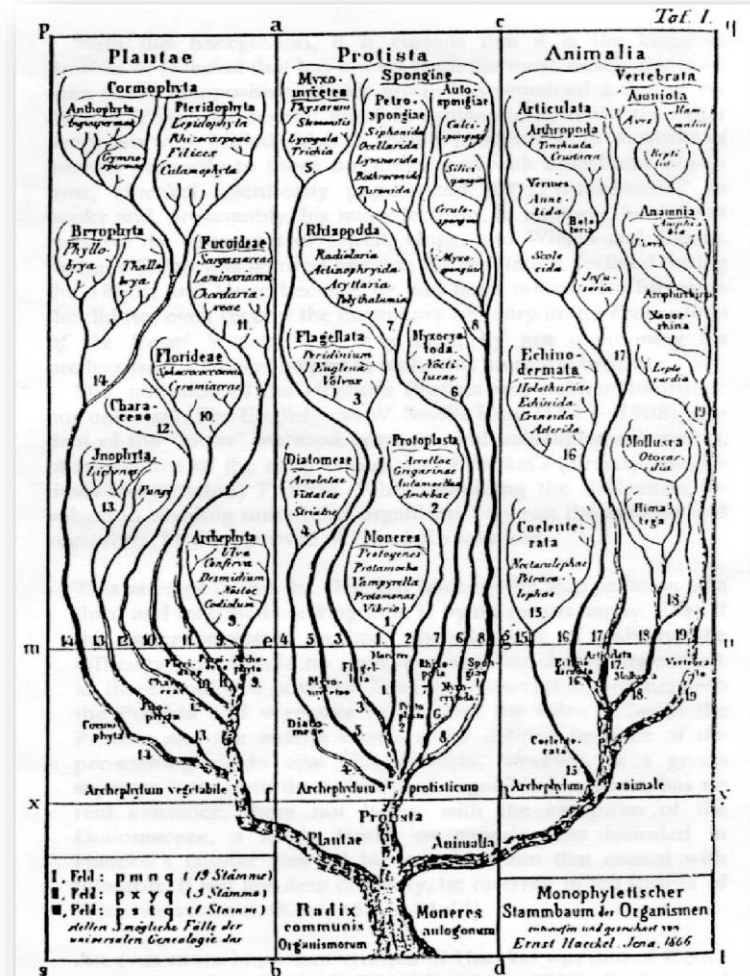
- term **Microzoaires** (1874)
- all microscopic organisms



# Taxonomy of unicellular organisms

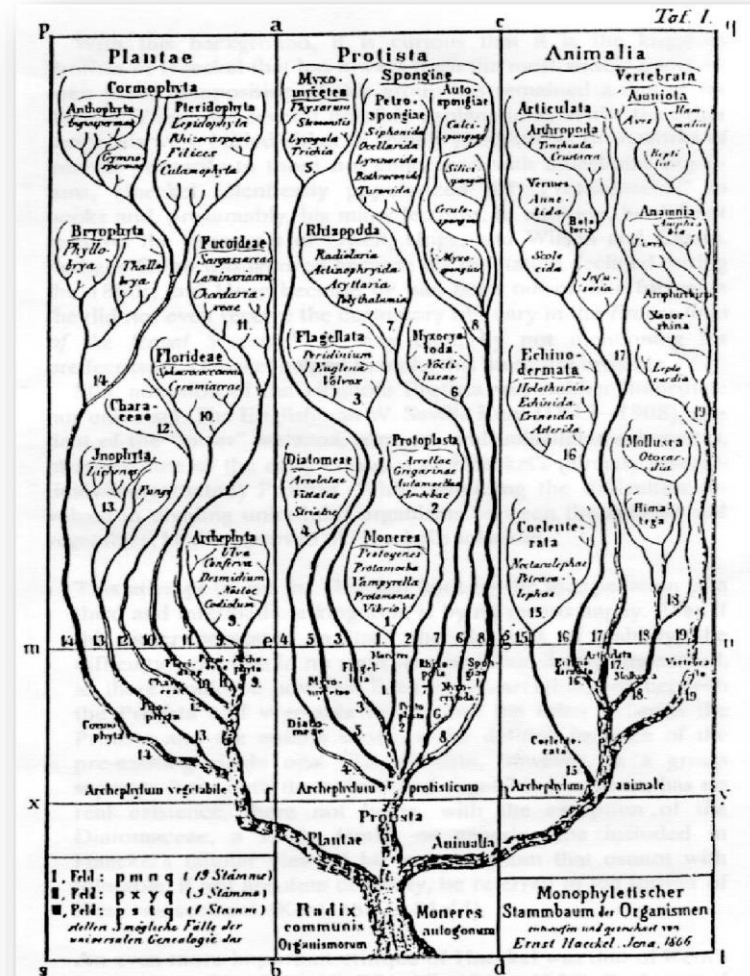
## Three frequently used terms:

- Protozoa
- Protocista
- Protista
- Czech term PRVOCI (not meant in the sense of a systematic monophyletic group)



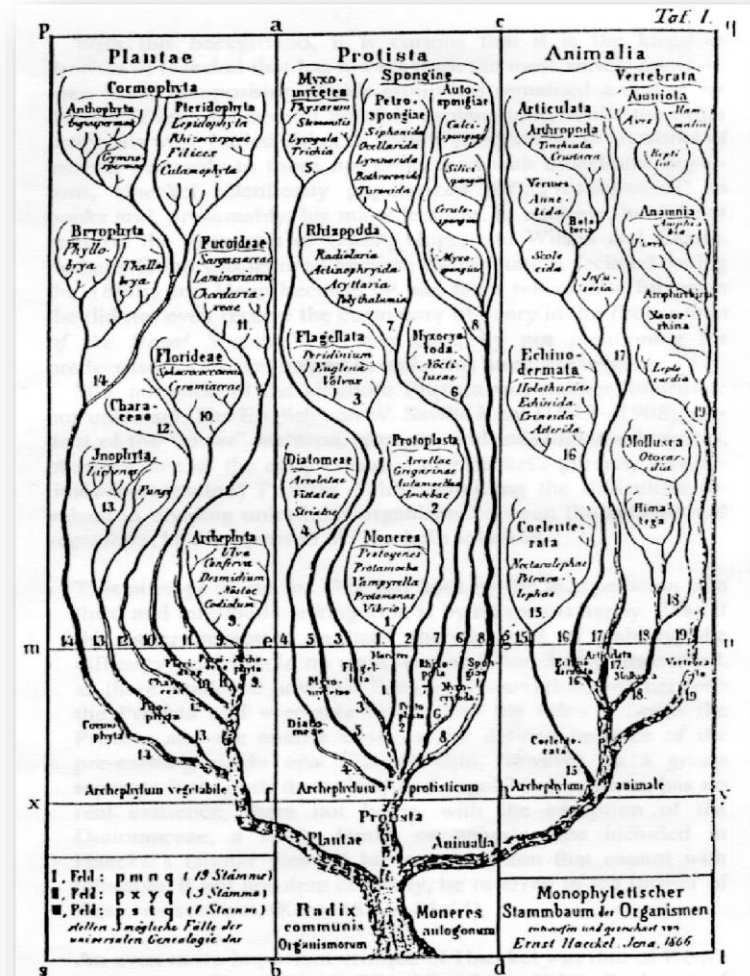
# Protozoa (protozoan, plural protozoans)

- its etymology is literally "first animals,"
- general term for a group of unicellular eukaryotes, either free-living or parasitic, which feed on organic matter such as other microorganisms or organic tissues and debris
- sometimes included within Protoctista or Protista



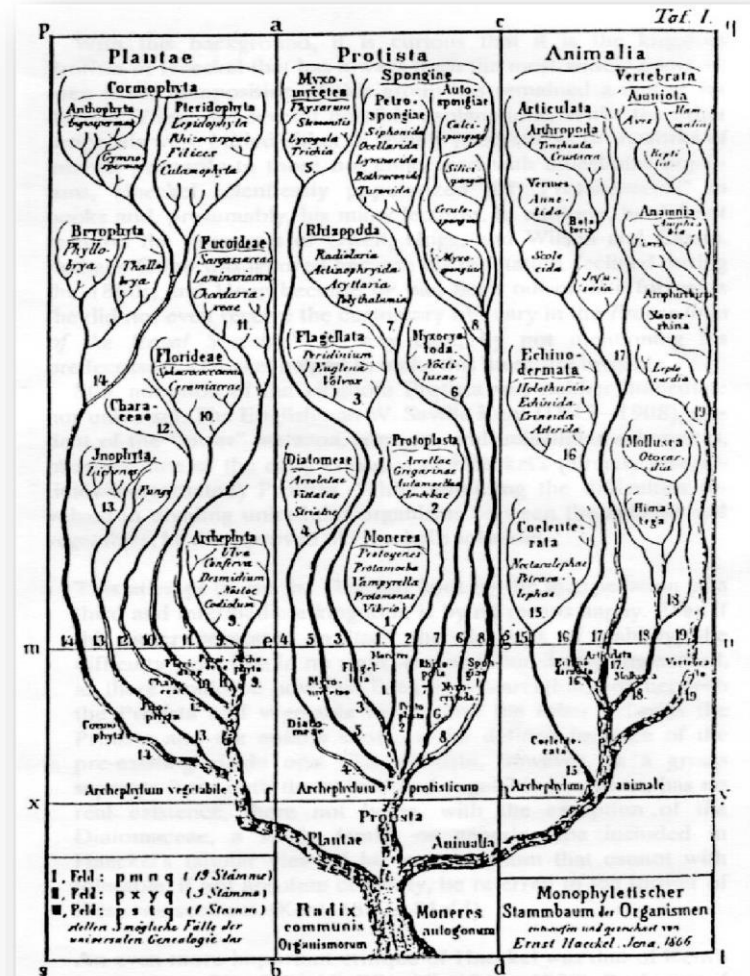
# Protocista

- John Hogg in 1860 – „all lower creatures, or primary organic beings, eukaryotic organisms which are neither true plants, animals, nor fungi“
- protists including unicellular algae, slime moulds and amoeba
- some that act like plants and make their own food, and some that are more like animal or fungal cells



# Protista

- protist = any eukaryotic organism that is not an animal, plant, or fungus
- Ernst Haeckel in 1866 - „the kingdom of primitive forms“.
- originally these also included prokaryotes
- protists do not form a natural group, or clade



# Taxonomy of eukaryotes

- Levine ND, Corliss JO, Cox FE, Deroux G, Grain J, Honigberg BM, Leedale GF, Loeblich AR, Lom J, Lynn D, Merinfeld EG, Page FC, Poljansky G, Sprague V, Vávra J, Wallace FG (1980): A newly revised classification of the protozoa. *J Protozool.* 27:37-58. **7 phyla**
- Cavalier-Smith T (1993): Kingdom protozoa and its **18 phyla**. *Microbiol Mol Biol Rev.* 57: 953-994
- Corliss JO (1994): An interim utilitarian (“user-friendly”) hierarchical classification and characterization of the Protists. *Acta Protozool.* 33: 1-51. **35 phyla**
- Cavalier-Smith T (1998): A revised **six-kingdom** system of life. *Biol Rev* 73: 203-266
- Cavalier-Smith T (2002): The phagotrophic origin of eukaryotes and phylogenetic classification of Protozoa. *Int J Syst Evol Microbiol.* 52: 297-354

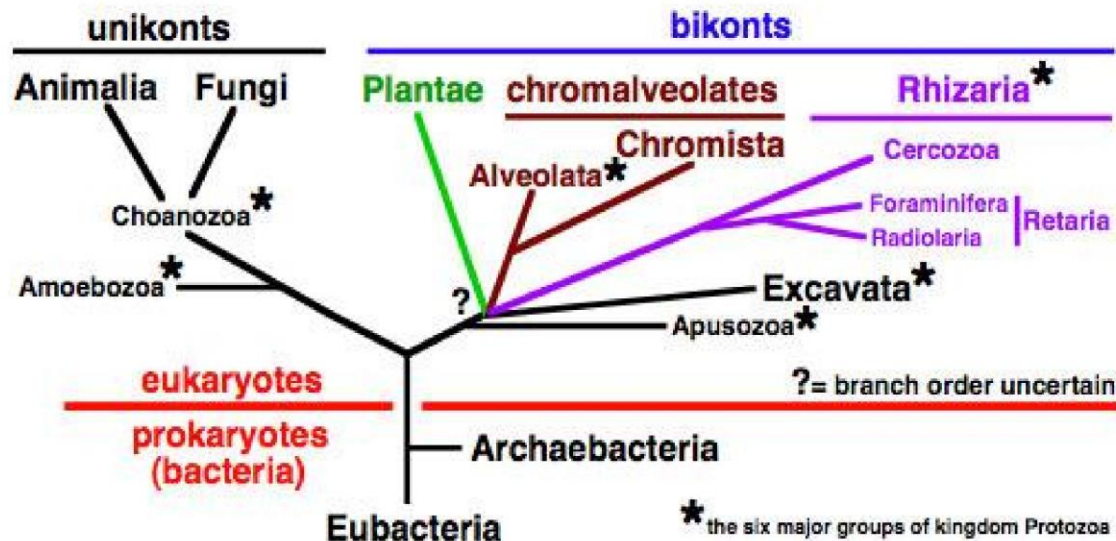


# Taxonomy of eukaryotes

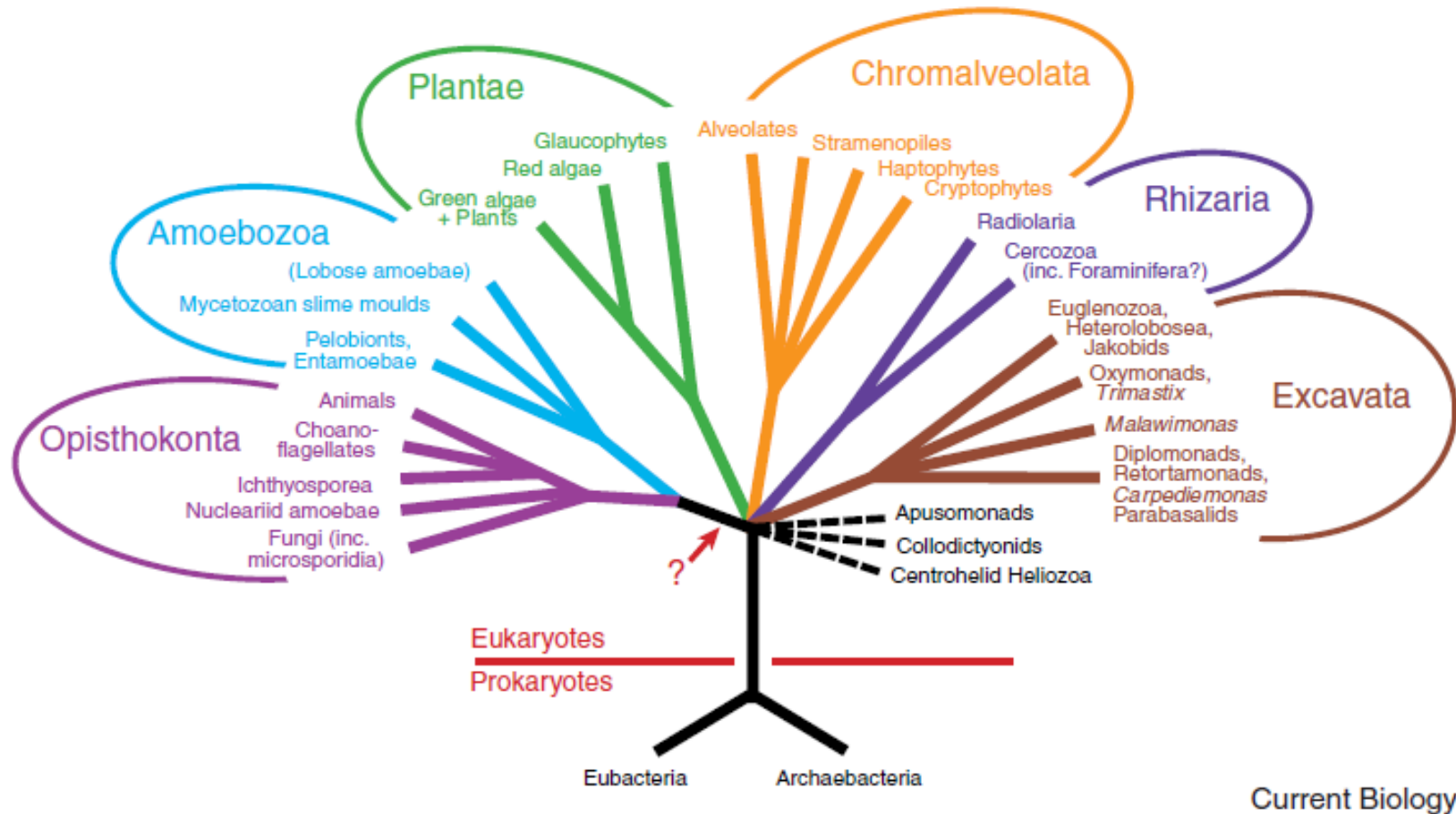
Thomas Cavalier-Smith (1942-2021)

Professor of Evolutionary Biology  
Department of Zoology, University of Oxford

[https://en.wikipedia.org/wiki/Thomas\\_Cavalier-Smith](https://en.wikipedia.org/wiki/Thomas_Cavalier-Smith)



# Six major groups



# The New Higher Level Classification of Eukaryotes with Emphasis on the Taxonomy of Protists

SINA M. ADL,<sup>a</sup> ALASTAIR G. B. SIMPSON,<sup>a</sup> MARK A. FARMER,<sup>b</sup> ROBERT A. ANDERSEN,<sup>c</sup>  
O. ROGER ANDERSON,<sup>d</sup> JOHN R. BARTA,<sup>e</sup> SAMUEL S. BOWSER,<sup>f</sup> GUY BRUGEROLLE,<sup>g</sup>  
ROBERT A. FENSOME,<sup>h</sup> SUZANNE FREDERICQ,<sup>i</sup> TIMOTHY Y. JAMES,<sup>j</sup> SERGEI KARPOV,<sup>k</sup>  
PAUL KUGRENS,<sup>l</sup> JOHN KRUG,<sup>m</sup> CHRISTOPHER E. LANE,<sup>n</sup> LOUISE A. LEWIS,<sup>o</sup> JEAN LODGE,<sup>p</sup> DENIS H. LYNN,<sup>q</sup>  
DAVID G. MANN,<sup>r</sup> RICHARD M. MCCOURT,<sup>s</sup> LEONEL MENDOZA,<sup>t</sup> ØJVIND MOESTRUP,<sup>u</sup>  
SHARON E. MOZLEY-STANDRIDGE,<sup>v</sup> THOMAS A. NERAD,<sup>w</sup> CAROL A. SHEARER,<sup>x</sup> ALEXEY V. SMIRNOV,<sup>y</sup>  
FREDERICK W. SPIEGEL<sup>z</sup> and MAX F. J. R. TAYLOR<sup>aa</sup>

**ABSTRACT.** This revision of the classification of unicellular eukaryotes updates that of Levine et al. (1980) for the protozoa and expands it to include other protists. Whereas the previous revision was primarily to incorporate the results of ultrastructural studies, this revision incorporates results from both ultrastructural research since 1980 and molecular phylogenetic studies. We propose a scheme that is based on nameless ranked systematics. The vocabulary of the taxonomy is updated, particularly to clarify the naming of groups that have been repositioned. We recognize six clusters of eukaryotes that may represent the basic groupings similar to traditional “kingdoms.” The multicellular lineages emerged from within monophyletic protist lineages: animals and fungi from Opisthokonta, plants from Archaeplastida, and brown algae from Stramenopiles.

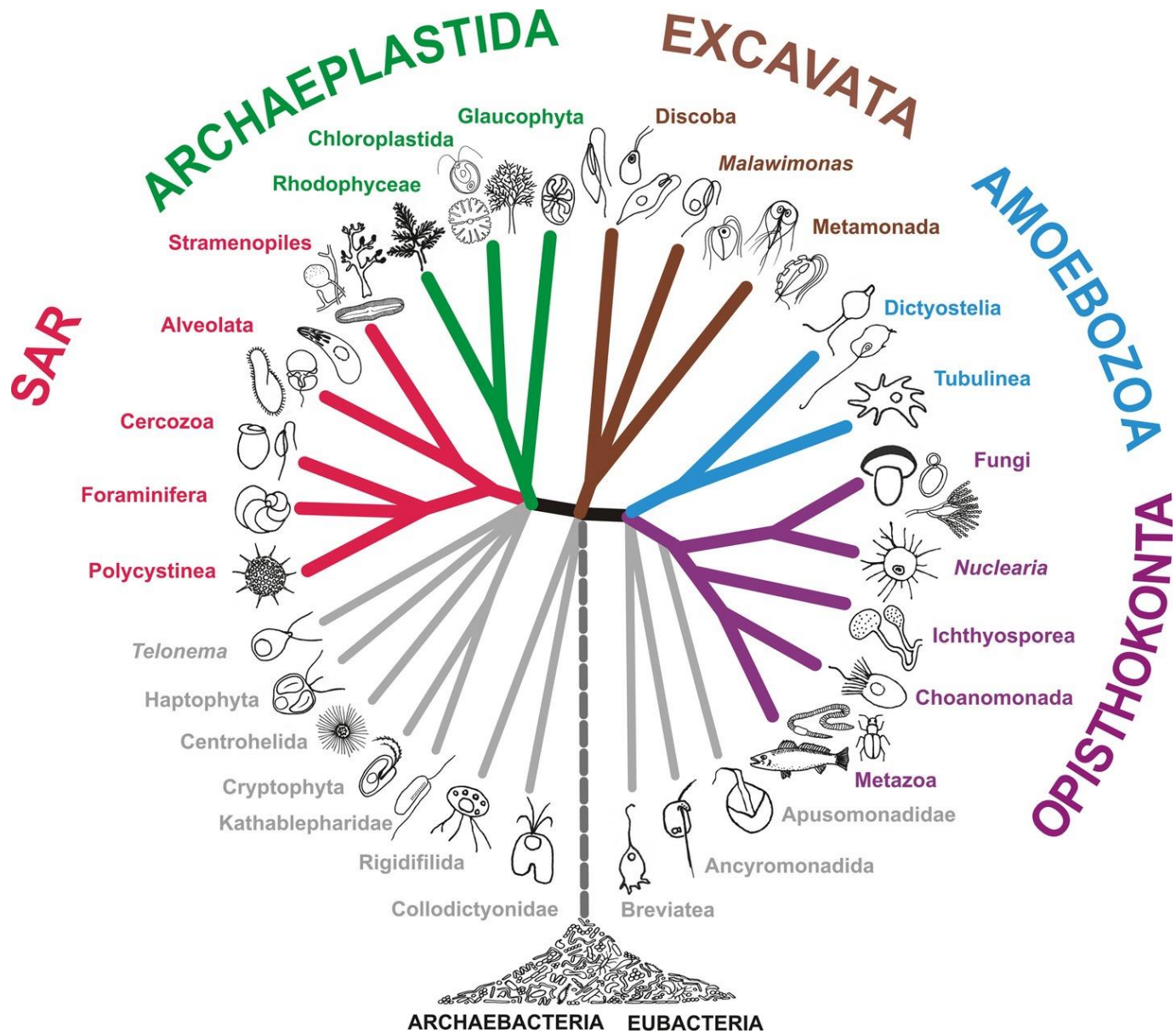
**Key Words.** Algae, amoebae, ciliates, flagellates, fungi, microbiology, microorganisms, parasites, plankton, protozoa, systematics, taxonomy.

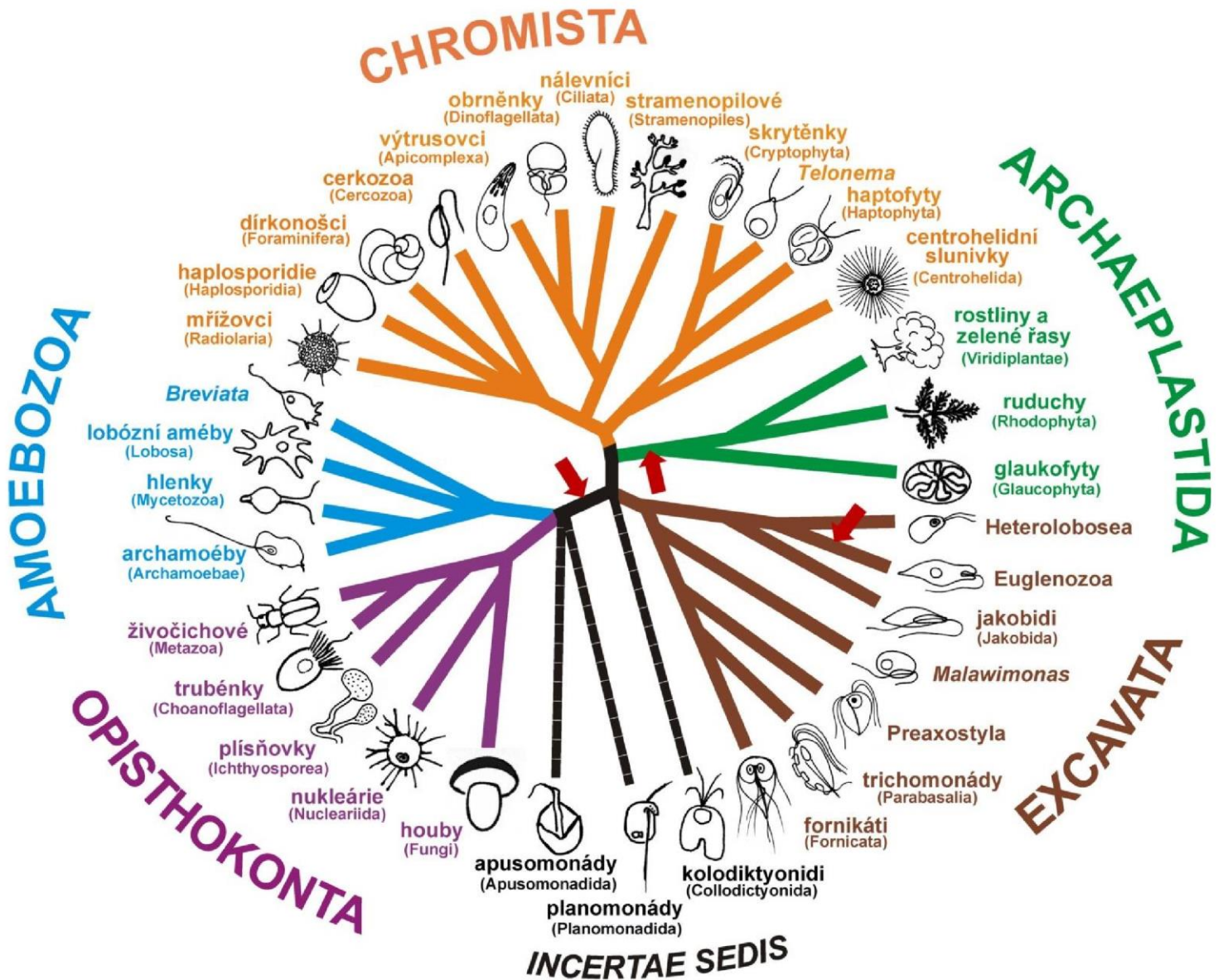
## The Revised Classification of Eukaryotes

SINA M. ADL,<sup>a,b</sup> ALASTAIR G. B. SIMPSON,<sup>b</sup> CHRISTOPHER E. LANE,<sup>c</sup> JULIUS LUKEŠ,<sup>d</sup> DAVID BASS,<sup>e</sup>  
SAMUEL S. BOWSER,<sup>f</sup> MATTHEW W. BROWN,<sup>g</sup> FABIEN BURKI,<sup>b</sup> MICAH DUNTHORN,<sup>h</sup> VLADIMIR HAMPL,<sup>i</sup>  
AARON HEISS,<sup>b</sup> MONA HOPPENRATH,<sup>k</sup> ENRIQUE LARA,<sup>l</sup> LINE LE GALL,<sup>m</sup> DENIS H. LYNN,<sup>n,1</sup> HILARY MCMANUS,<sup>o</sup>  
EDWARD A. D. MITCHELL,<sup>1</sup> SHARON E. MOZLEY-STANRIDGE,<sup>p</sup> LAURA W. PARFREY,<sup>q</sup> JAN PAWLOWSKI,<sup>r</sup>  
SONJA RUECKERT,<sup>s</sup> LAURA SHADWICK,<sup>t</sup> CONRAD L. SCHOCH,<sup>u</sup> ALEXEY SMIRNOV<sup>v</sup> and FREDERICK W. SPIEGEL<sup>t</sup>

**ABSTRACT.** This revision of the classification of eukaryotes, which updates that of Adl et al. [*J. Eukaryot. Microbiol.* **52** (2005) 399], retains an emphasis on the protists and incorporates changes since 2005 that have resolved nodes and branches in phylogenetic trees. Whereas the previous revision was successful in re-introducing name stability to the classification, this revision provides a classification for lineages that were then still unresolved. The supergroups have withstood phylogenetic hypothesis testing with some modifications, but despite some progress, problematic nodes at the base of the eukaryotic tree still remain to be statistically resolved. Looking forward, subsequent transformations to our understanding of the diversity of life will be from the discovery of novel lineages in previously under-sampled areas and from environmental genomic information.

**Key Words.** Algae, amoebae, biodiversity, ciliates, flagellates, fungi, parasites, protozoa, systematics, taxonomy.





Original Article | Open Access |

## Revisions to the Classification, Nomenclature, and Diversity of Eukaryotes

Sina M. Adl , David Bass, Christopher E. Lane, Julius Lukeš, Conrad L. Schoch, Alexey Smirnov, Sabine Agatha, Cedric Berney, Matthew W. Brown, Fabien Burki, Paco Cárdenas ... [See all authors](#)

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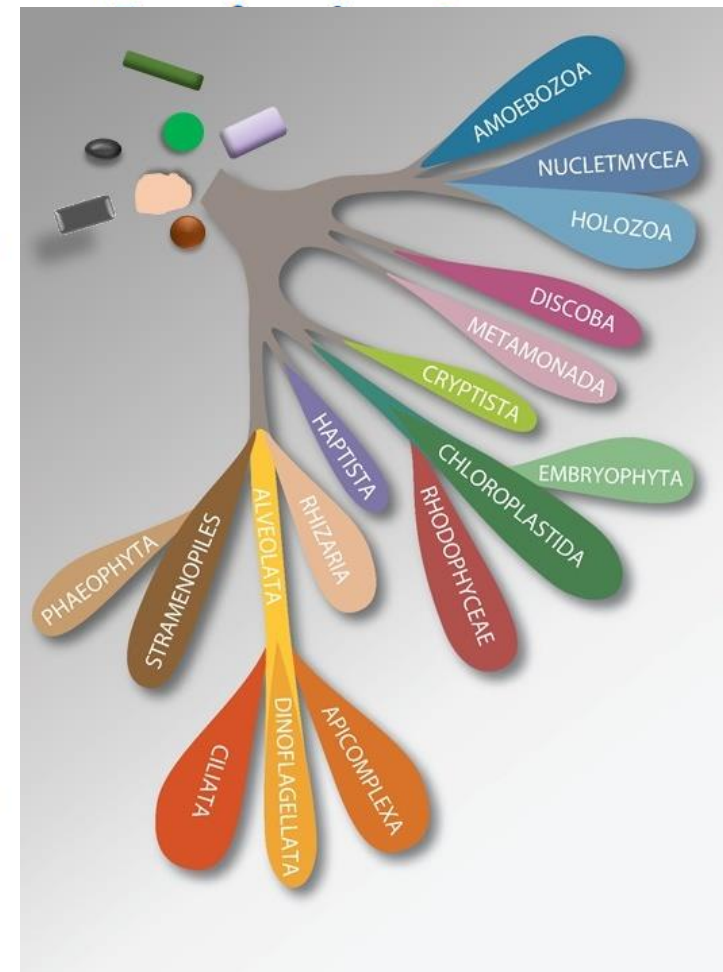
SECTIONS

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### Abstract

This revision of the classification of eukaryotes follows that of Adl et al., 2012 [*J. Euk. Microbiol.* 59(5)] and retains an emphasis on protists. Changes since have improved the resolution of many nodes in phylogenetic analyses. For some clades even families are being clearly resolved. As we had predicted, environmental sampling in the intervening years has massively increased the genetic information at hand. Consequently, we have discovered novel clades, exciting new genera and uncovered a massive species level diversity beyond the morphological species descriptions. Several clades known from environmental samples only have now found their home. Sampling soils, deeper marine waters and the deep sea will continue to fill us with surprises. The main changes in this revision are the confirmation that eukaryotes form at least two domains, the loss of monophyly in the Excavata, robust support for the Haptista and Cryptista. We provide suggested primer sets for DNA sequences from environmental samples that are effective for each clade. We have provided a guide to trophic functional guilds in an appendix, to facilitate the interpretation of environmental samples, and a standardized taxonomic guide for East Asian users.

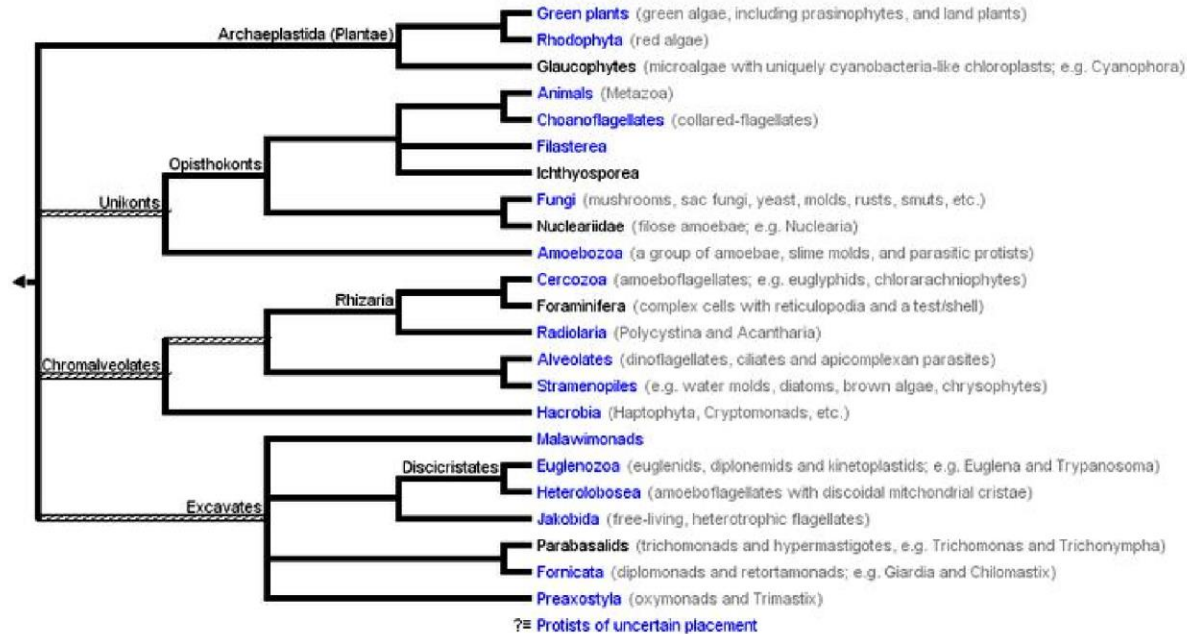
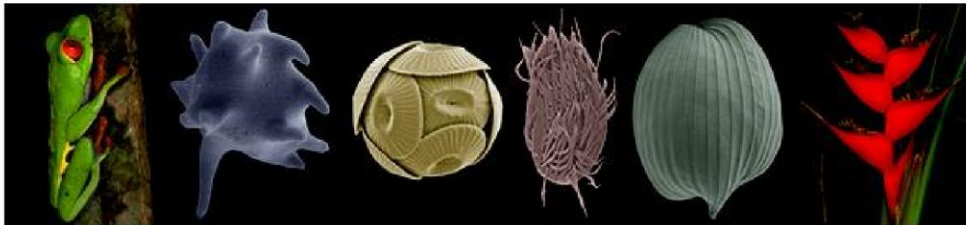
THIS revision of the classification of eukaryotes updates that of the International Society of Protistologists (Adl et al. [2012](#)). Since then, there has been a massive increase in DNA



## Eukaryotes

Eukaryota, Organisms with nucleated cells

Patrick Keeling, Brian S. Leander, and Alastair Simpson





## RESEARCH ARTICLE

# A Higher Level Classification of All Living Organisms

Michael A. Ruggiero<sup>1\*</sup>, Dennis P. Gordon<sup>2</sup>, Thomas M. Orrell<sup>1</sup>, Nicolas Bailly<sup>3</sup>, Thierry Bourgoin<sup>4</sup>, Richard C. Brusca<sup>5</sup>, Thomas Cavalier-Smith<sup>6</sup>, Michael D. Guiry<sup>7</sup>, Paul M. Kirk<sup>8</sup>

**1** Integrated Taxonomic Information System, National Museum of Natural History, Smithsonian Institution, Washington, District of Columbia, United States of America, **2** National Institute of Water & Atmospheric Research, Wellington, New Zealand, **3** WorldFish—FIN, Los Baños, Philippines, **4** Institut Systématique, Evolution, Biodiversité (ISYEB), UMR 7205 MNHN-CNRS-UPMC-EPHE, Sorbonne Universités, Museum National d'Histoire Naturelle, 57, rue Cuvier, CP 50, F-75005, Paris, France, **5** Department of Ecology & Evolutionary Biology, University of Arizona, Tucson, Arizona, United States of America, **6** Department of Zoology, University of Oxford, Oxford, United Kingdom, **7** The AlgaeBase Foundation & Irish Seaweed Research Group, Ryan Institute, National University of Ireland, Galway, Ireland, **8** Mycology Section, Royal Botanic Gardens, Kew, London, United Kingdom

\* [ruggierm@si.edu](mailto:ruggierm@si.edu)



## Abstract

We present a consensus classification of life to embrace the more than 1.6 million species already provided by more than 3,000 taxonomists' expert opinions in a unified and coherent, hierarchically ranked system known as the [Catalogue of Life \(CoL\)](#). The intent of this collaborative effort is to provide a hierarchical classification serving not only the needs of the CoL's database providers but also the diverse public-domain user community, most of whom are familiar with the Linnaean conceptual system of ordering taxon relationships. This classification is neither phylogenetic nor evolutionary but instead represents a consensus view that accommodates taxonomic choices and practical compromises among diverse expert opinions, public usages, and conflicting evidence about the boundaries between taxa and the ranks of major taxa, including kingdoms. Certain key issues, some not fully resolved, are addressed in particular. Beyond its immediate use as a management tool for the CoL and ITIS (Integrated Taxonomic Information System), it is immediately valuable as a reference for taxonomic and biodiversity research, as a tool for societal communication, and as a classificatory "backbone" for biodiversity databases, museum collections, libraries, and textbooks. Such a modern comprehensive hierarchy has not previously existed at this level of specificity.

Ruggiero MA, Gordon DP, Orrell TM, Bailly N, Bourgoin T, Brusca RC, et al. (2015) A Higher Level Classification of All Living Organisms. *PLoS ONE* 10(4): e0119248. doi: [10.1371/journal.pone.0119248](https://doi.org/10.1371/journal.pone.0119248) PMID: [25923521](https://pubmed.ncbi.nlm.nih.gov/25923521/)

CORRECTION

## Correction: A Higher Level Classification of All Living Organisms

Michael A. Ruggiero, Dennis P. Gordon, Thomas M. Orrell, Nicolas Bailly, Thierry Bourgoïn, Richard C. Brusca, Thomas Cavalier-Smith, Michael D. Guiry, Paul M. Kirk

**Table 1. List of ranks used in the hierarchy with the number of taxa per rank**

Rank	Number of Taxa
Superkingdom	2
<b>Kingdom</b>	<b>7</b>
Subkingdom	11
Infrakingdom	8
Superphylum	6
<b>Phylum</b>	<b>96</b>
Subphylum	60
Infraphylum	4
Superclass	12
<b>Class</b>	<b>352</b>
Subclass	145
Infraclass	23
Superorder	52
<b>Order</b>	<b>1,468</b>

Main ranks are in bold type; unnamed taxa are not counted.

Ruggiero MA, Gordon DP, Orrell TM, Bailly N, Bourgoïn T, et al. (2020) Correction: A Higher Level Classification of All Living Organisms. PLoS ONE 10(6): e0130114. doi:10.1371/journal.pone.0130114

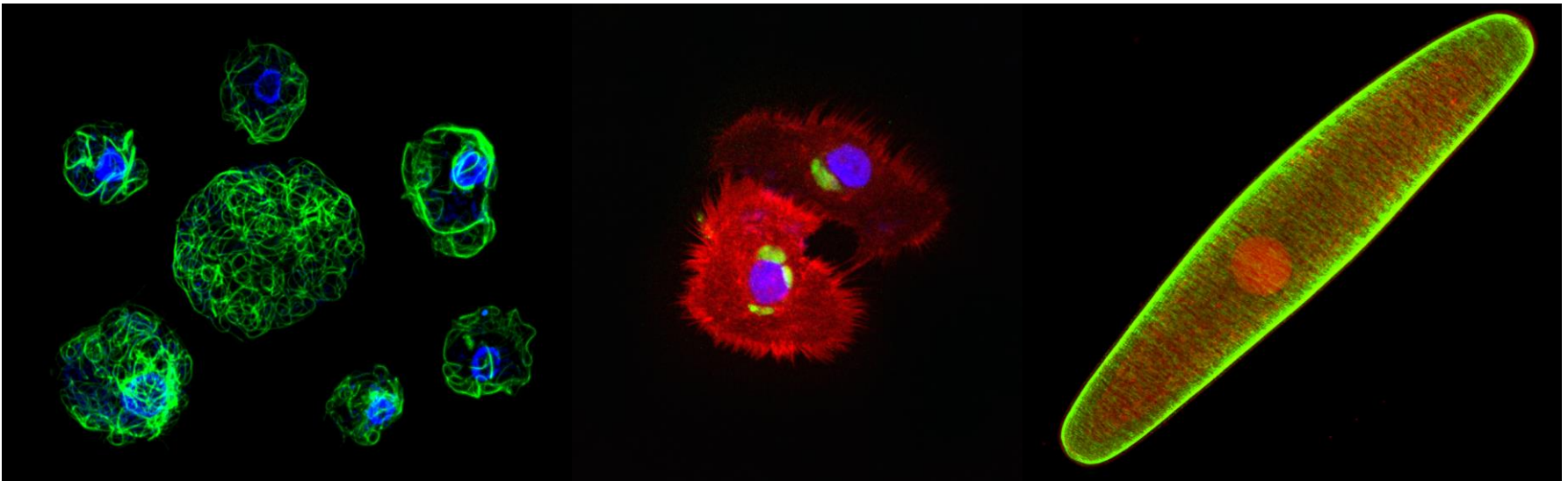
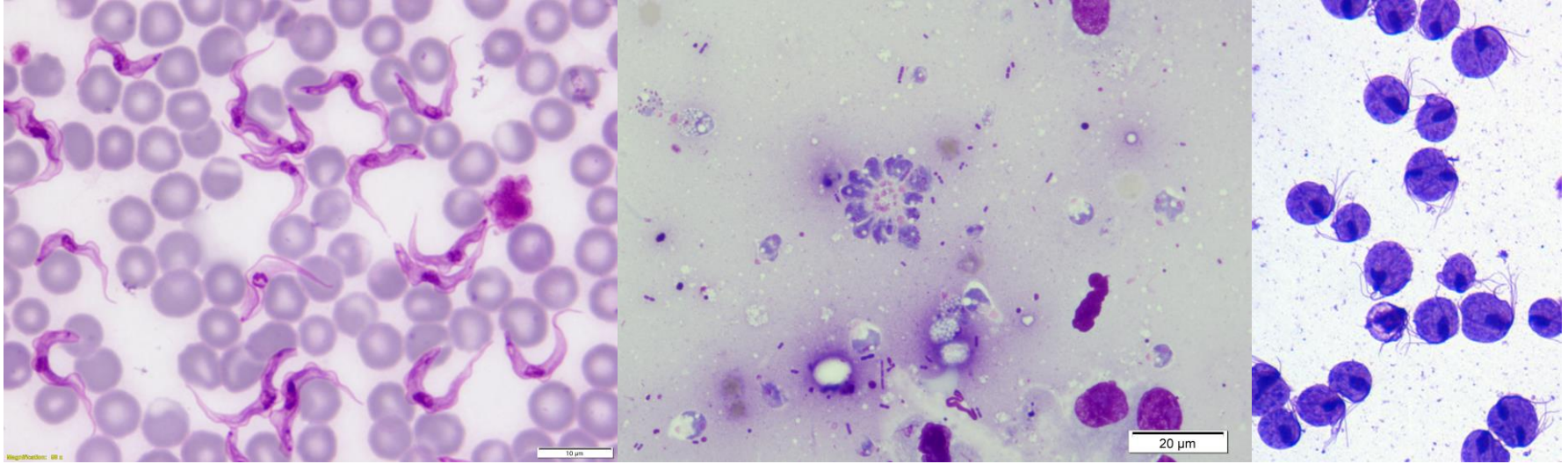
<http://journals.plos.org/plosone/article?id=info:doi/10.1371/journal.pone.0130114>

# Methodology of protozoology / protistology

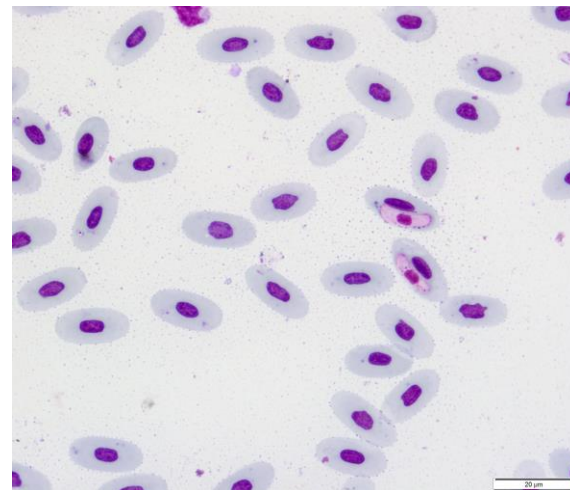
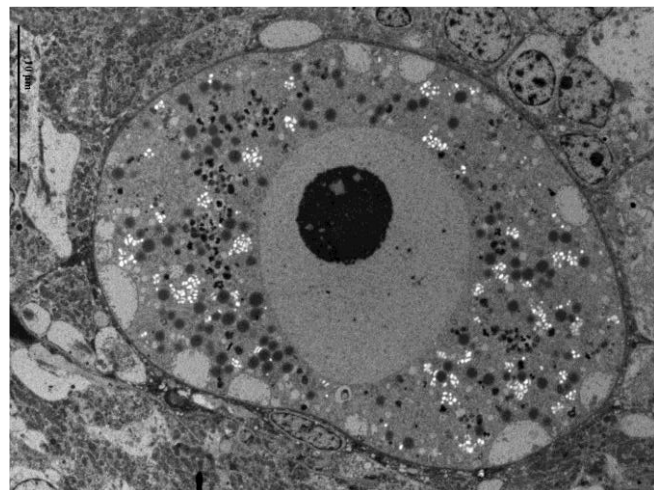
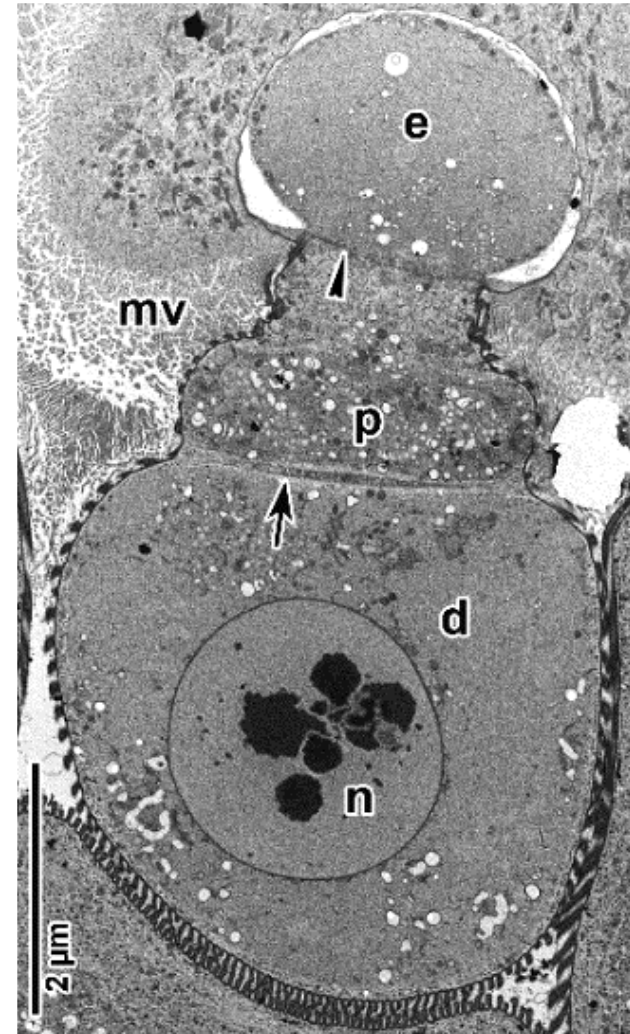
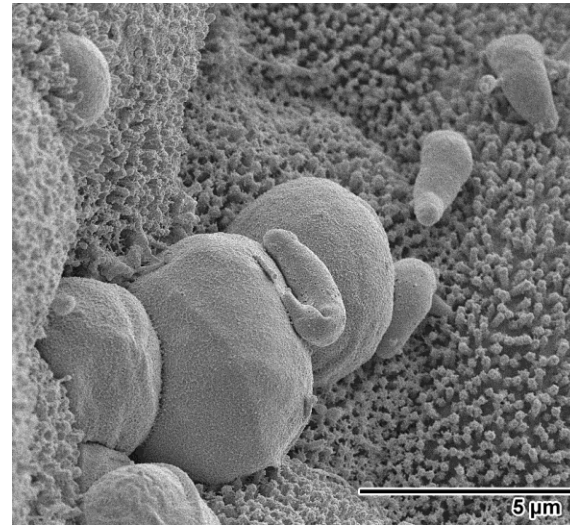
- ✓ light microscopy
- ✓ electron microscopy
- ✓ experimental assays
- ✓ biochemistry
- ✓ genetics
- ✓ genomics
- ✓ proteomics
- ✓ ...



# Diversity in general morphology and subcellular organisation of parasitic protists



# Lifestyle and niche diversity in parasitic protists



Thank you for your attention 😊

# Lectures

✓ Introduction: BPP 2022 I

⇒ **Euglenozoa (Excavata): BPP 2022 II**

- Fornicata / Preaxostyla / Parabasala (Excavata): BPP 2022 III
- Apicomplexa I (SAR): BPP 2022 IV
- Apicomplexa II (SAR): BPP 2022 V
- Amoebae (Excavata, Amoebozoa): BPP 2022 VI
- Ciliophora, Opalinata (SAR): BPP 2022 VII

- *Pneumocystis* (Opisthokonta, Fungi): BPP 2022 VIII
- Microsporidia (Opisthokonta, Fungi): BPP 2022 IX
- Myxozoa (Opisthokonta, Animalia): BPP 2022 X