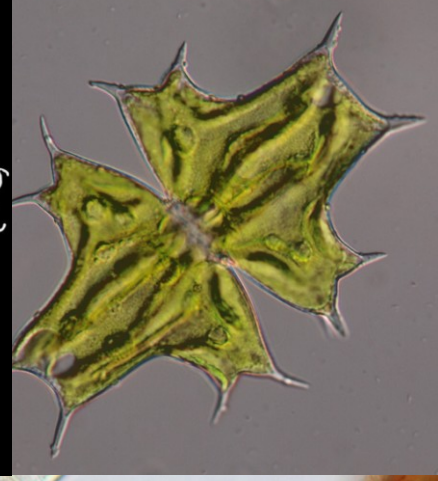
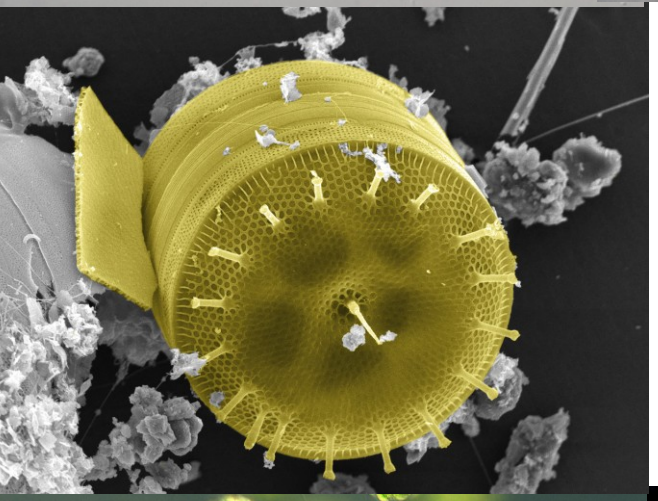
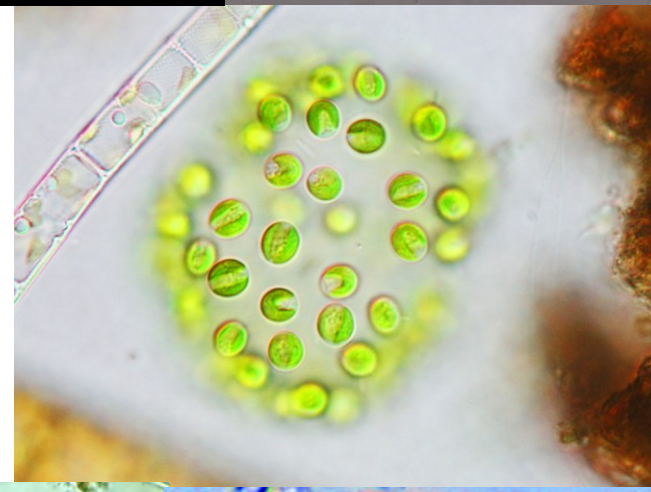
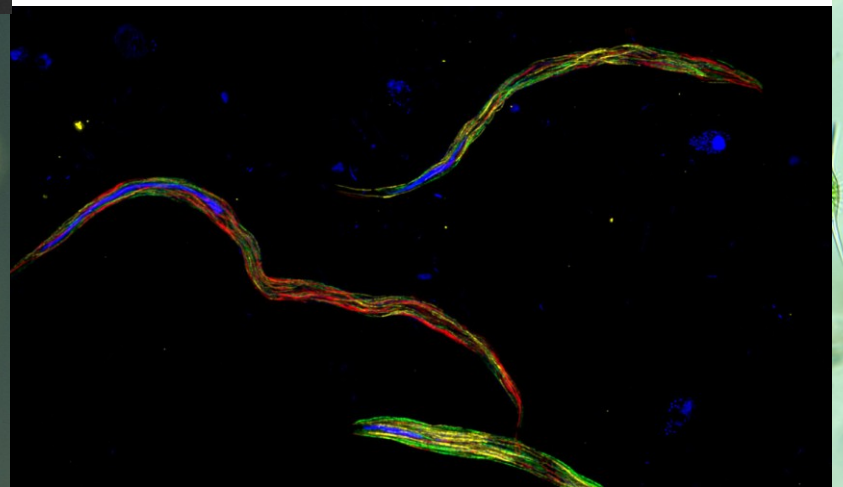


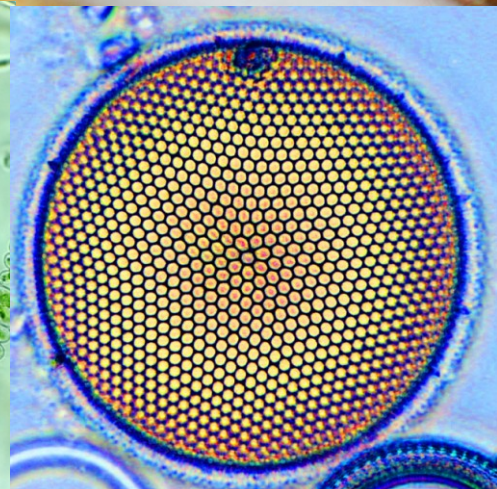


Bunečná biologie prvoků

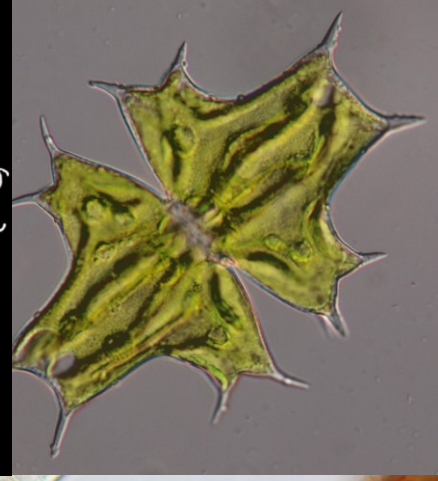
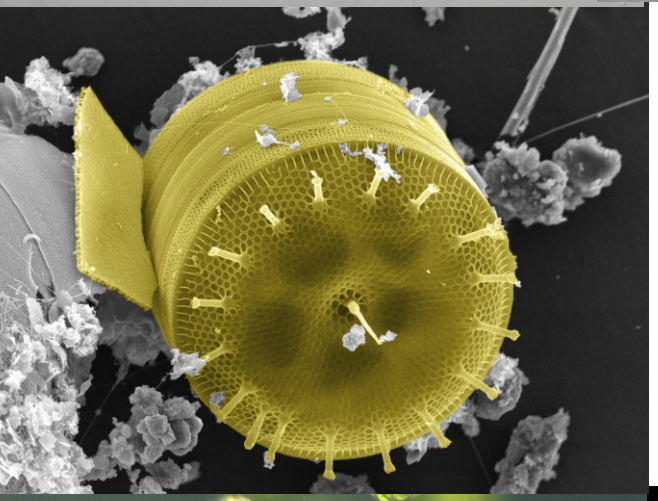




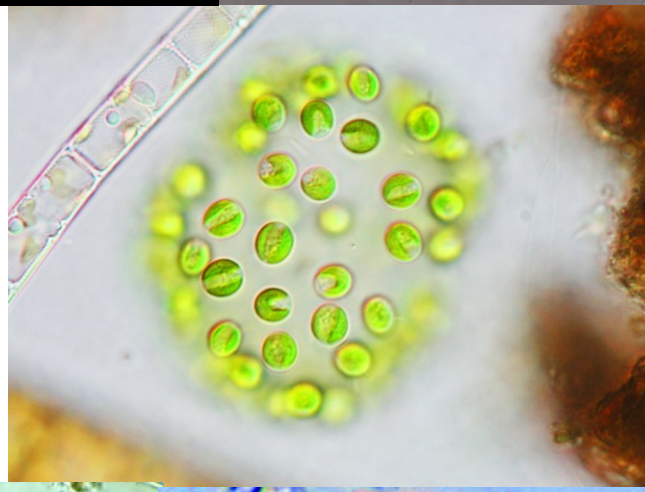


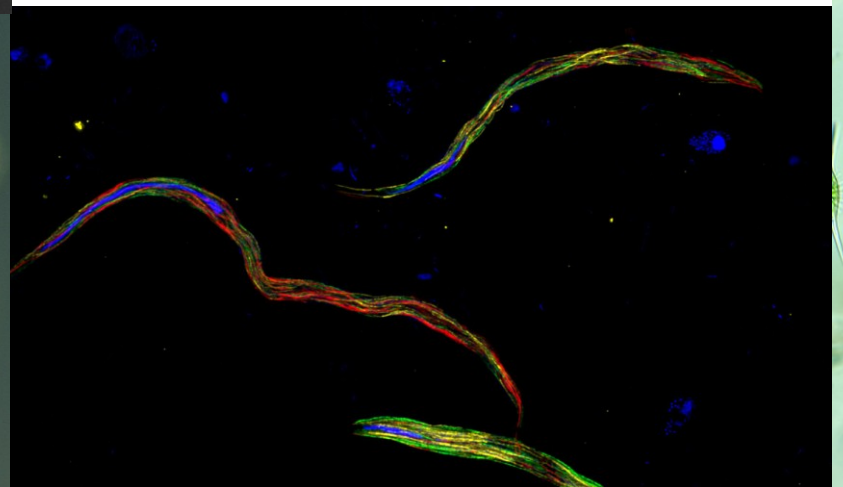


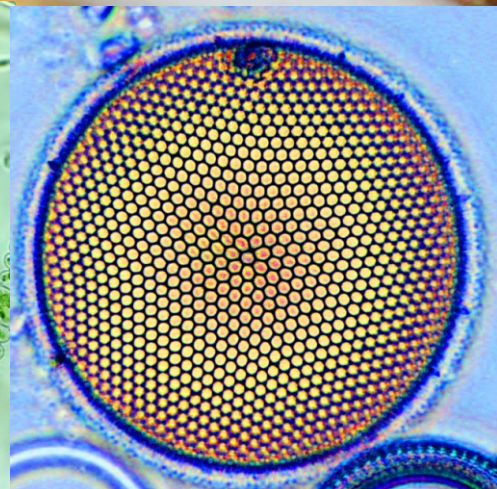


ČEHO?!

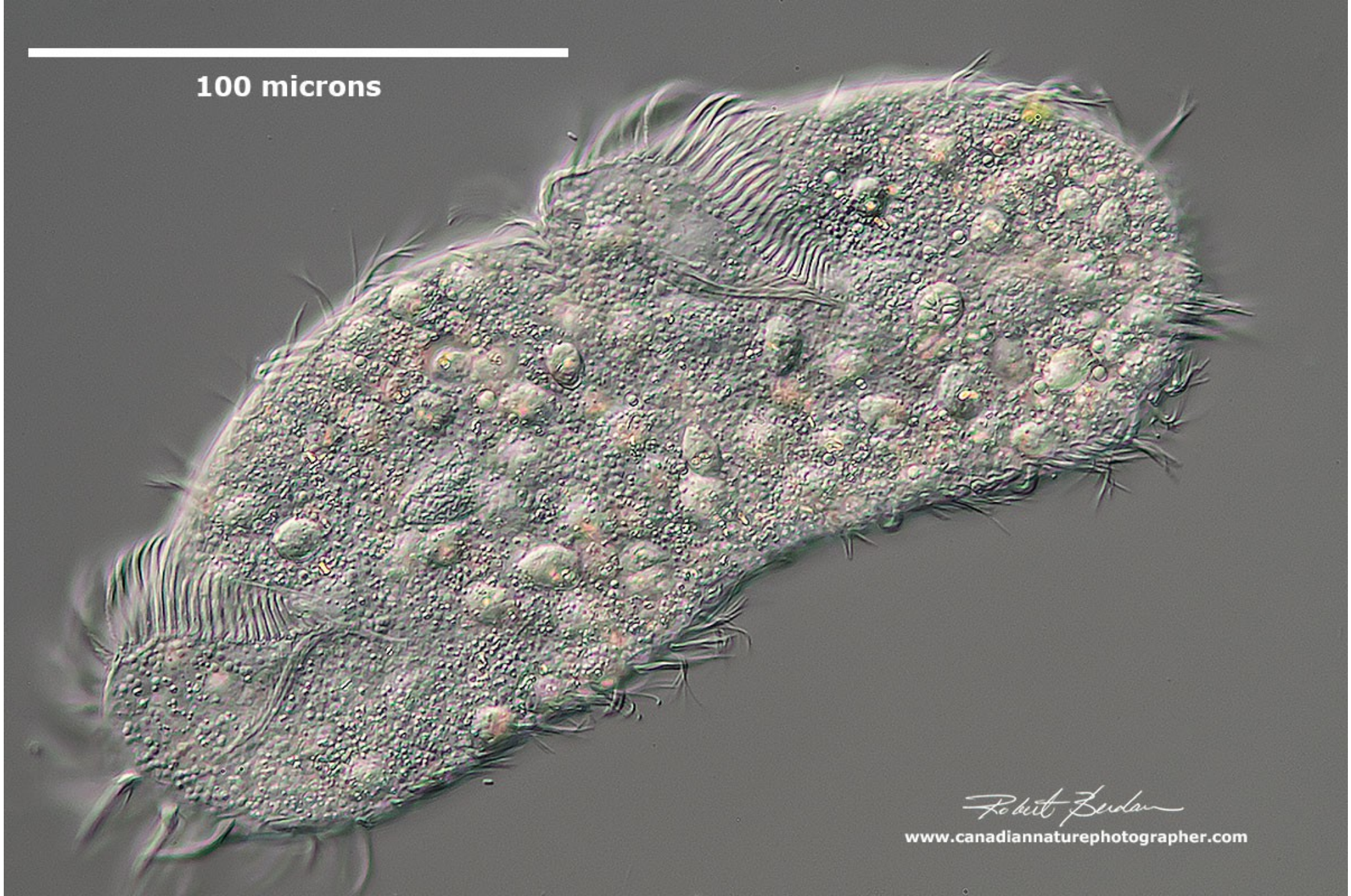


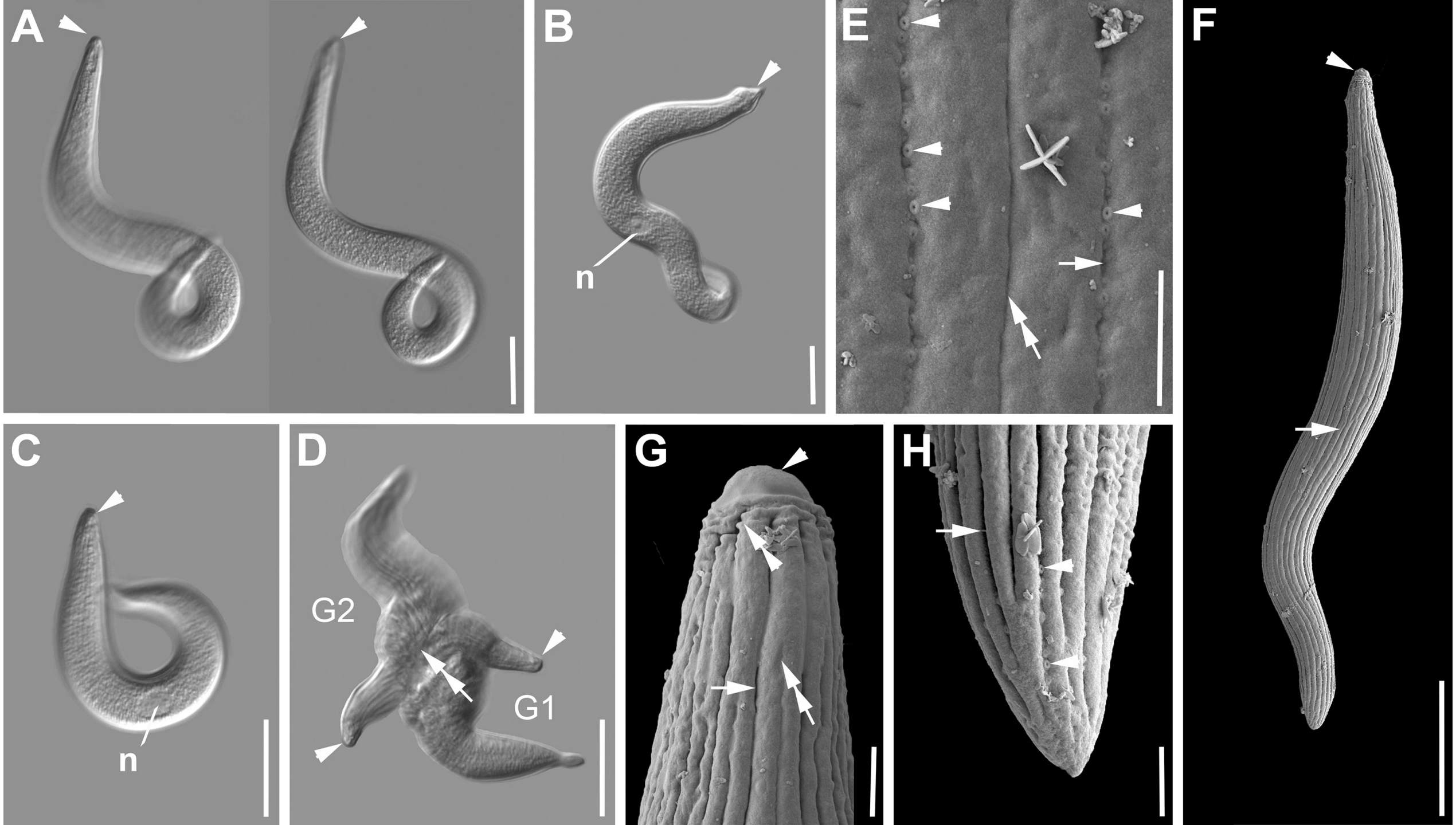




Co to jako je?

Co to jako není?


100 microns
Robert Berdan
www.canadiannaturephotographer.com


A
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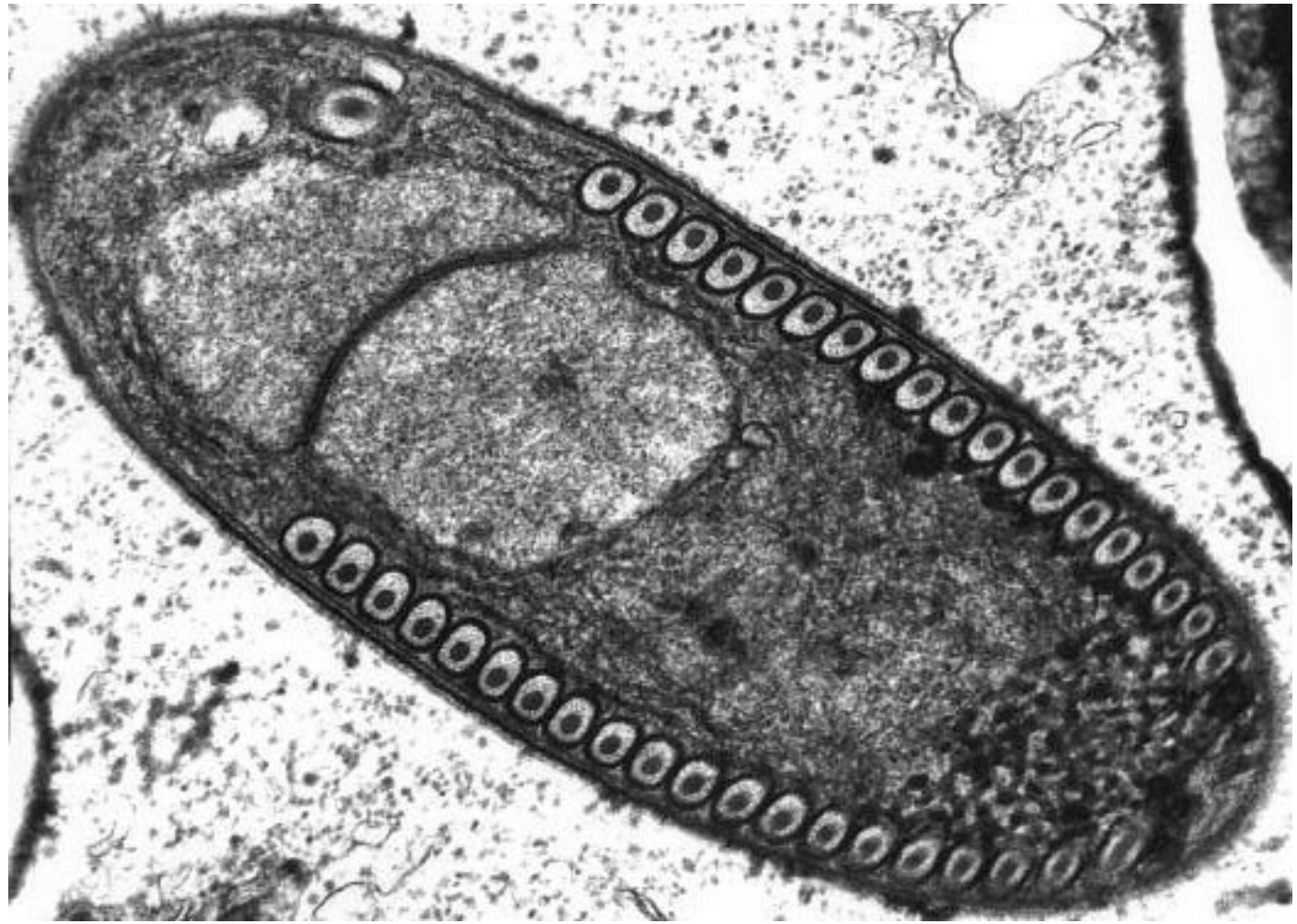
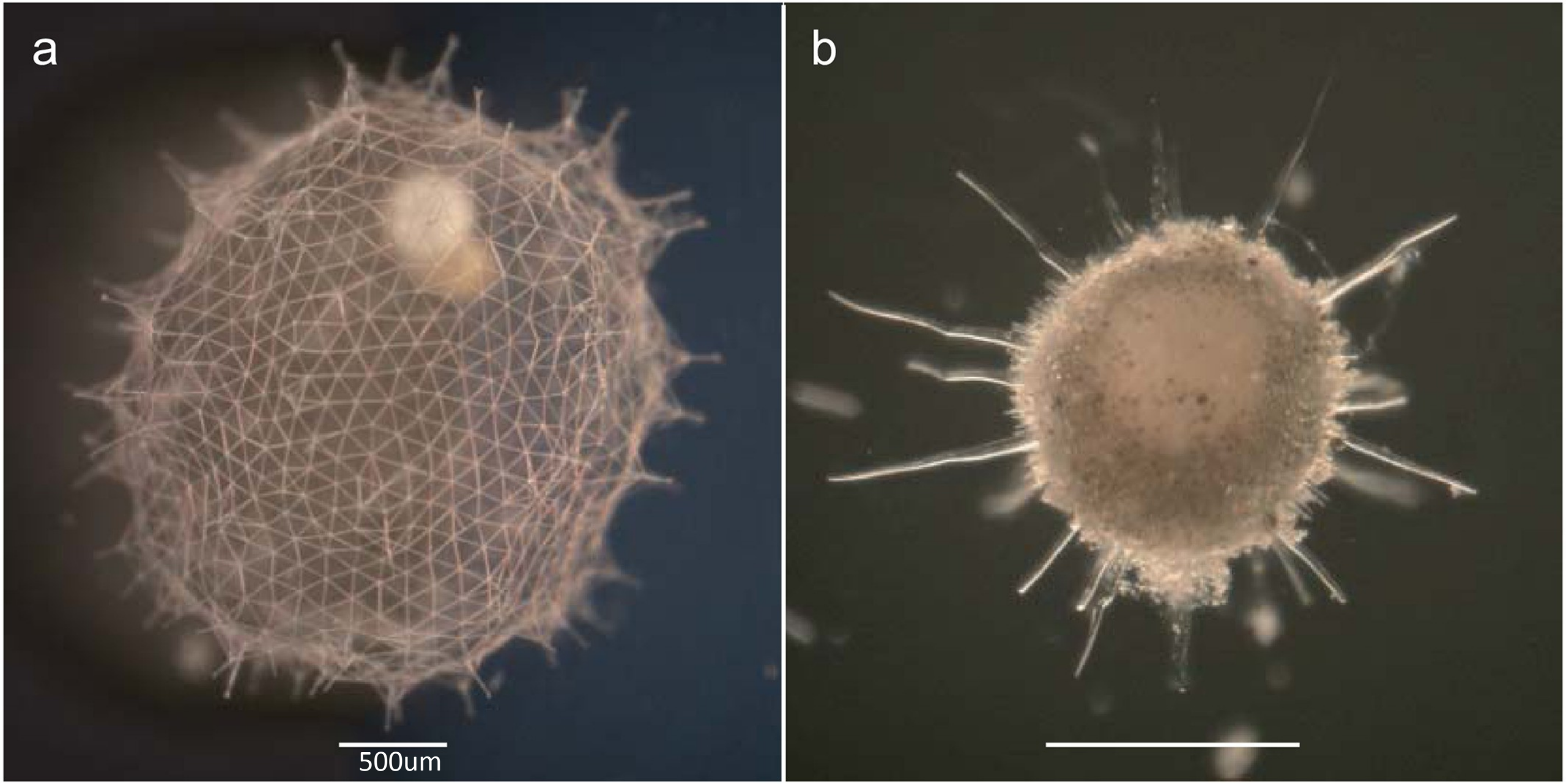
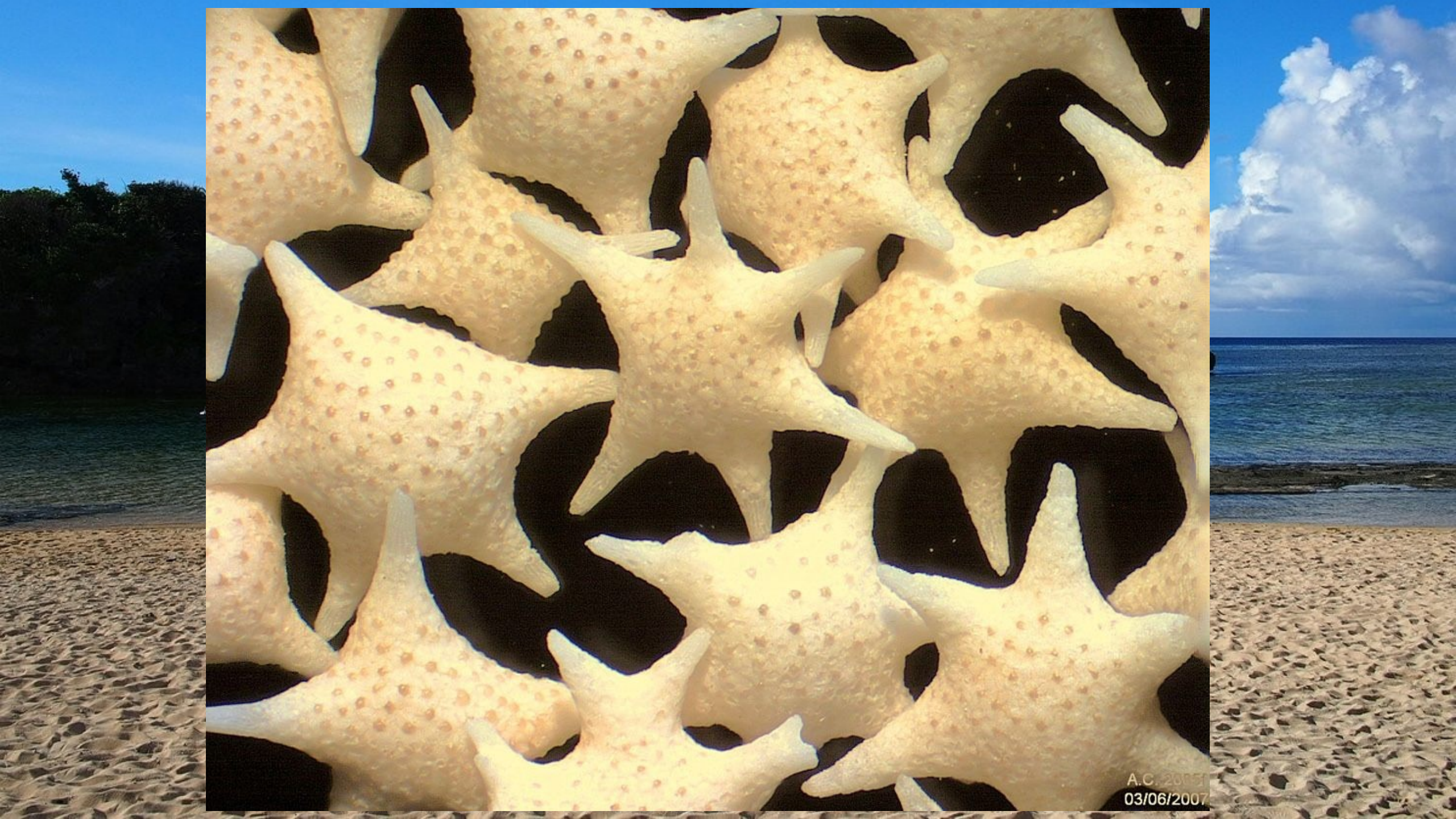


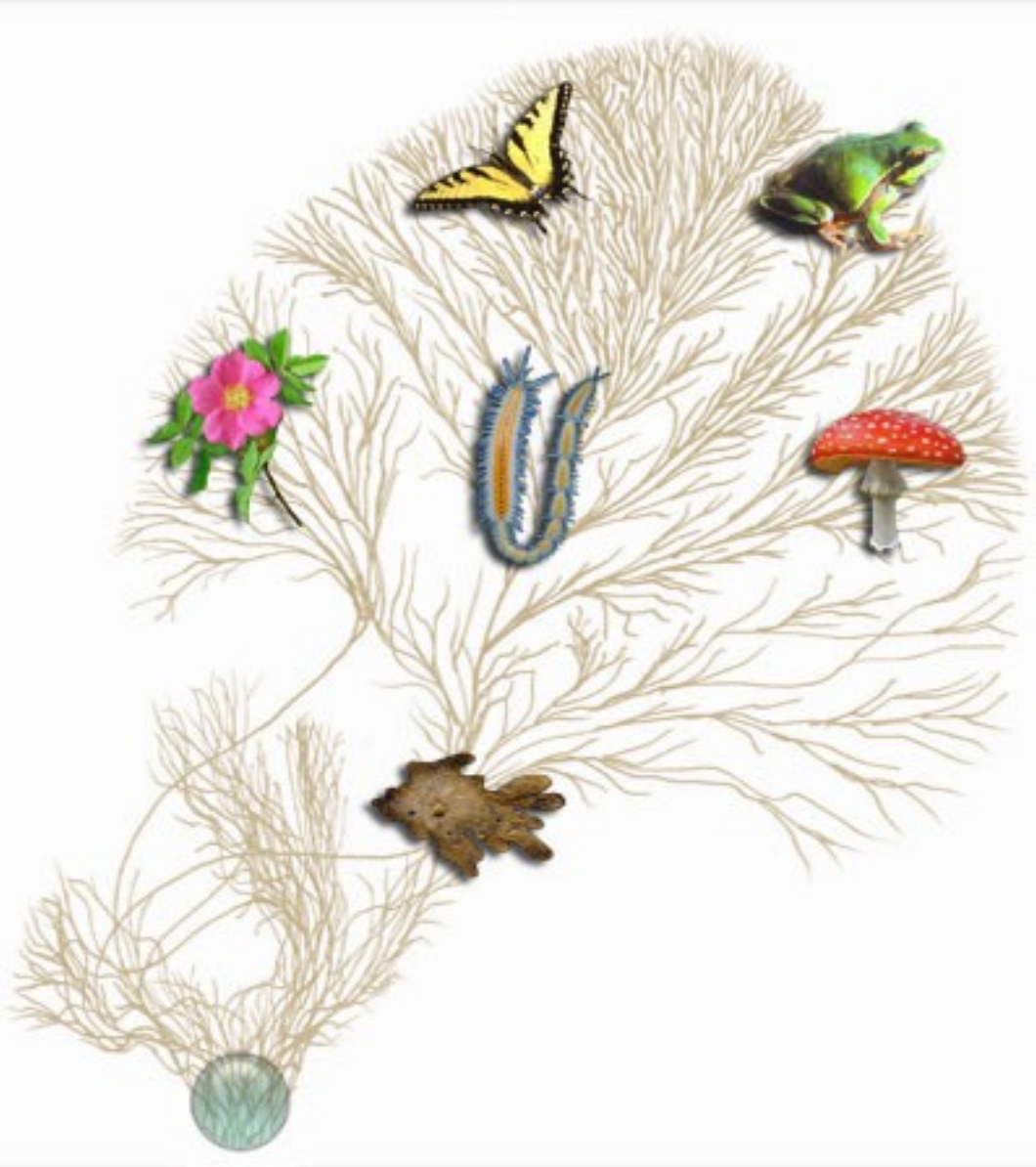


Biard, et al. 2018 *Global Biogeochemical Cycles*

By Alexander Vasenin - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=25459491


03/06/2007

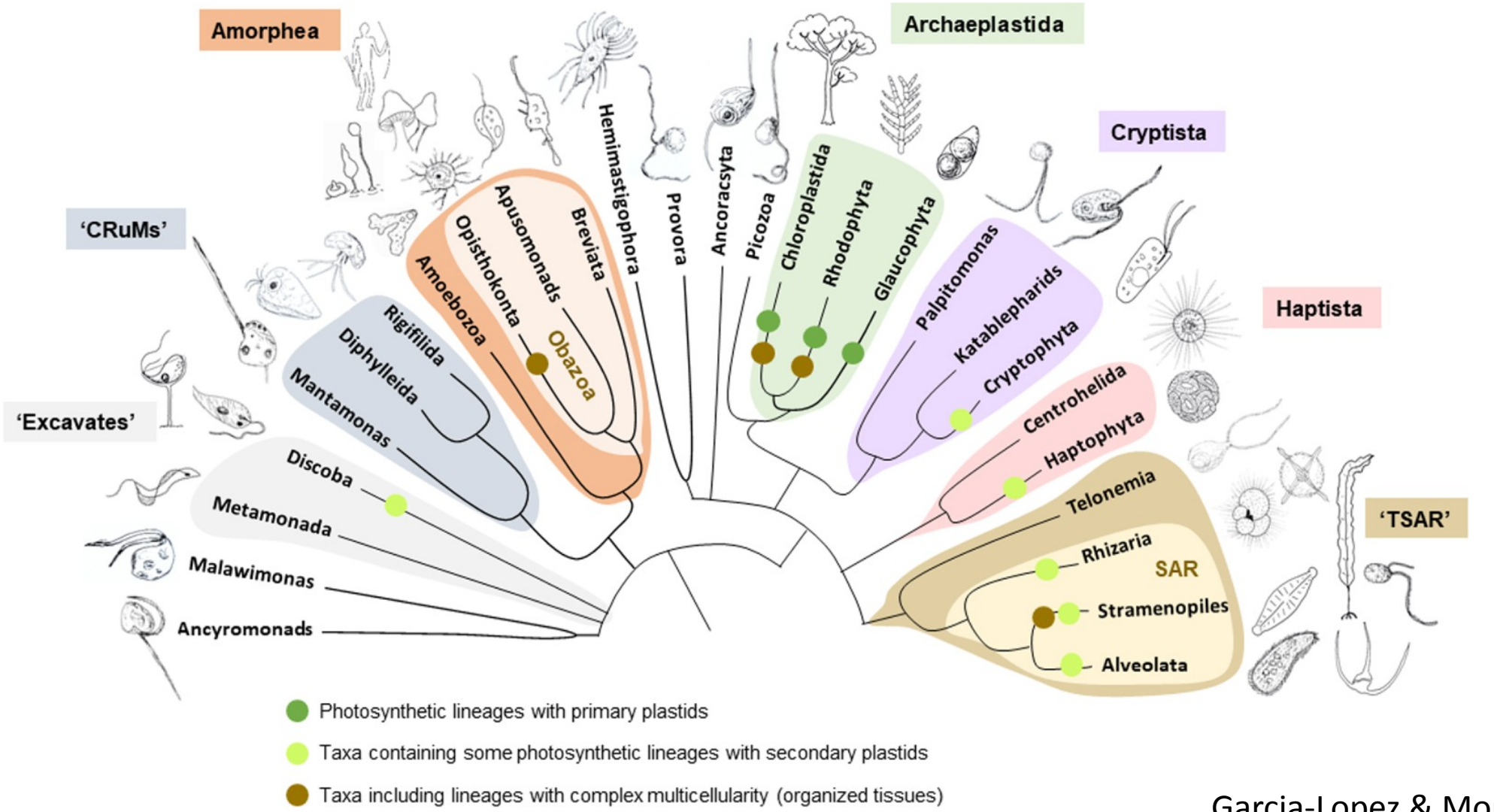
Podle Tree of life



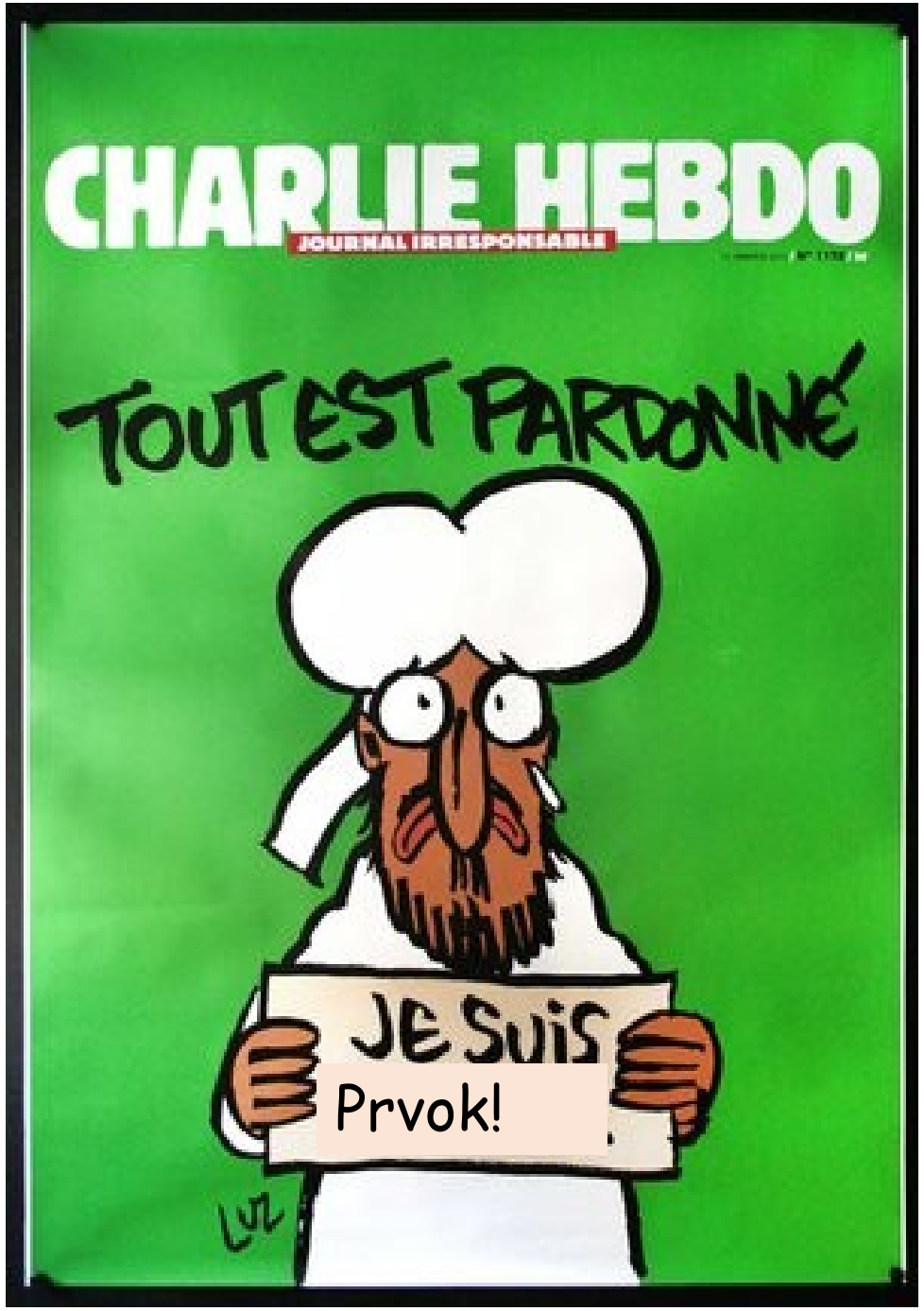
http://tolweb.org/tree/

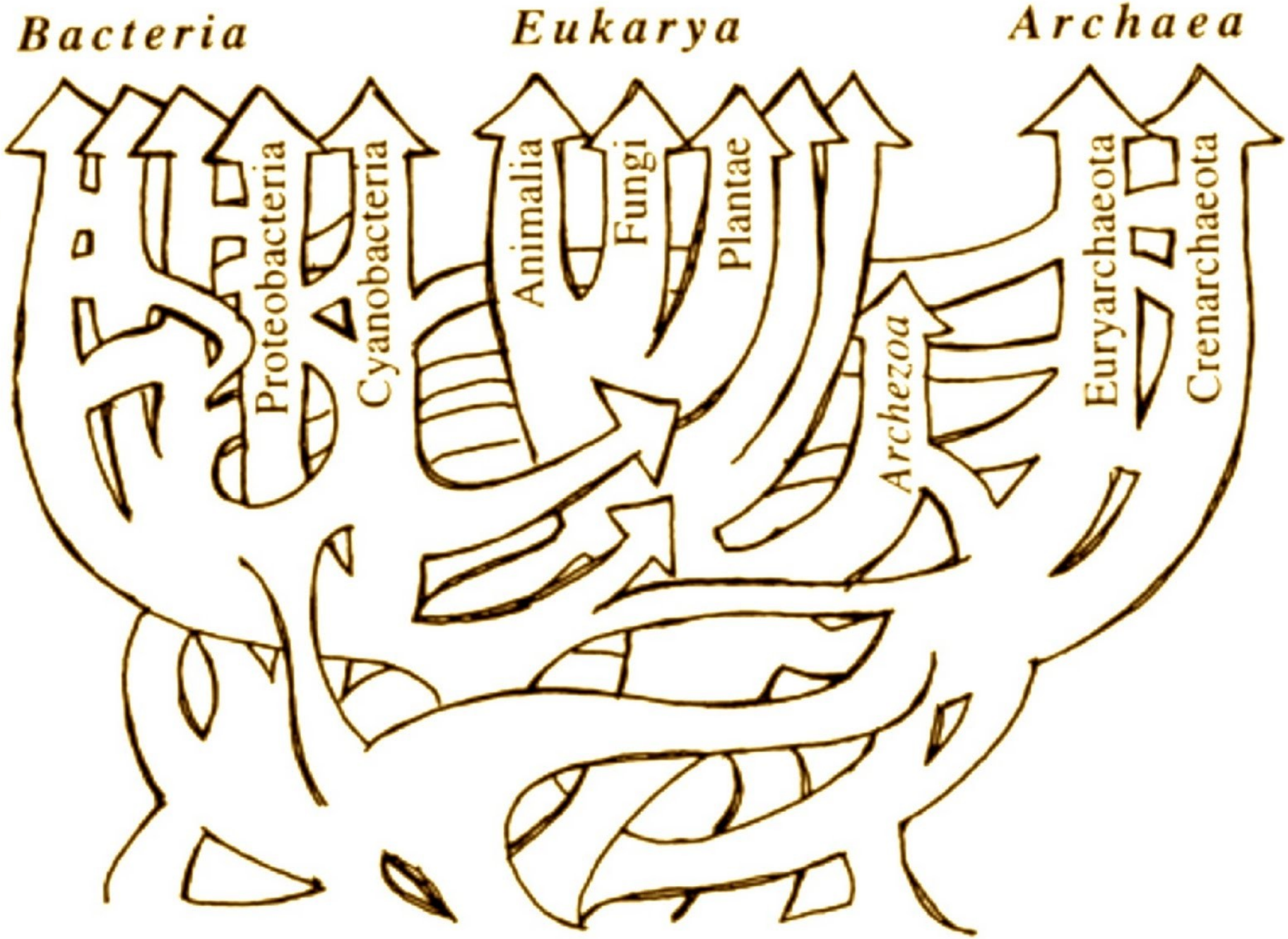
Prvoci = Eukaryota

Eukaryota = Prvoci!



Garcia-Lopez & Moreira 2023


CHARLIE HEBDO
JOURNAL IRRESPONSABLE
TOUT EST PARDONNÉ
JE SUIS
Prvok!
LUZ


Bacteria
Eukarya
Archaea
Proteobacteria
Cyanobacteria
Animalia
Fungi
Plantae
Archezoa
Euryarchaeota
Crenarchaeota

Prokaryota vs. Eukaryota

Co definuje eukaryota?

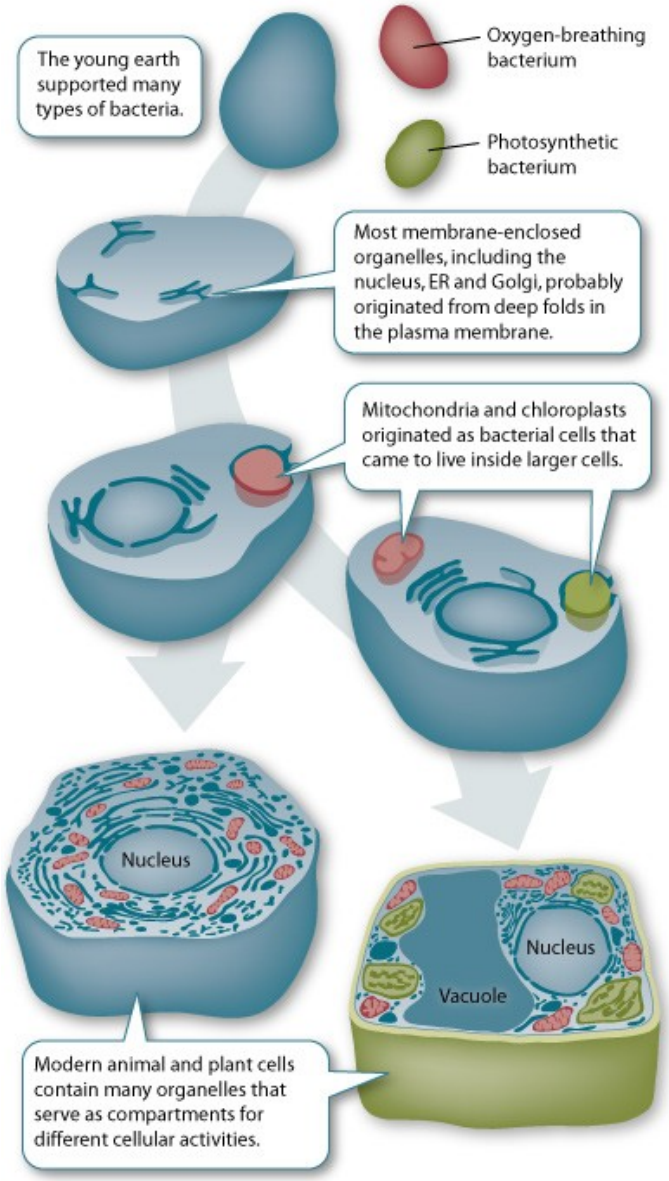
Archiv für Mikrobiologie 42, 17—35 (1962)

From the Department of Bacteriology, University of California, Berkeley,
and the Hopkins Marine Station of Stanford University, Pacific Grove, California

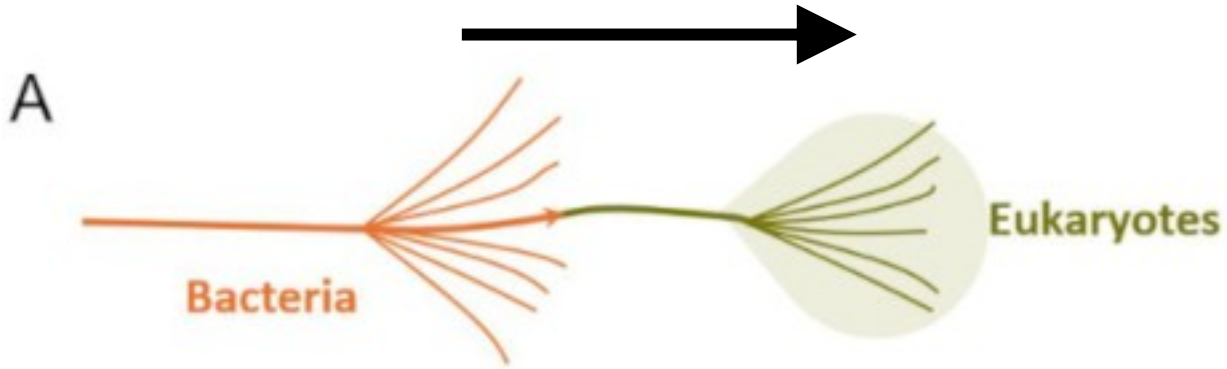
The Concept of a Bacterium*

By
R. Y. STANIER and C. B. VAN NIEL

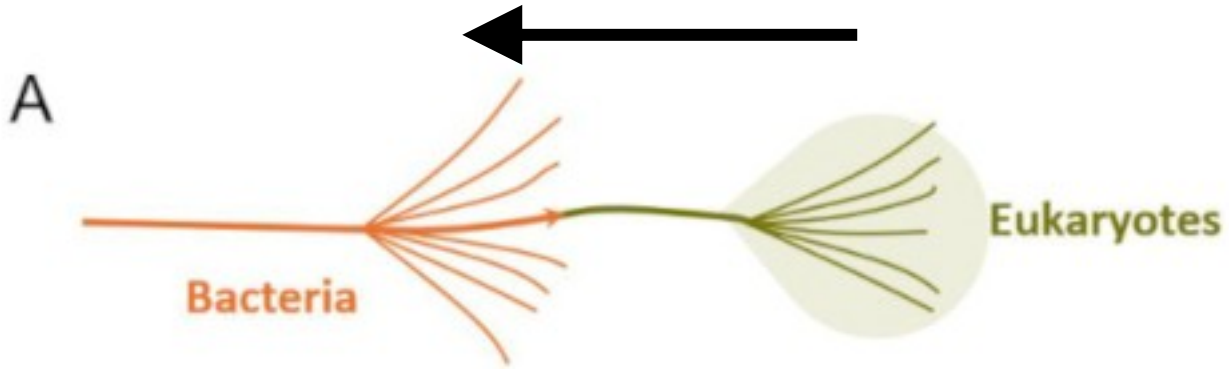
Klasická darwinovská evoluční teorie předpokládá nárust komplexity živých systémů v čase



Kde se tady vzali? I.



Postupný nárůst komplexity ”jednoduché” prokaryotické buňky (thylakoidy sinic, Cavalier-Smith 1975)



Postupná redukce komplexity eukaryotické buňky (RNA splicingRearney 1974, Darnell 1978)

EOCYT – eukaryota vznikla z divezifikované linie archaeí - eocytů

Eocytes: A new ribosome structure indicates a kingdom with a clos relationship to eukaryotes

(eocyta/eocytic gap/parsimony analysis/unrooted dendrogram/electron microscopy)

JAMES A. LAKE, ERIC HENDERSON, MELANIE OAKES, AND MICHAEL W. CLARK

Molecular Biology Institute and Department of Biology, University of California, Los Angeles, CA 90024

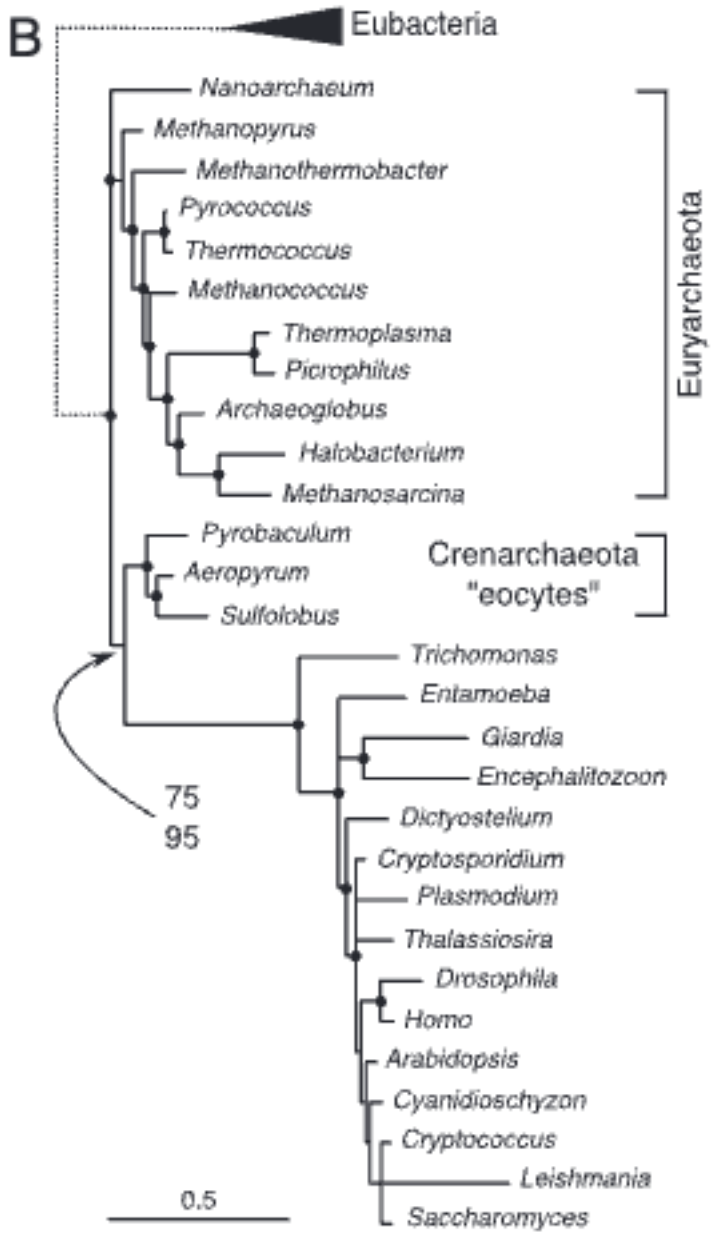
Communicated by Everett C. Olson, March 12, 1984

The archaebacterial origin of eukaryotes

Cymon J. Cox[a,1], Peter G. Foster[a,1], Robert P. Hirt[b], Simon R. Harris[b], and T. Martin Embley[b,1]

[a]Department of Zoology, Natural History Museum, Cromwell Road, London, SW7 5BD, United Kingdom; and [b]Institute for Cell and Molecular Biosciences, Newcastle University, Newcastle, NE2 4HH, United Kingdom

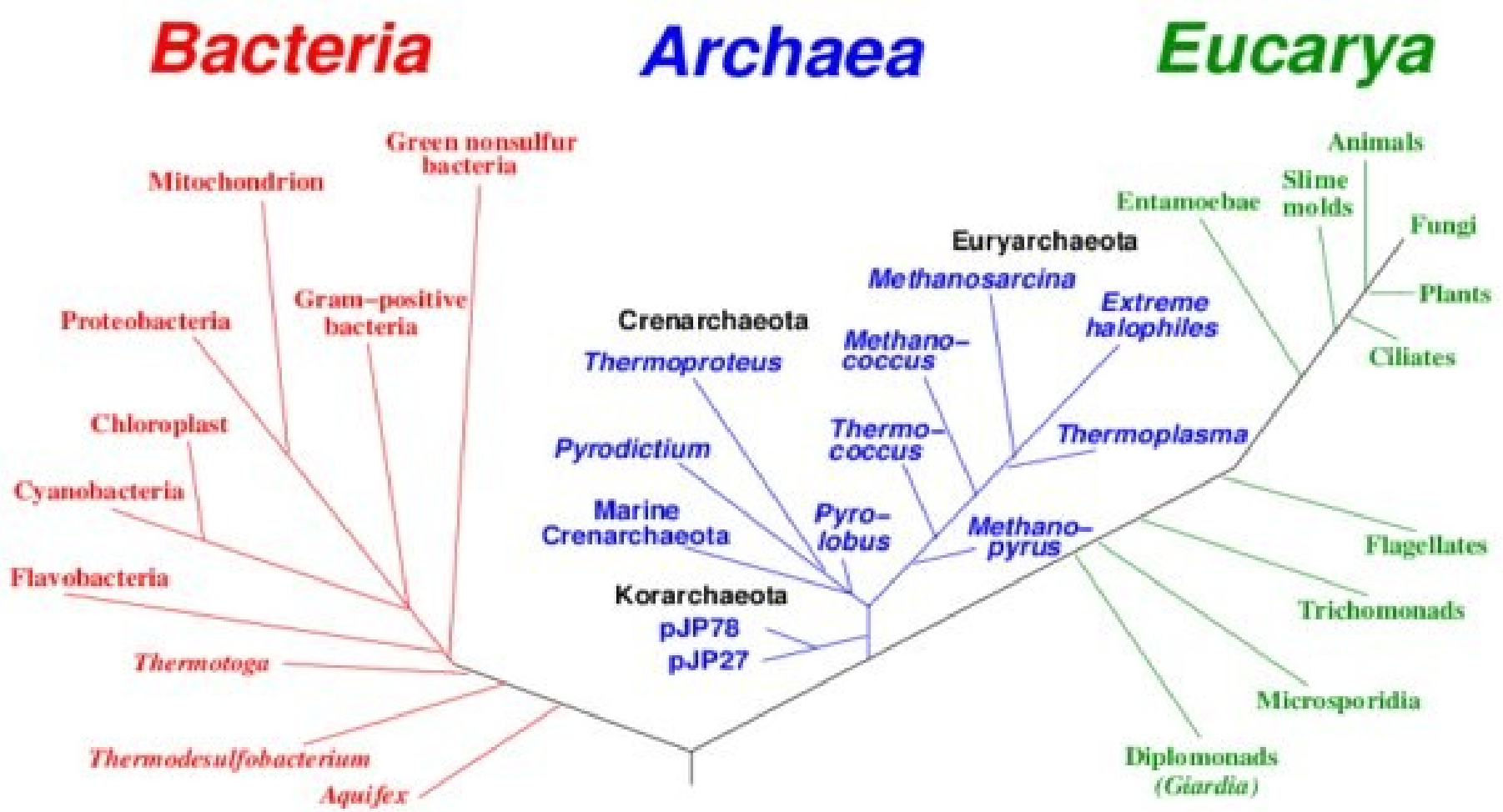
Communicated by Jeffrey D. Palmer, Indiana University, Bloomington, IN, October 24, 2008 (received for review April 16, 2008)



Kde se tady vzali? II.

Objev Archaea – třídoménový systém buněčných organismů

Arc
nav
arc

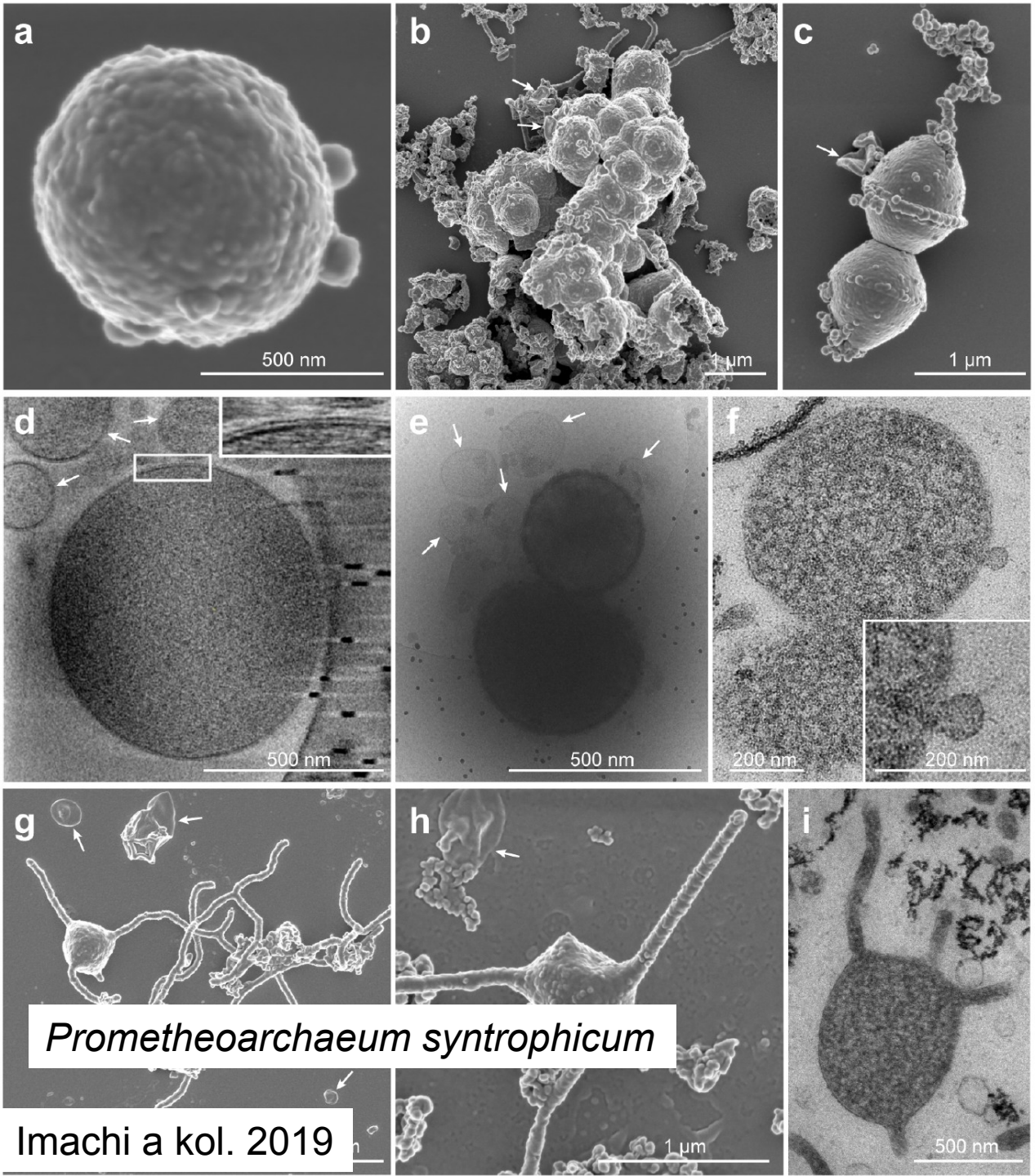


Woese et al., 1990

fylogenetický přístup nutí přehodnotit pohled na evoluci eukaryot

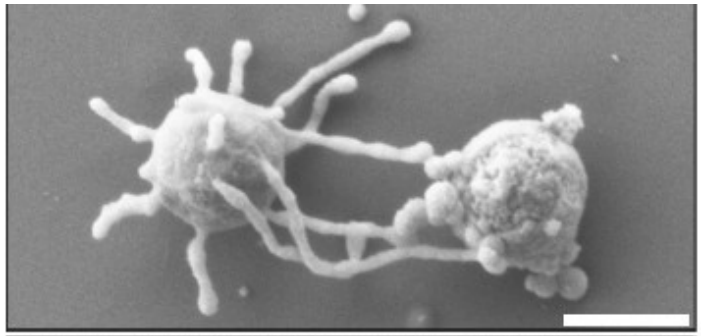
Kde se tady vzali? II.

Božský původ Eukaryot?

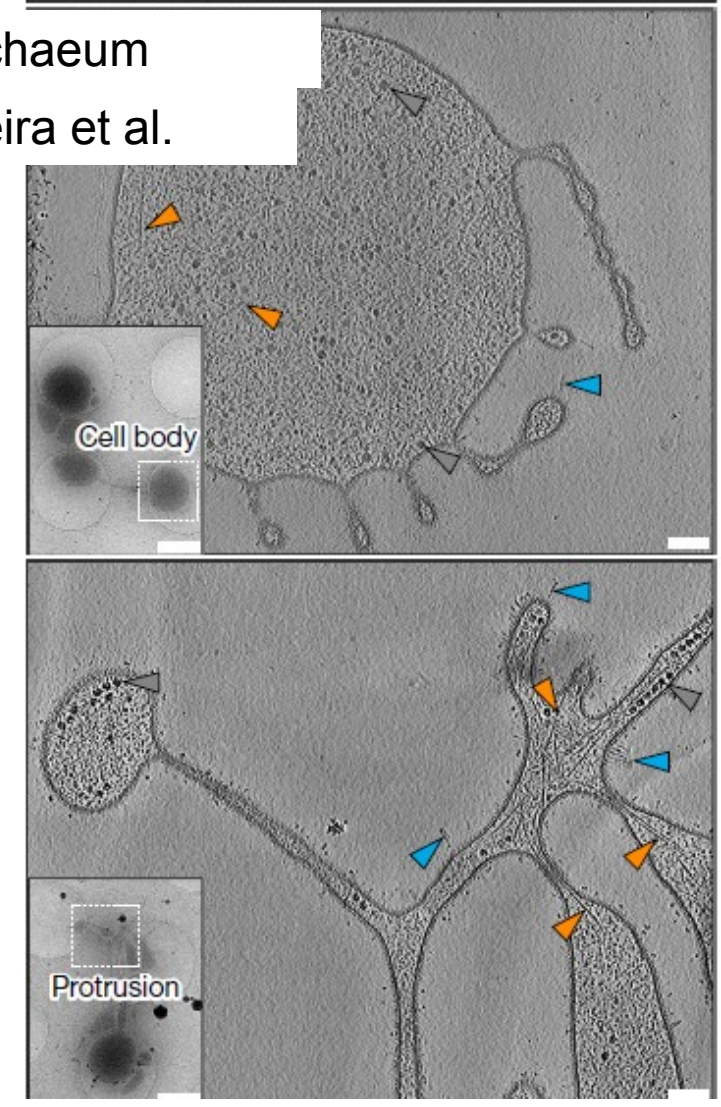


Prometheoarchaeum syntrophicum

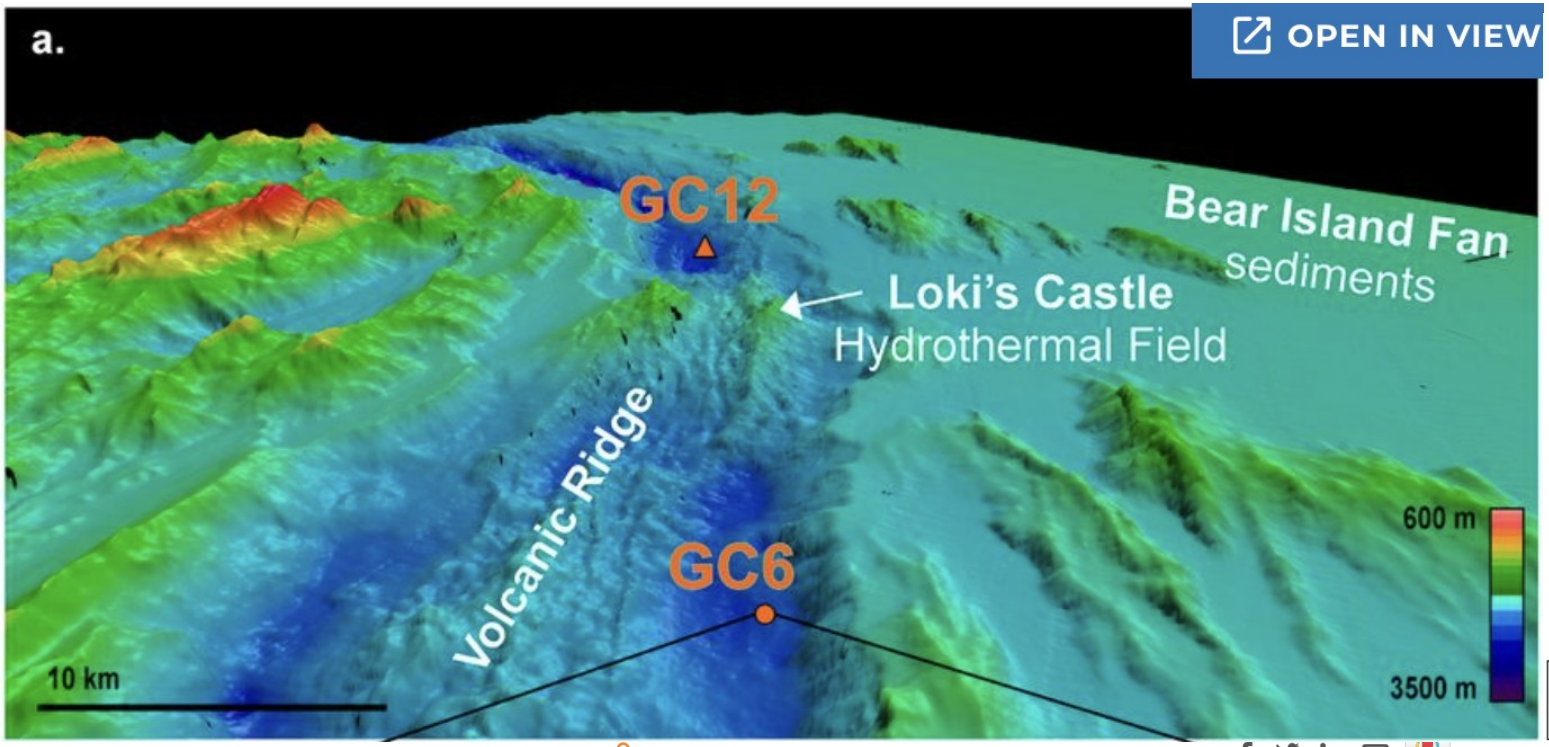
Imachi a kol. 2019

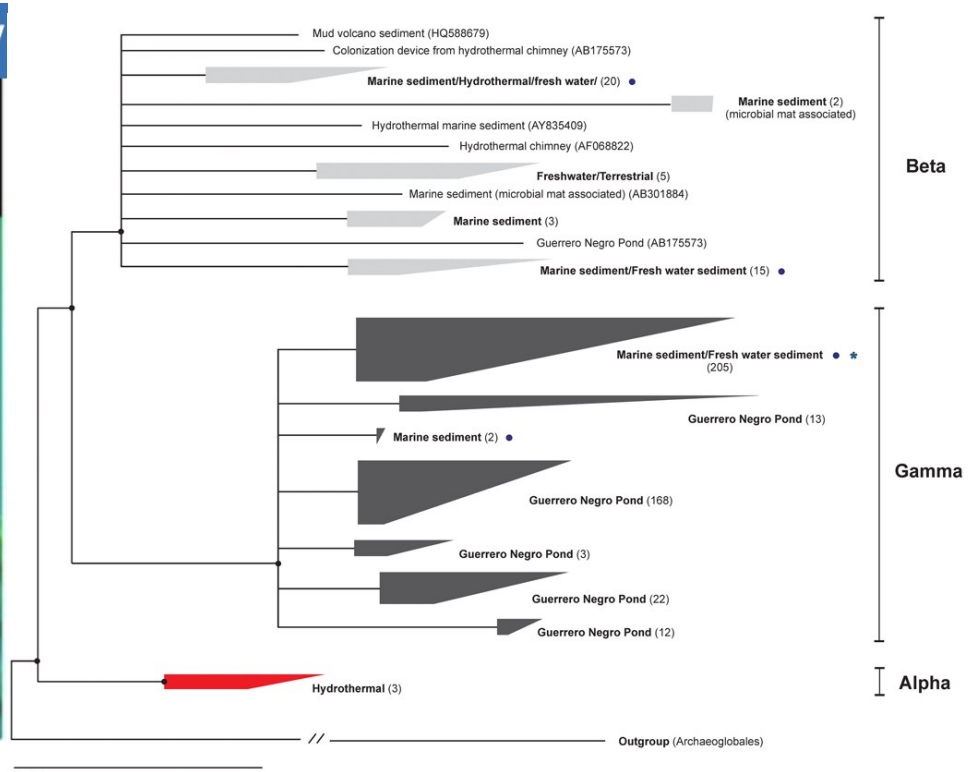


Candidatus Lokiarchaeum os Rodrigues-Oliveira et al. 2022



Kde se tady vzali? II.





RESEARCH ARTICLE | ENVIRONMENTAL SCIENCES |

Correlating microbial community profiles with geochemical data in highly stratified sediments from the Arctic Mid-Ocean Ridge

Steffen Leth Jorgensen, Bjarte Hannisdal, Anders Lanzén, +7, and Christa Schleper Authors Info & Affiliations

Edited by David M. Karl, University of Hawaii, Honolulu, HI, and approved September 5, 2012 (received for review May 4, 2012)

October 1, 2012 | 109 (42) E2846-E2855 | https://doi.org/10.1073/pnas.1207574109

ORIGINAL RESEARCH article

Front. Microbiol., 04 October 2013

Sec. Extreme Microbiology

Volume 4 - 2013 | https://doi.org/10.3389/fmicb.2013.00299

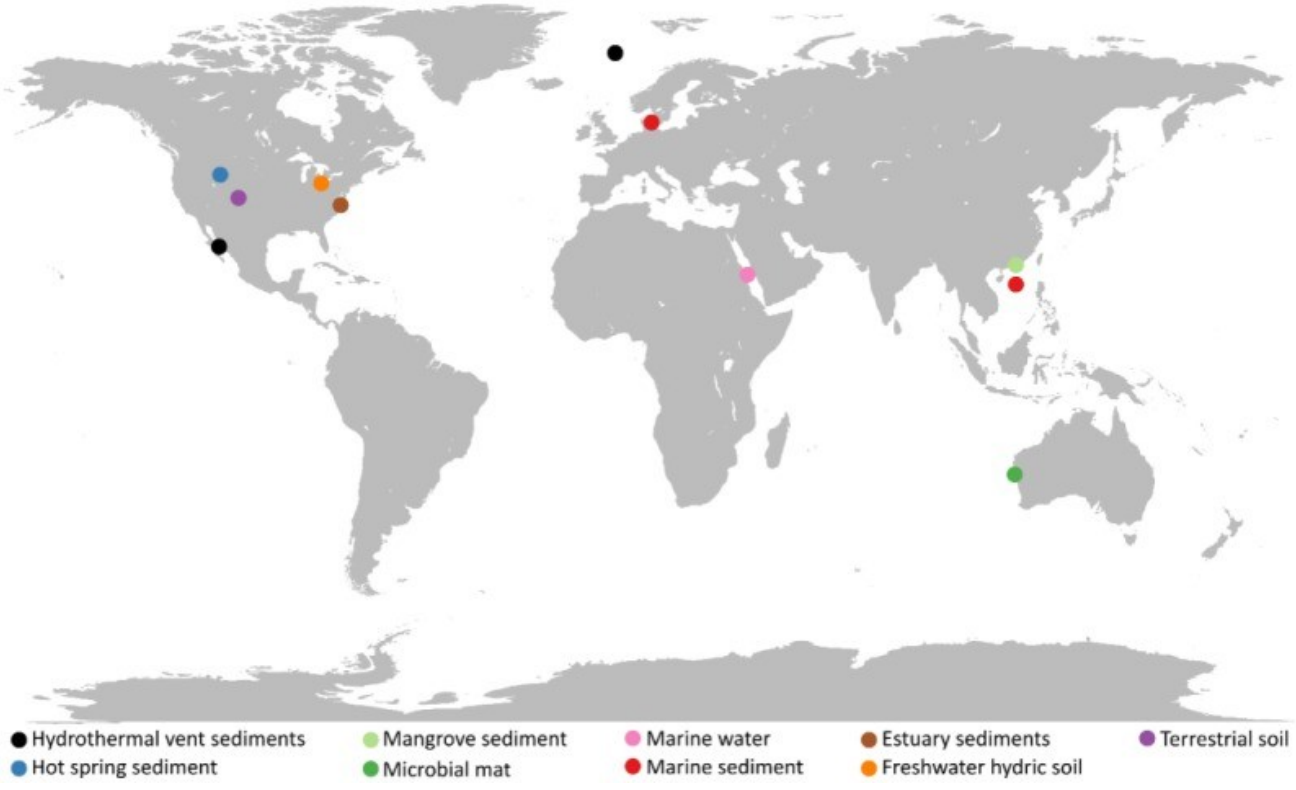
Quantitative and phylogenetic study of the Deep Sea Archaeal Group in sediments of the Arctic mid-ocean spreading ridge

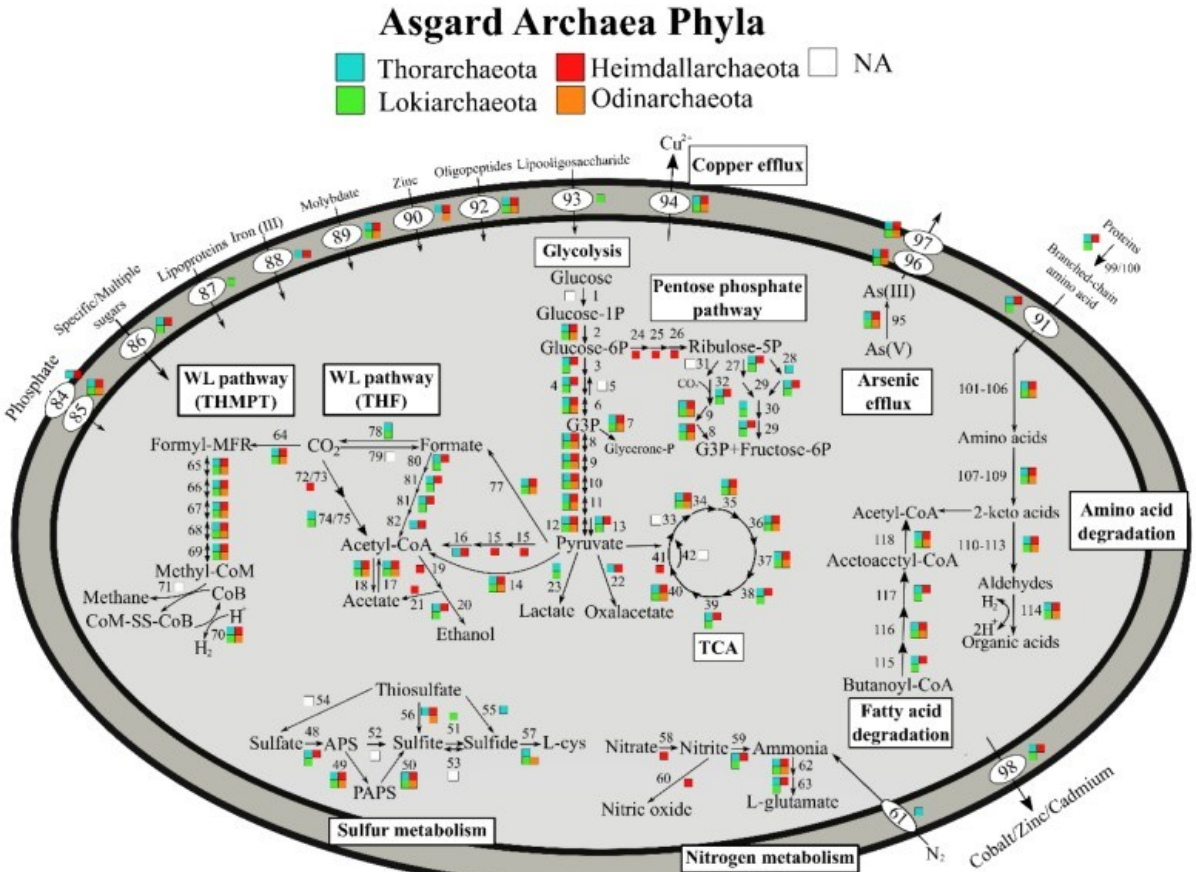
Steffen L. Jørgensen[1]* Ingunn H. Thorseth[2] Rolf B. Pedersen[2] Tamara Baumberger[2,3] Christa Schleper[1,4]

Argard archaea

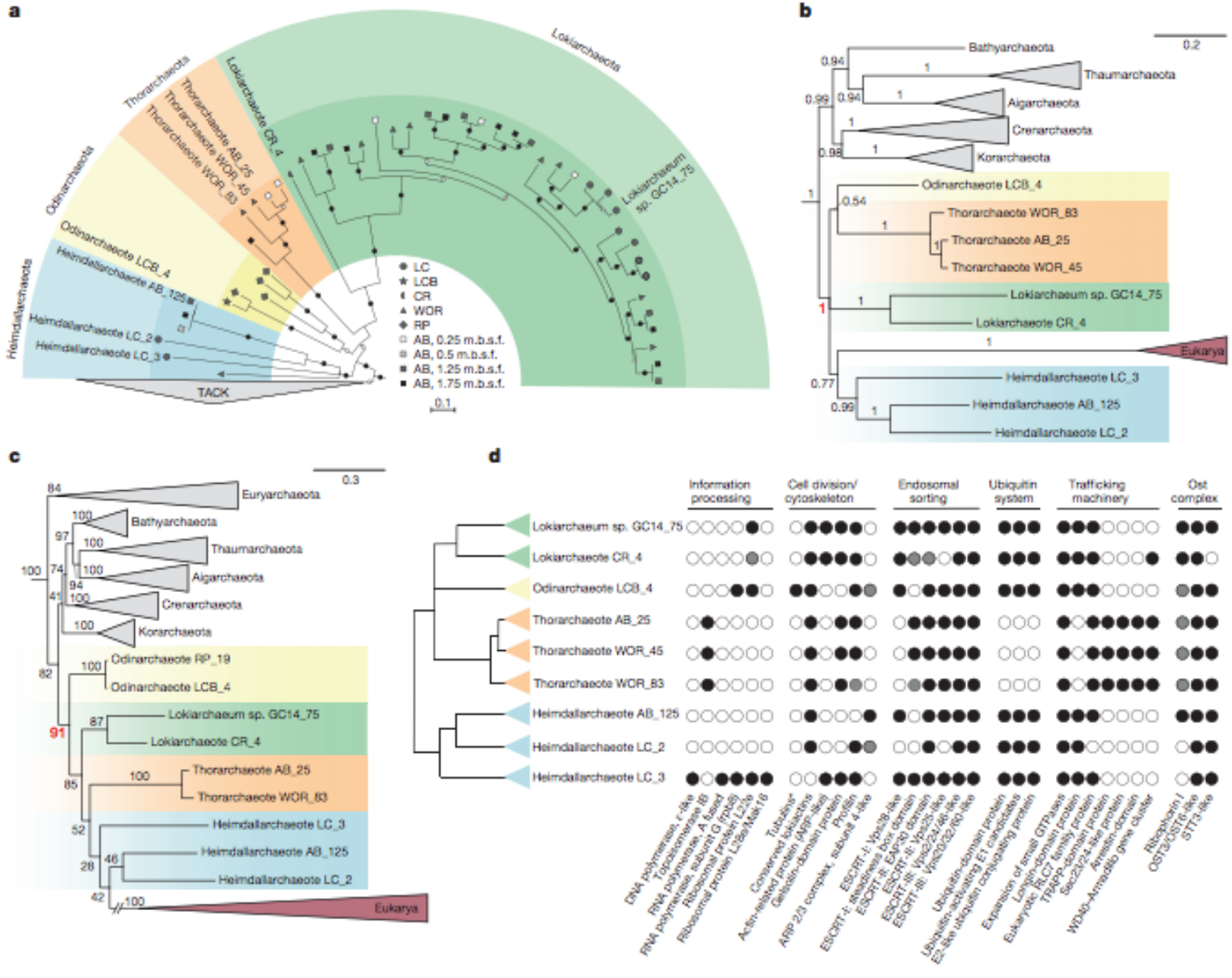
- Extremofilní,
- Chemolitotrofní I heterotrofní (mixo?)
- Glykolýza (vzácně TCA)
- Fixace C pomocí Wood-Ljungdahl (WL) dráhy
- Nejčastěji metanová a hydrotermální zřídla
- Lokiarchaeota jsou asi nejčetnější
- Často v obligátních vztazích s ostatními prokaryoty

MacLeod et al., 2019

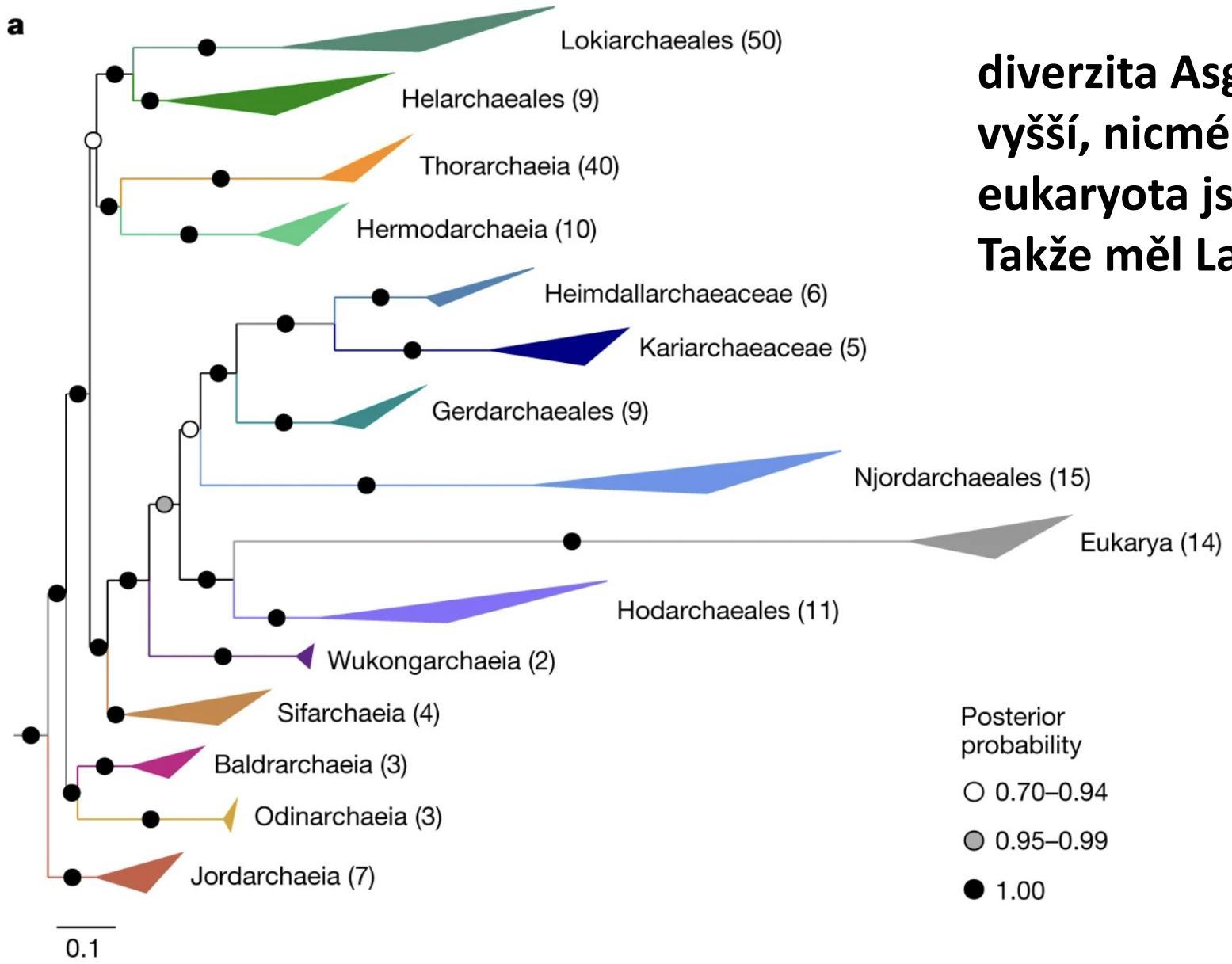




… Nakonec to tedy vypadá, že eukaryota jsou zdivočelá archaea, ASGARD archaea



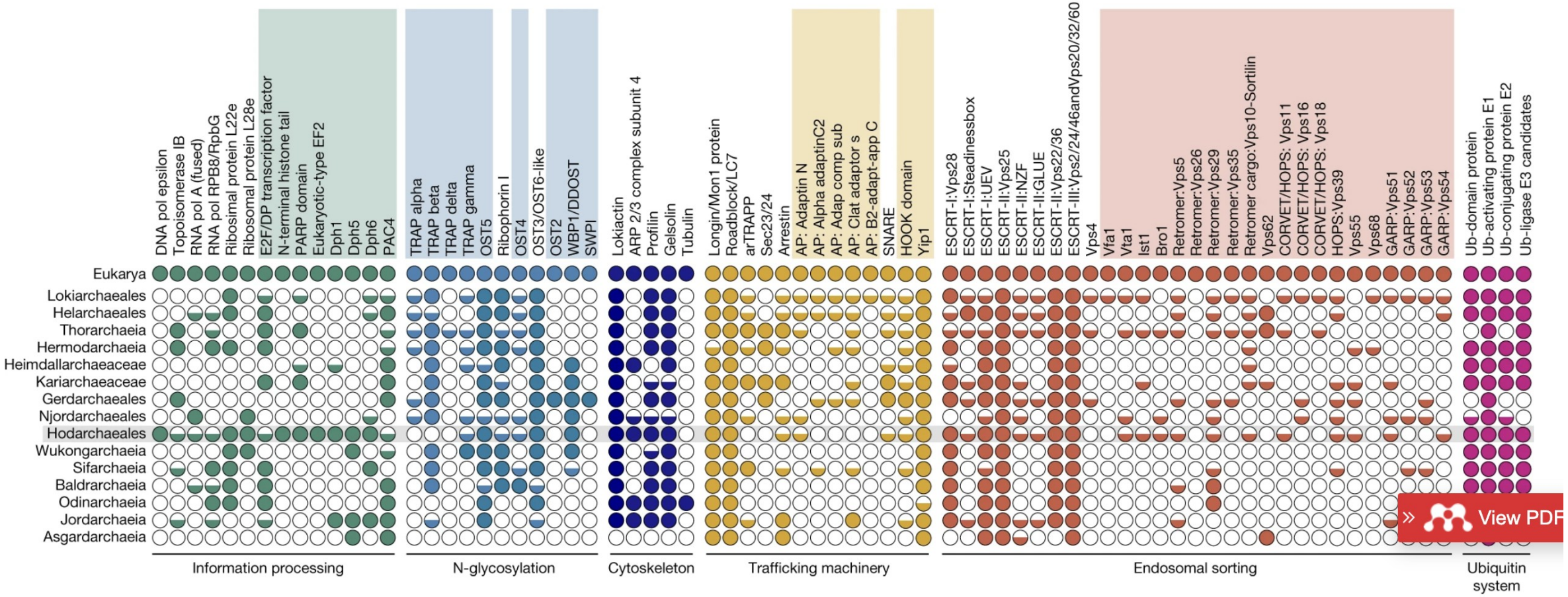
Zaremba-Niedzwiedzka et al. 2017. Nature



diverzita Asgard archaeí je nakonec mnohem vyšší, nicméně pořád nejspíš platí, že eukaryota jsou jednou z asgard linií. Takže měl Lake s eocytem pravdu?

Eme et al. 2023, Nature

Eukaryotic signature proteins - ESPs



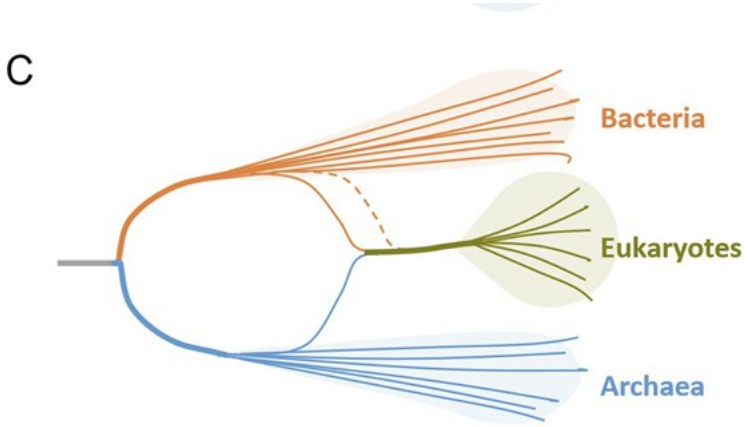
Lokiarchaeales a Hodarcheales mají největší arzenál genů, které jsou považovány za charakteristické pro eukaryota

Kde se tady vzali? III.

Co způsobilo, že se právě tahle jedna linie tak změnila?

Něco diverzifikaci nastartovalo?

Symbiogenetický původ: Eukaryota vznikla sloučením archaeální a bakteriální buňky



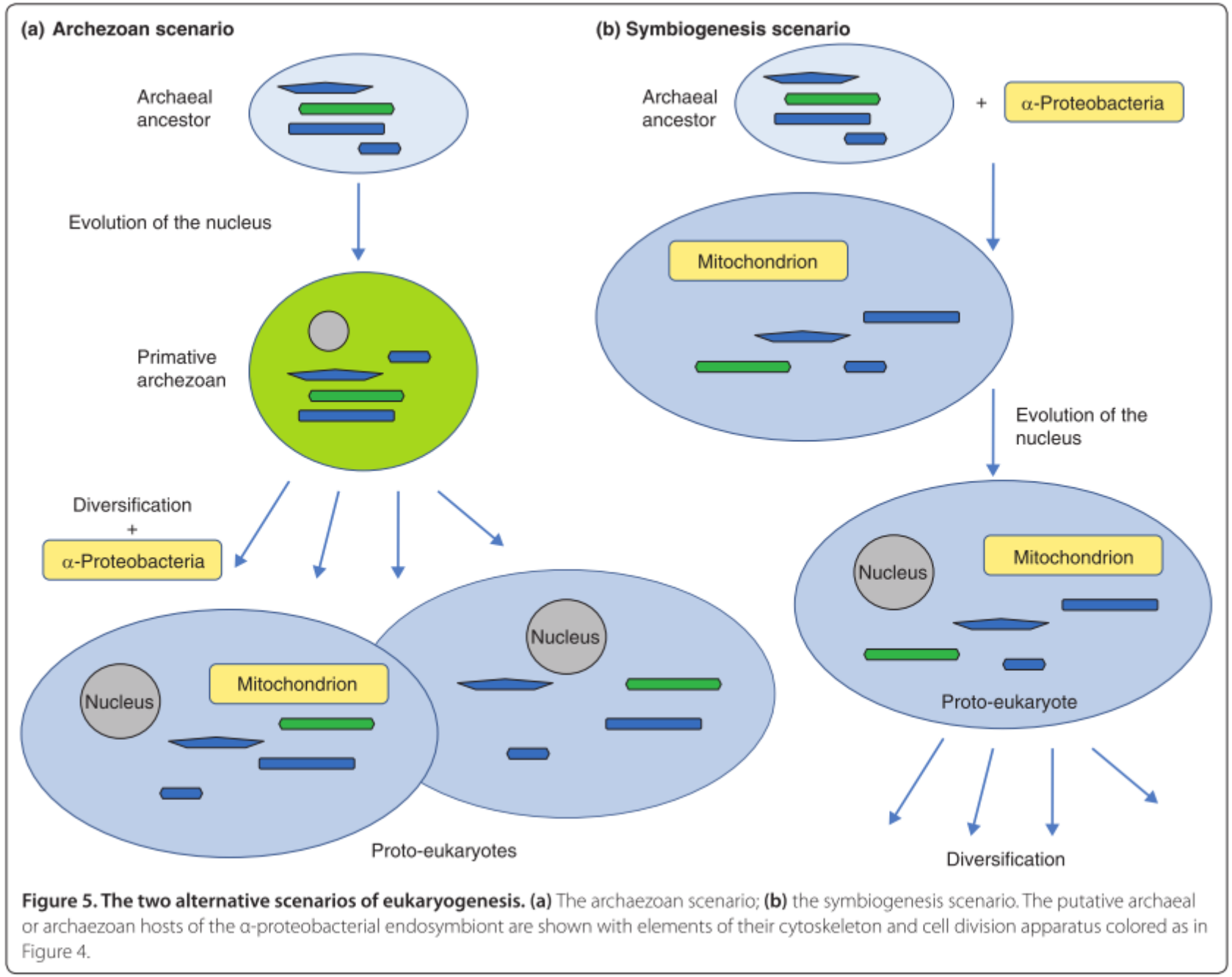
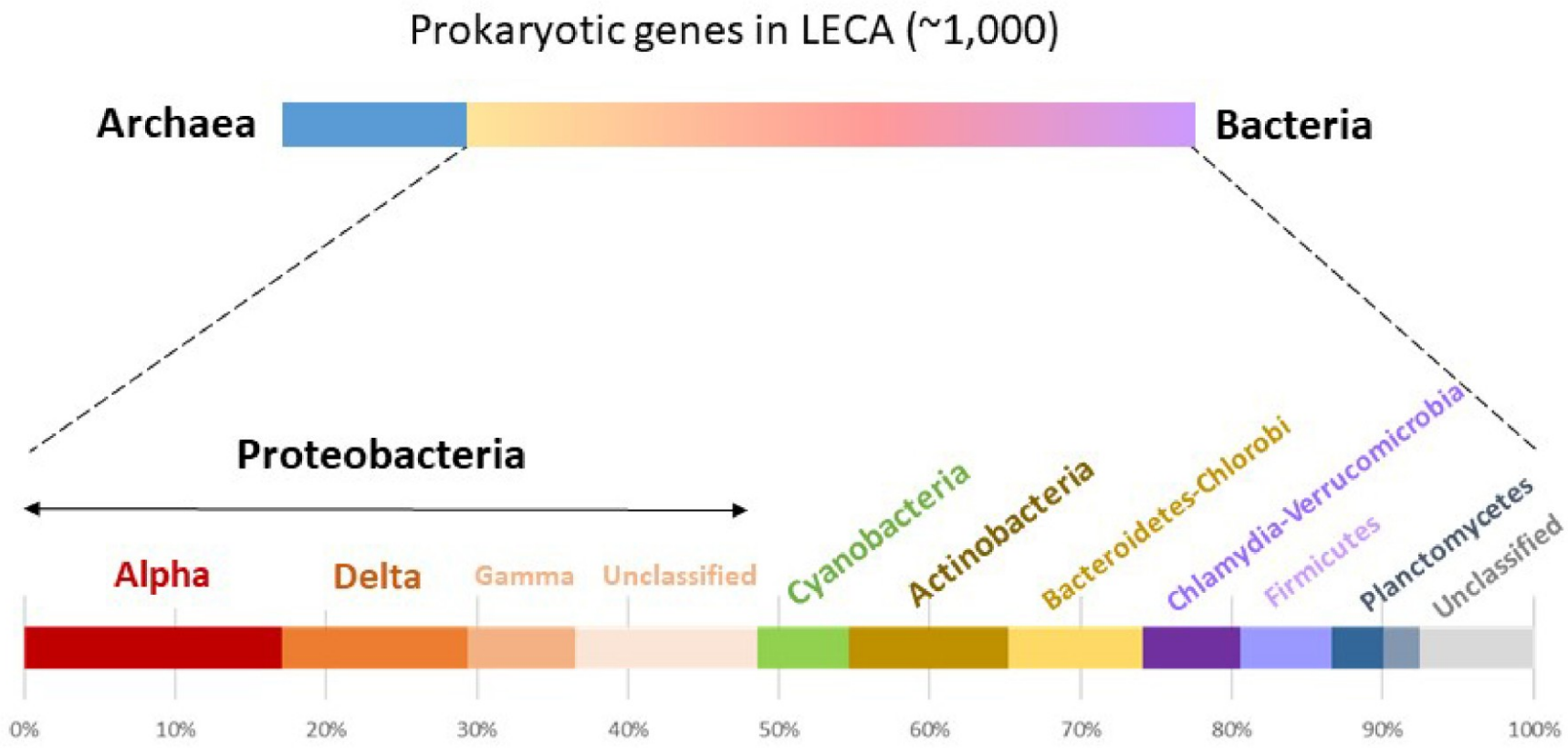


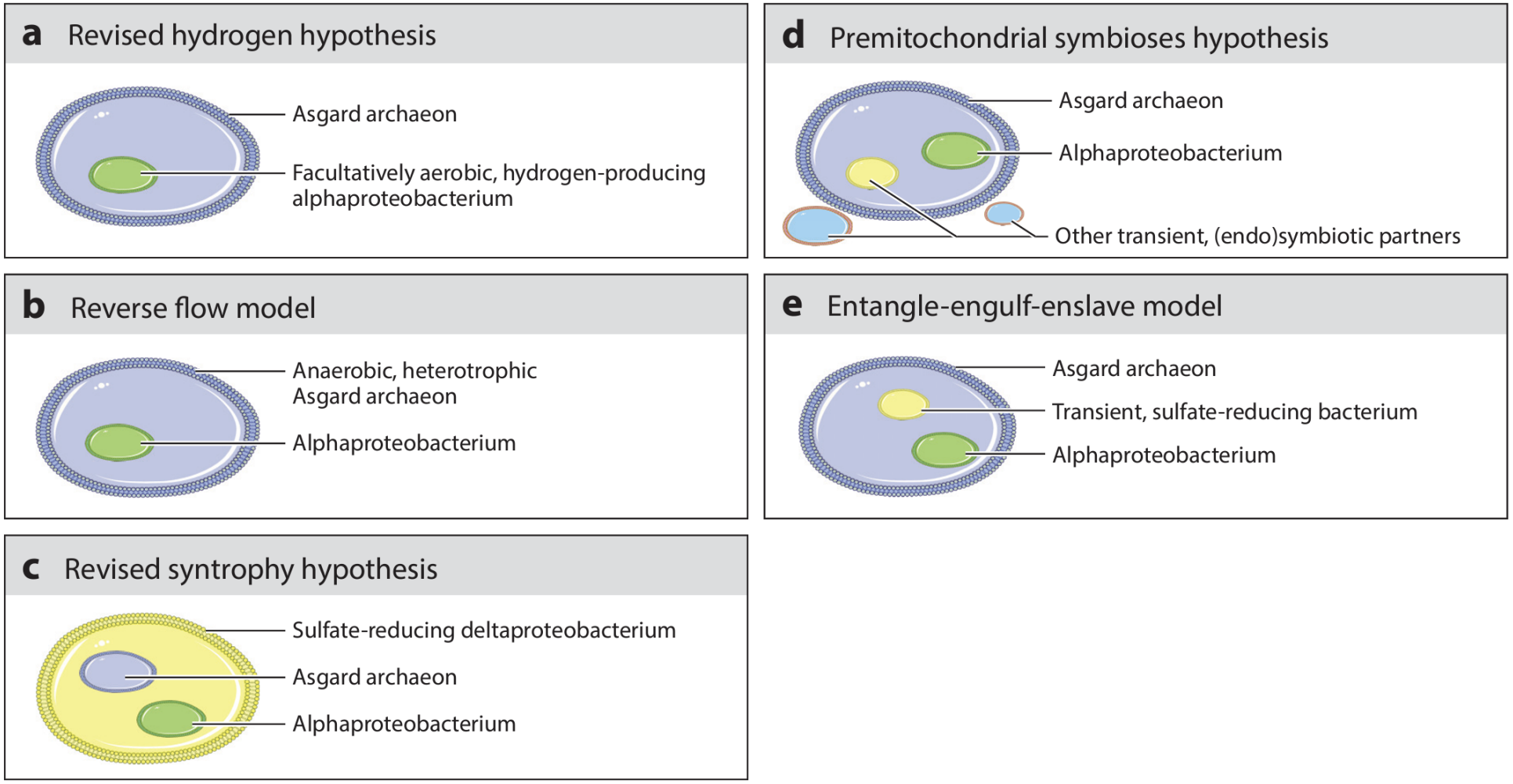
Figure 5. The two alternative scenarios of eukaryogenesis. (a) The archaezoan scenario; **(b)** the symbiogenesis scenario. The putative archaeal or archaezoan hosts of the α-proteobacterial endosymbiont are shown with elements of their cytoskeleton and cell division apparatus colored as in Figure 4.

Cizí geny v předchůdci všech moderních eukaryot

Mnohem víc než jen archaea

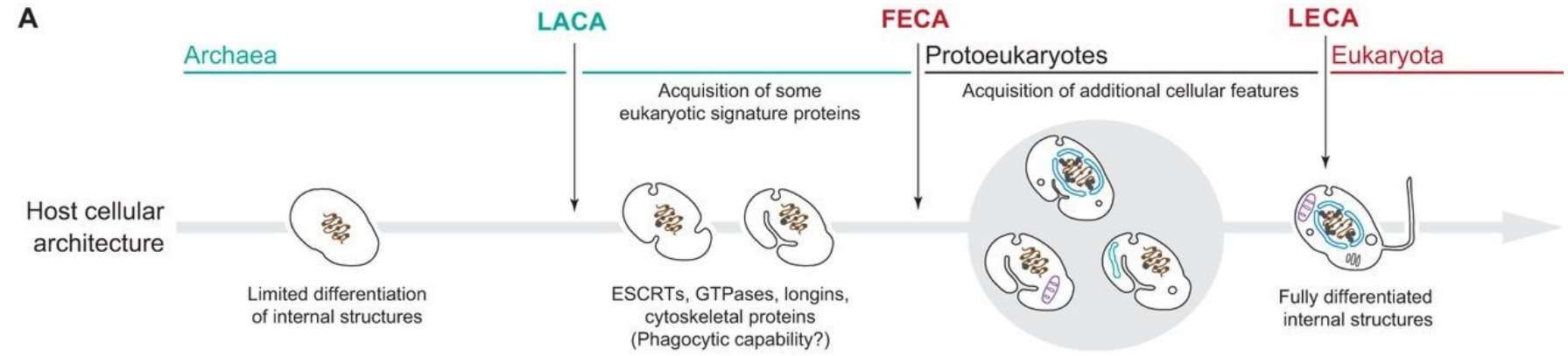


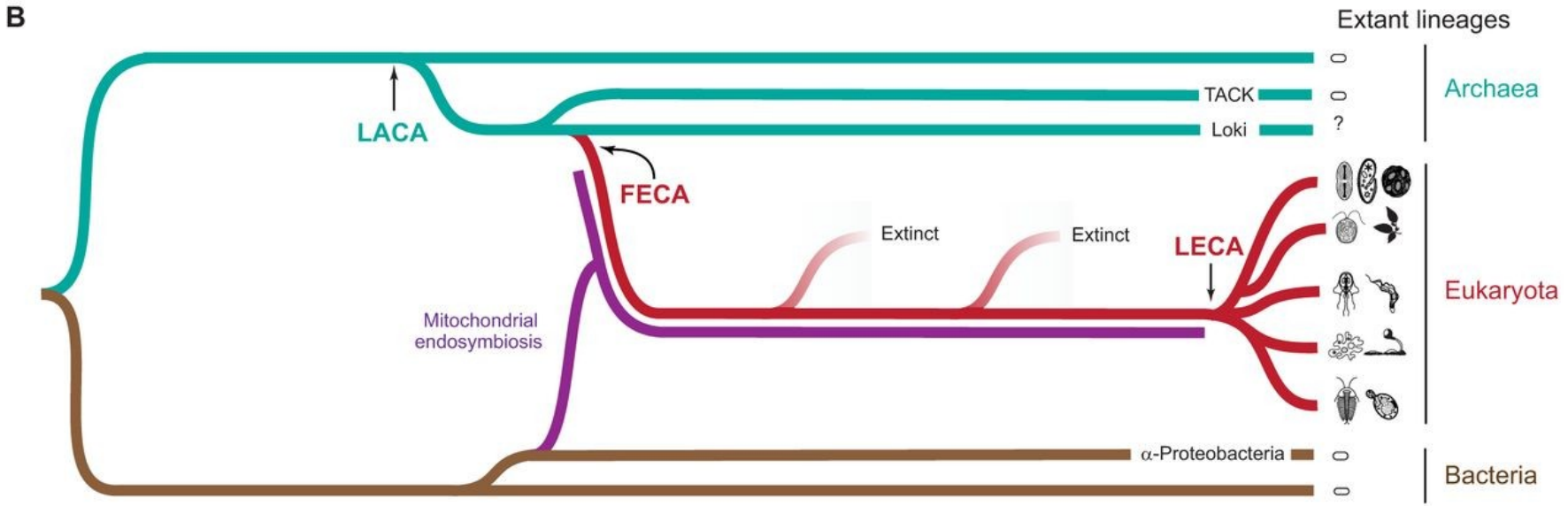
Kdo byli ale další partneři?



Jak vypadala první eukaryota?

FECA vs LECA

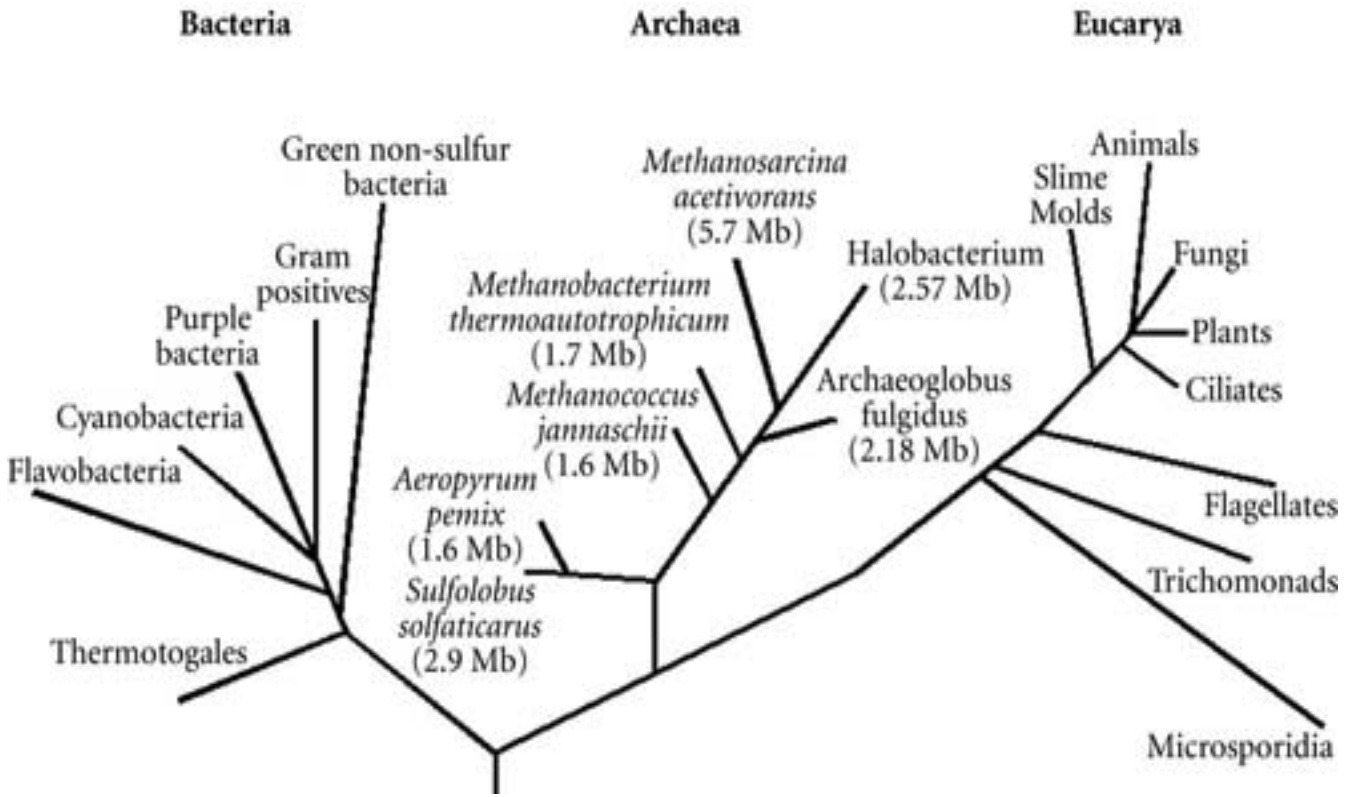




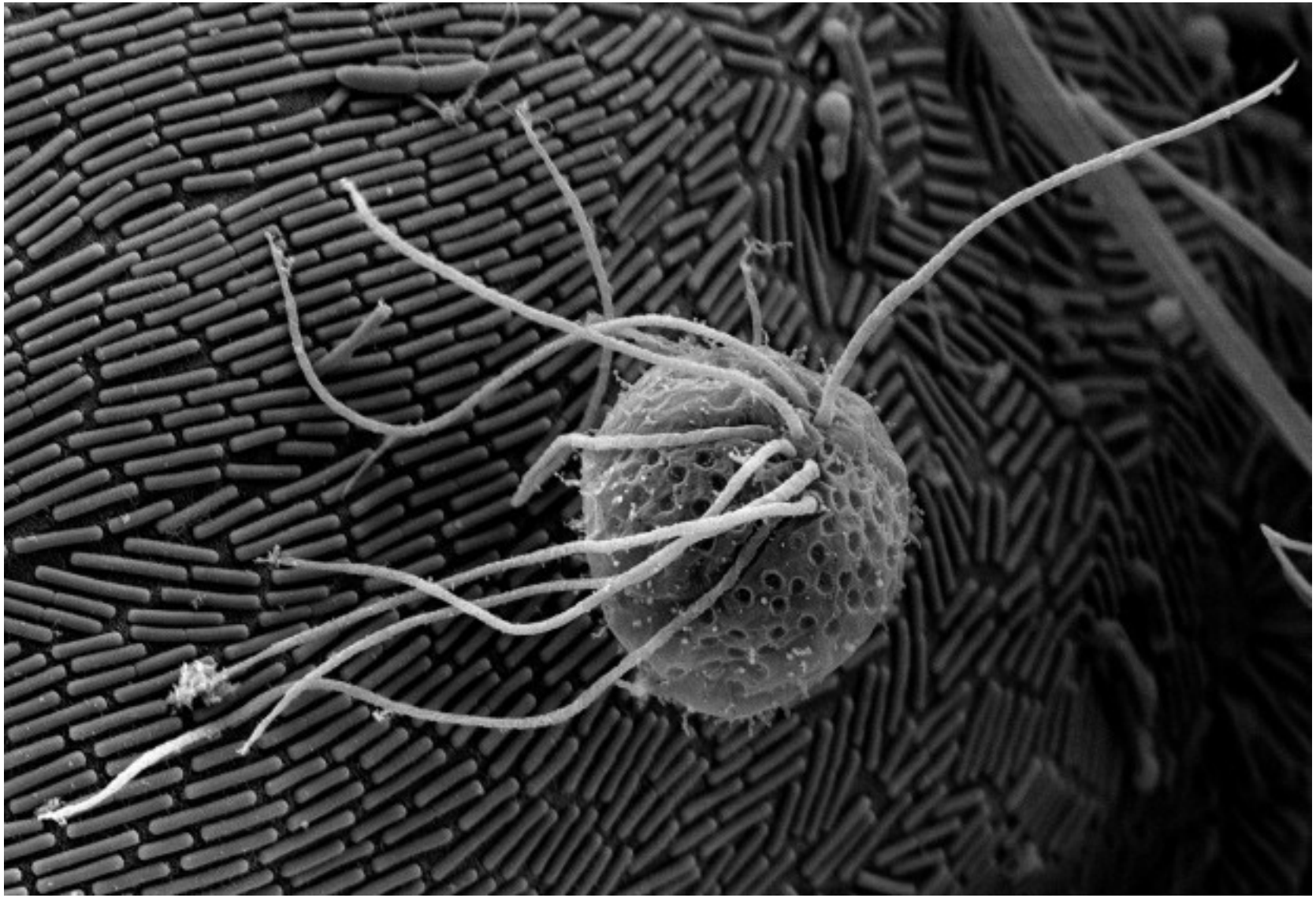
Dacks et al. 2016 J Cell Sci

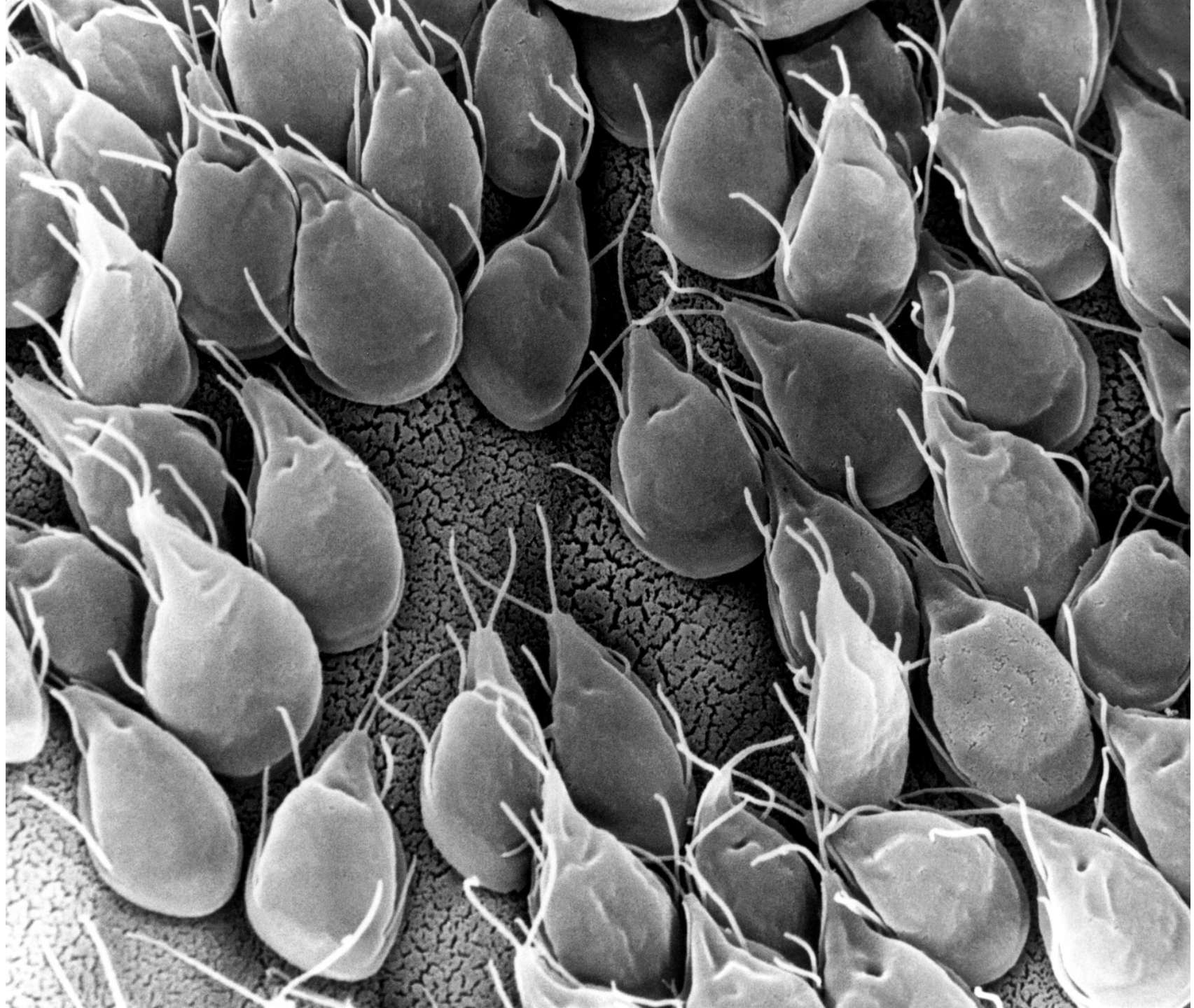
Hypotéza Archezoa#2

Primitivní eukaryota nemají mitochodrie, ta vznikla až později v evoluci eukaryot

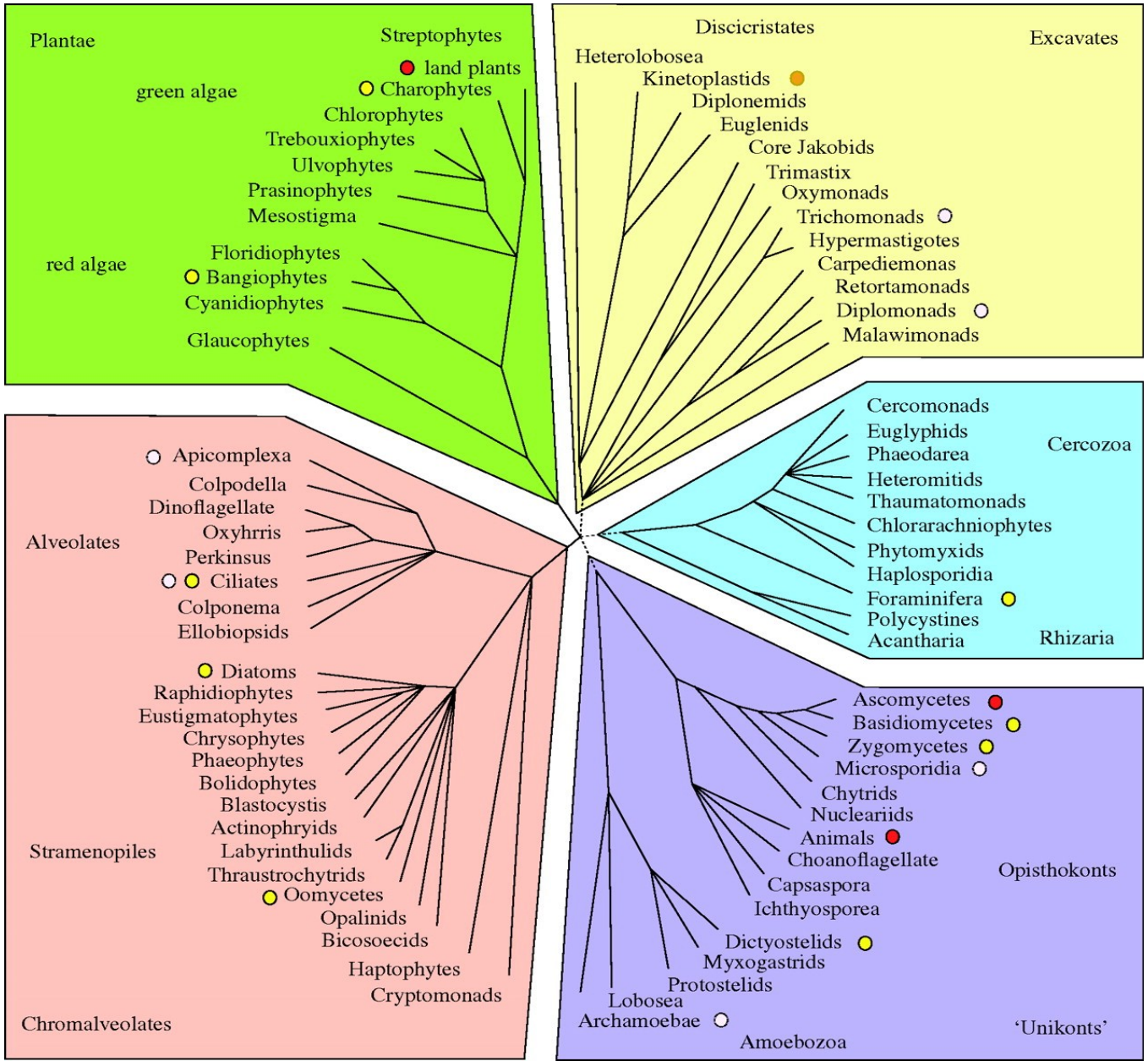


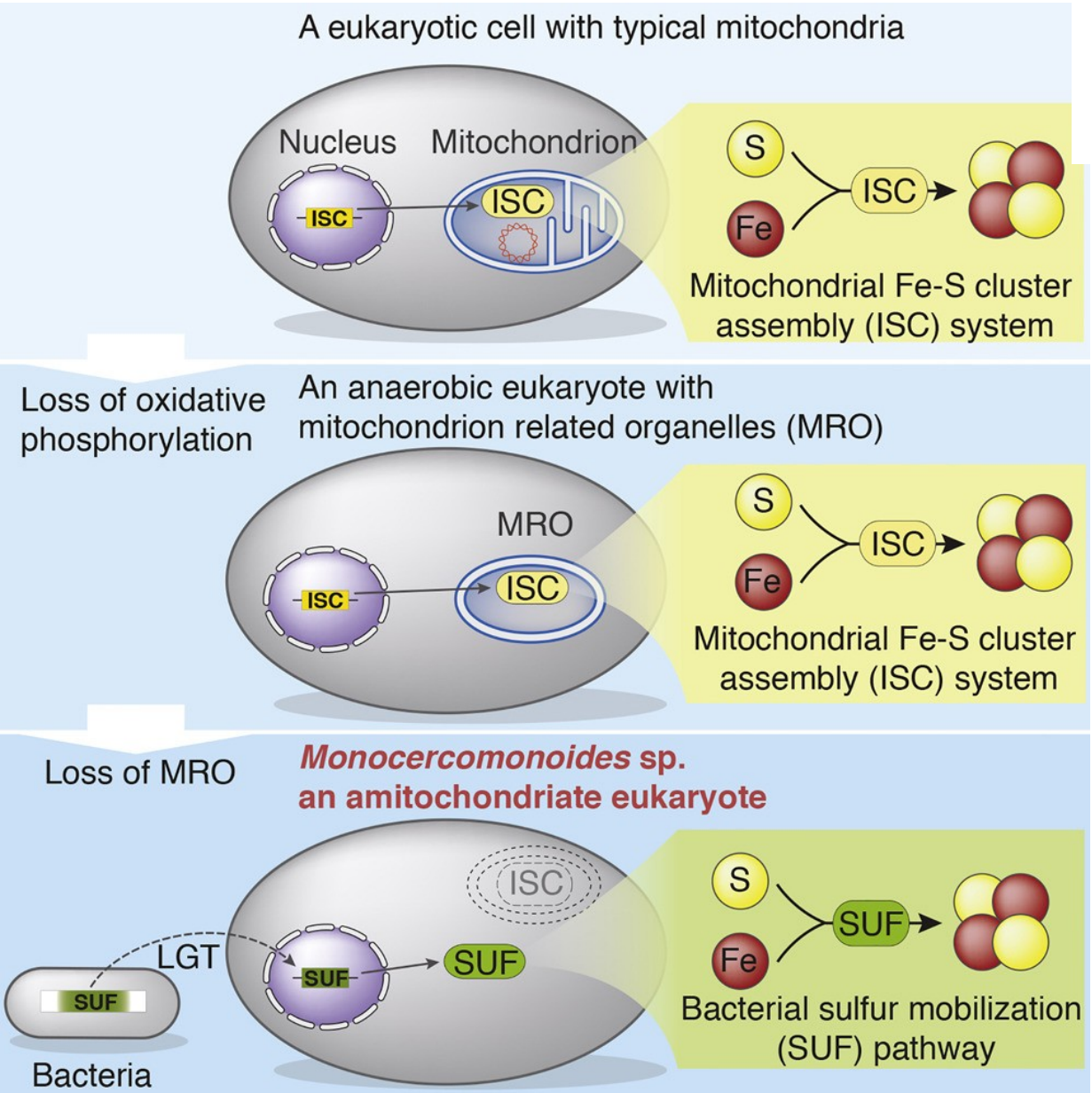
Woesse, 1990





Nemít klasickou mitochondrii je spíš odvozený znak související s životním stylem



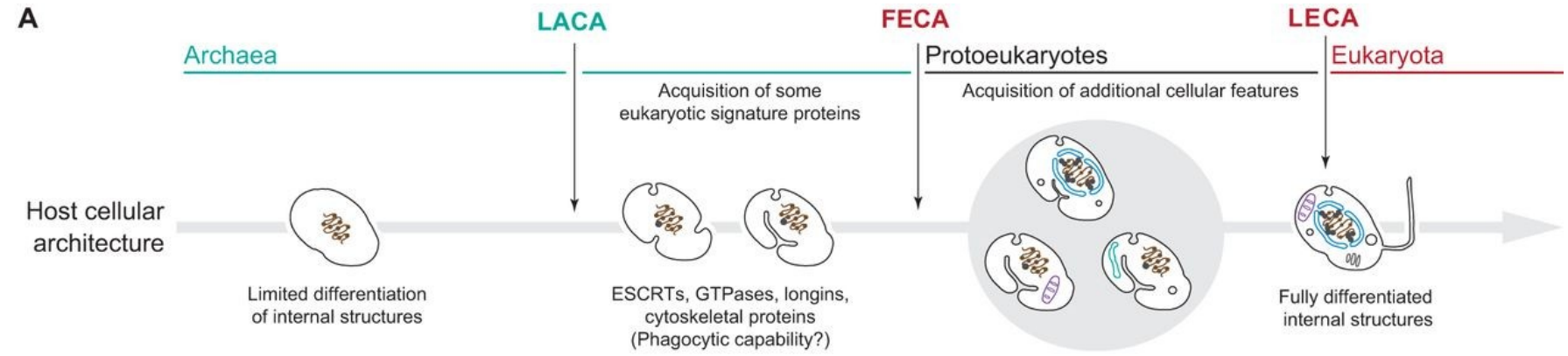


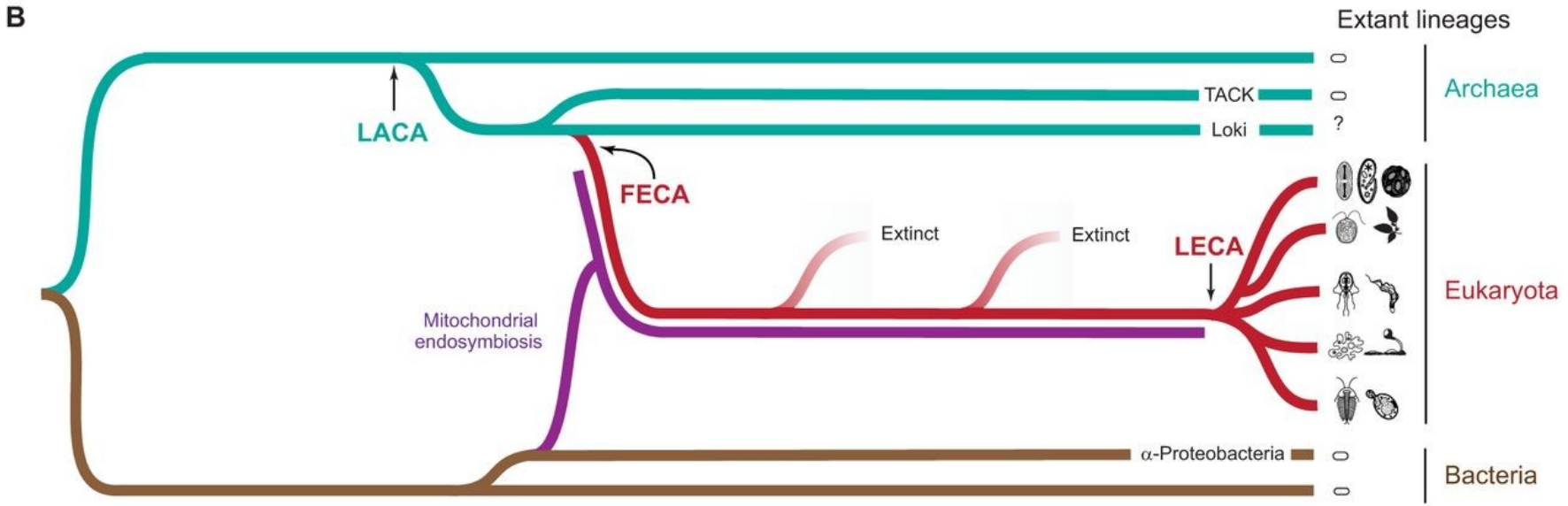
A Eukaryote without a Mitochondrial Organelle

Anna Karnkowska,[1,2,7,*] Vojtěch Vacek,[1] Zuzana Zubáčová,[1] Sebastian C. Treitli,[1] Romana Petrželková,[3] Laura Eme,[4] Lukáš Novák,[1] Vojtěch Žárský,[1] Lael D. Barlow,[5] Emily K. Herman,[5] Petr Soukal,[1] Miluše Hroudová,[6] Pavel Doležal,[1] Courtney W. Stairs,[4] Andrew J. Roger,[4] Marek Eliáš,[3] Joel B. Dacks,[5] Čestmír Vlček,[6] and Vladimír Hampl[1,*]
[1]Department of Parasitology, Charles University in Prague, Prague 12843, Czech Republic
[2]Department of Molecular Phylogenetics and Evolution, University of Warsaw, Warsaw 00478, Poland

Jak vypadala první eukaryota?

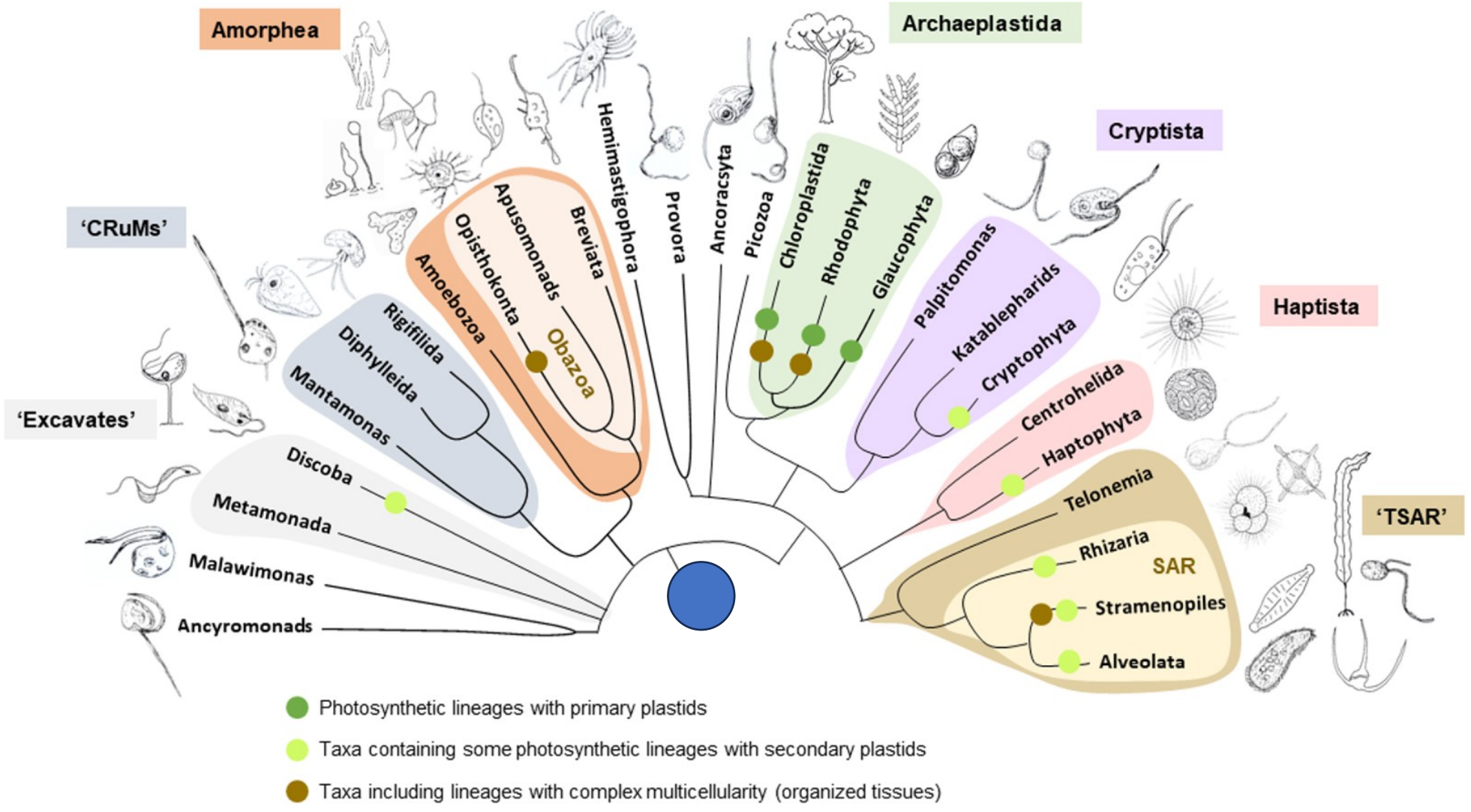
FECA vs LECA





Dacks et al. 2016 J Cell Sci

LECA – Last eukaryotic common ancestor



Stáří min 2 mld let, máme poměrně dobrou představu, jak vypadal

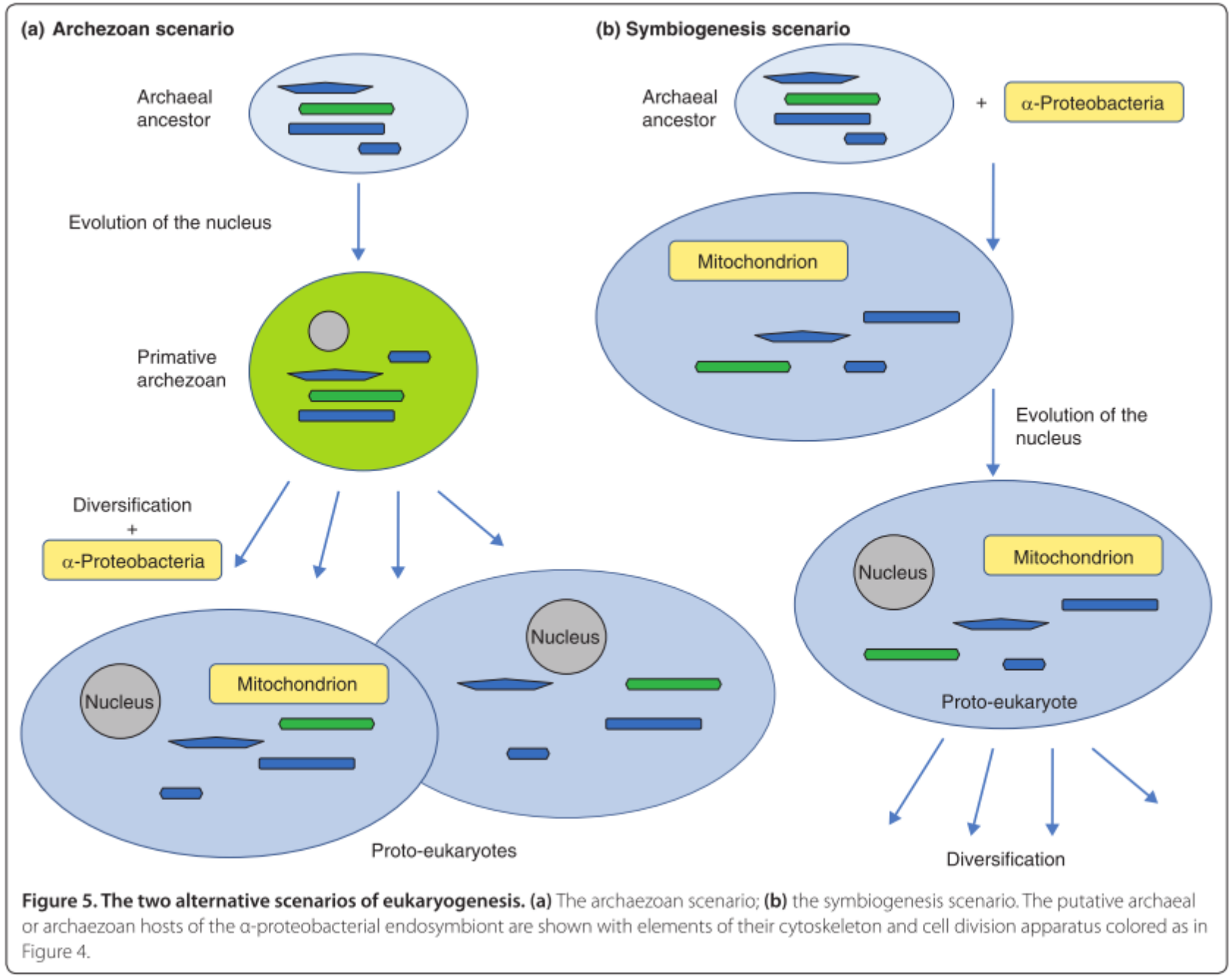


Figure 5. The two alternative scenarios of eukaryogenesis. (a) The archaezoan scenario; **(b)** the symbiogenesis scenario. The putative archaeal or archaezoan hosts of the α-proteobacterial endosymbiont are shown with elements of their cytoskeleton and cell division apparatus colored as in Figure 4.

Koonin Genome Biology 2010, 11:209

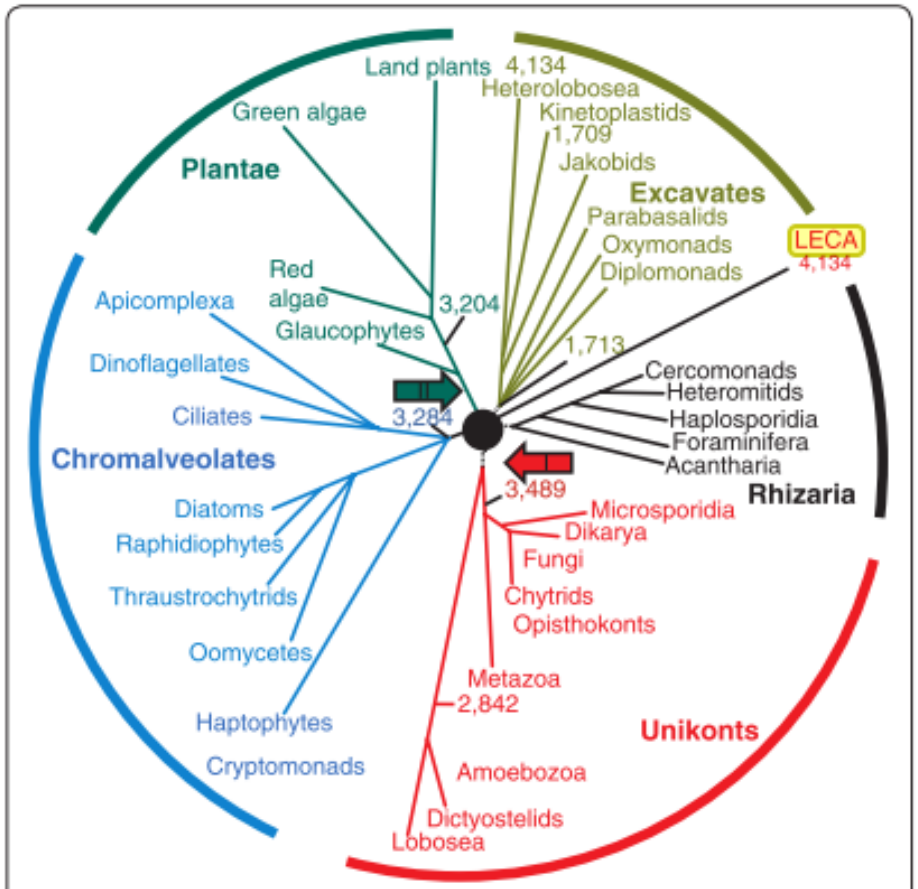
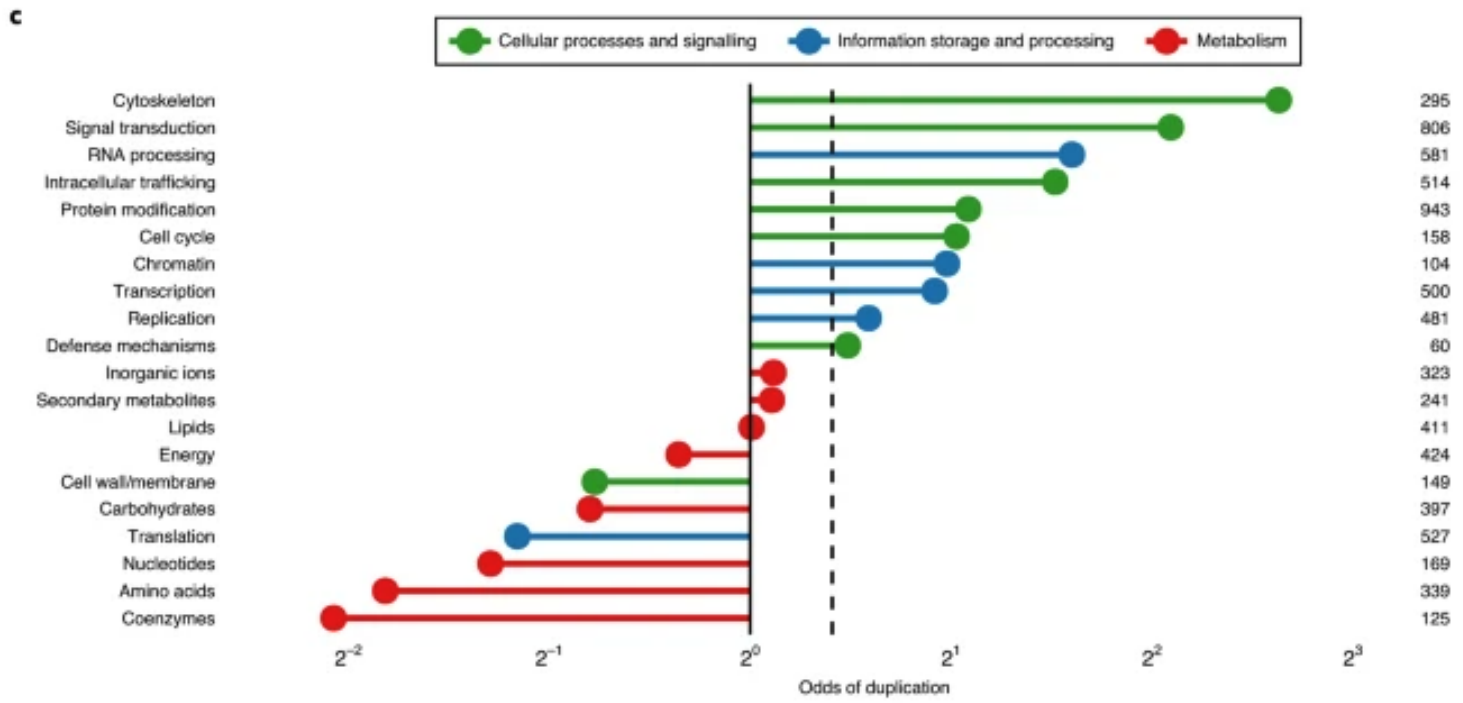
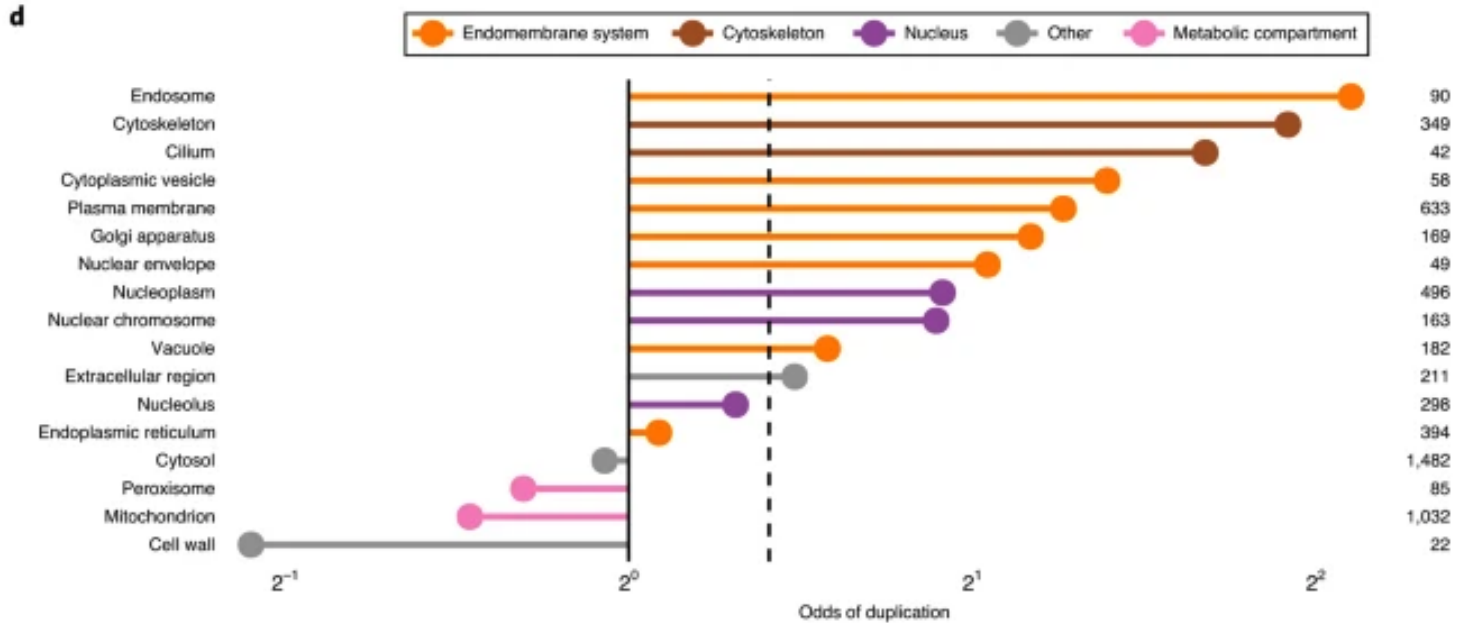


Figure 1. Evolution of the eukaryotes. The relationship between the five eukaryotic supergroups - Excavates, Rhizaria, Unikonts, Chromalveolates and Plantae - are shown as a star phylogeny with LECA placed in the center. The 4,134 genes assigned to LECA are those shared by the free-living excavate amoeboflagellate *Naegleria gruberi* with representatives of at least one other supergroup [67]. The numbers of these putative ancestral genes retained in selected lineages from different supergroups are also indicated. Branch lengths are arbitrary. Two putative root positions are shown: I, the Unikont-Bikont rooting [56,57]; II, rooting at the base of Plantae [60].

LECA měla všechny vlastnosti moderních eukaryot

- Jádro a jaderné póry
- Introny a RNA sestřih
- RNAi
- ubiquitin signalizaci
- EM systém





- Až 21840 genů z cca. 10000 rodin
- Duplikace zdvojnásobily genový repertoire
- Nejvíce duplikovaly Asgard geny
- Nejdříve (a nejvíce) duplikovaly spojené s EMS, cytoskeletem a jádrem
- Naopak redukce genů spojených s metabolismem a mitochondriemi

Vosseberg et al., 2021 Nat Ecol Evol

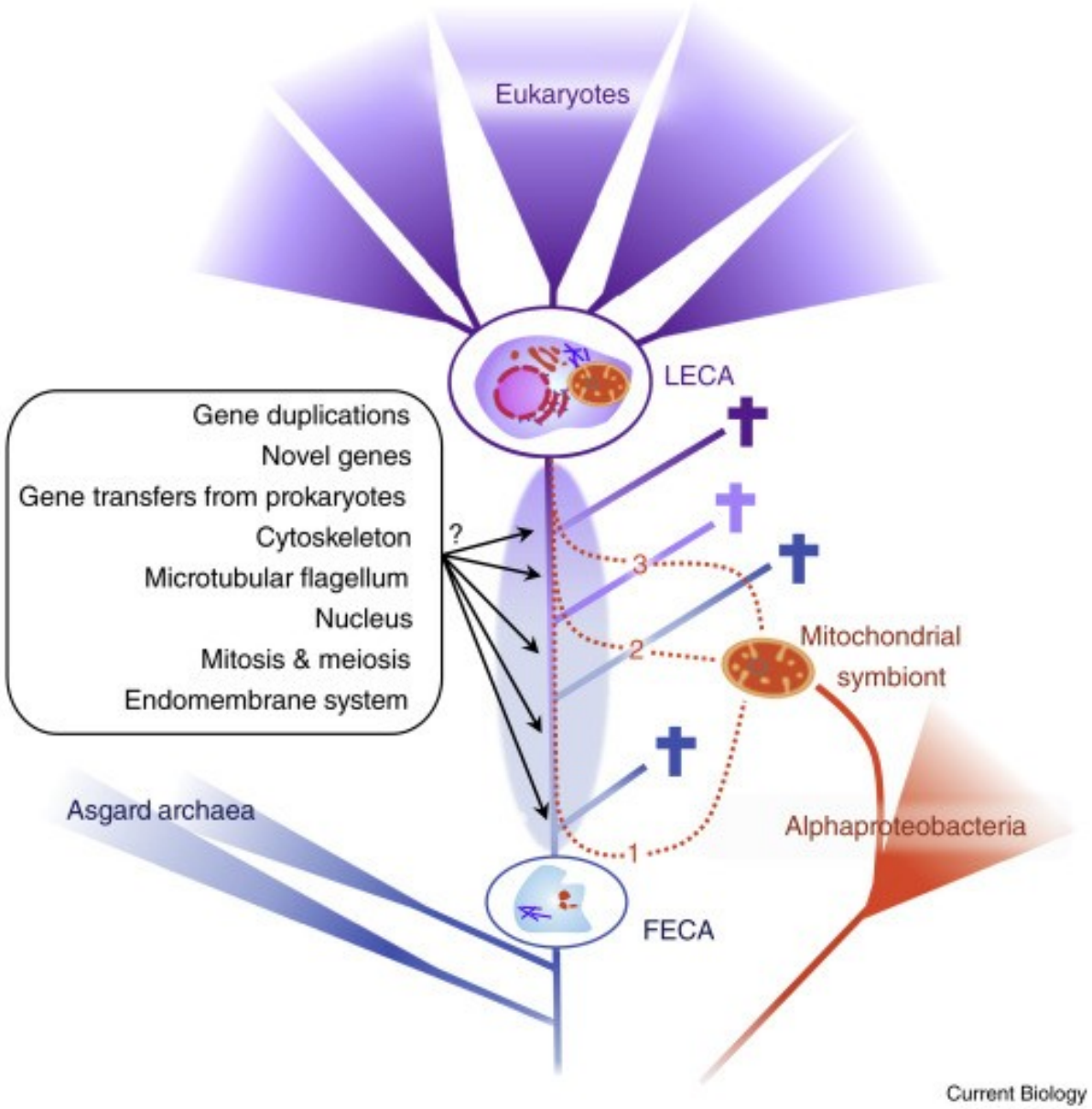
... kromě archaeí eukaryota "nakupovala" i jinde

Table 1. Apparent origins of some key functional systems and molecular machines of eukaryotes

System/complex/function	Inferred origins	References
DNA replication and repair machinery	Archaeal, with either crenarchaeotal or euryarchaeotal affinities for DNA polymerases and other central replication proteins; a mix of archaeal and bacterial for repair enzymes	[99,100,128]
Transcription machinery	Archaeal; at least two RNA polymerase subunits of crenarchaeotal/korarchaeotal origin	[63,86,89,93,94,129]
Translation apparatus, including ribosomes	Mostly archaeal; some aminoacyl-tRNA synthetases displaced with bacterial homologs	[91,130]
Cell division and membrane remodeling systems; phagocytosis	Primarily archaeal (Crenarchaeota) but some key regulators like Ras superfamily GTPases of bacterial origin	[105,113,114]
Cytoskeleton	Primarily archaeal; euryarchaeal affinity for tubulin, crenarchaeotal for actin	[96,105]
Proteasome: regulated proteolysis	Archaeal	[110]
Ubiquitin signaling: regulated proteolysis and protein topogenesis	Archaeal but origin of some essential components, such as E2 and E3 ubiquitin ligases, uncertain	[115,131]
Exosome: regulated RNA degradation	Archaeal	[132]
Nuclear pore complex: nucleocytosolic transport	Bacterial; some key proteins of the nuclear pore complex repetitive and of uncertain origin	[28]
Chromatin/nucleosomes	Complex mix of archaeal and bacterial	[66]
RNA interference	Hybrid of archaeal and bacterial	[70,133,134]
Endomembrane system/endoplasmic reticulum	Complex mix of archaeal and bacterial	[9,10,105]
Mitochondrion/electron transfer chain	Bacterial	[81,135]

A co FECA?

Záleží na typu vzniku eukaryot, eocyt vs. symbiogeneze



Kolikrát vznikla ”eukaryota”?

1x?

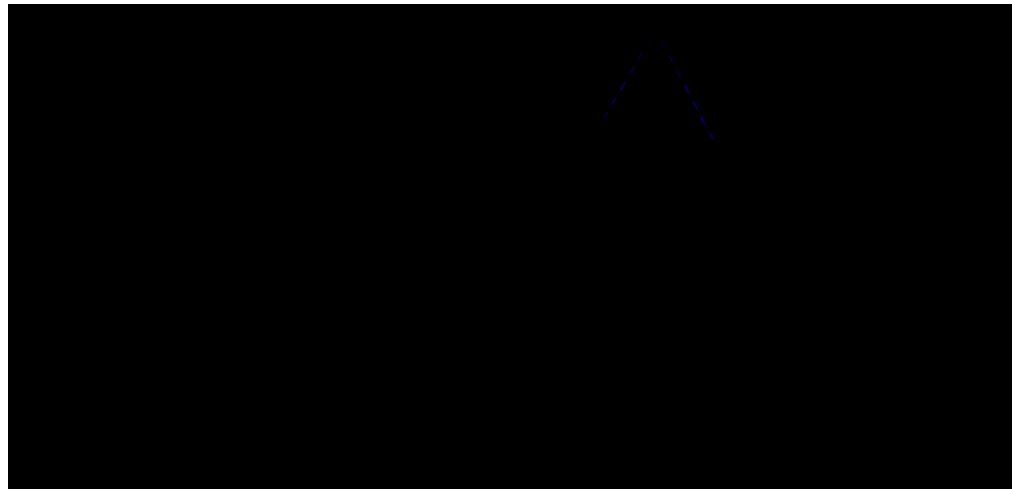
Všichni zástupci známých eukaryot jsou potomci společného předka (LECA)

Evoluce je hravá!

Parakaryon myojinensis

Structure	Prokaryotes	Eukaryotes	*Parakaryon myojinensis*
Nucleus present	No	Yes	Yes
No. of nuclear membrane layers	—	2	1
Nuclear pores present	—	Yes	No
Ribosome location	Cytoplasmic	Cytoplasmic	Cytoplasmic and intranuclear
Endosymbionts present	No	Yes	Yes
Endoplasmic reticulum present	No	Yes	No
Golgi apparatus present	No	Yes	No
Mitochondria present	No	Usually	No
Chromosome structure	Variable	Linear	Filamentous
Cytoskeleton present	Yes	Yes	No

Yamaguchi et al., 2012 *J Electron Microsc*



By Ian Alexander - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=63833419

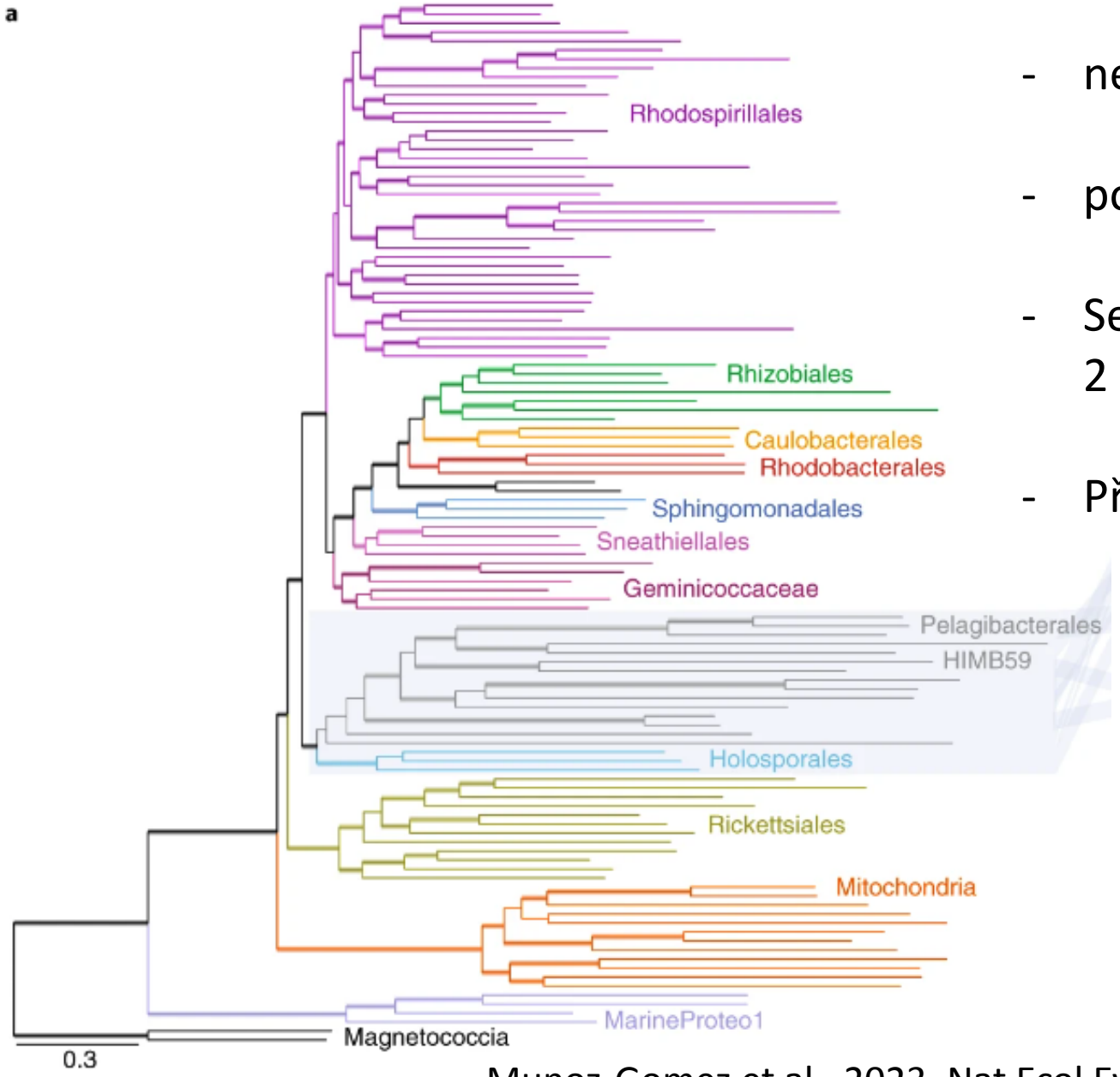
Mitochondrie

Endosymbiotický původ mitochondrie původně Mereškovskij (a další) na zač. 20 století

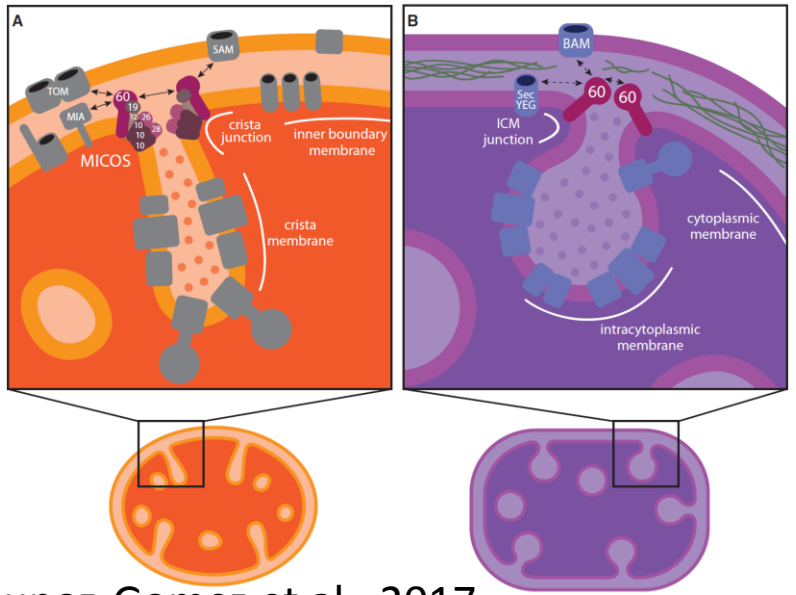
Lynn Margulisová publikovala znovu v 1967

Původ

- nejspíš z hodně hluboké linie alfaproteobakterií
- podle mol. časování cc. 2 mld let stará
- Semiautonomní organela, vlastní genom a exprese, 2 membrány
- Předek měl už nejspíš kristy



Munoz-Gomez et al., 2023, Nat Ecol Evol



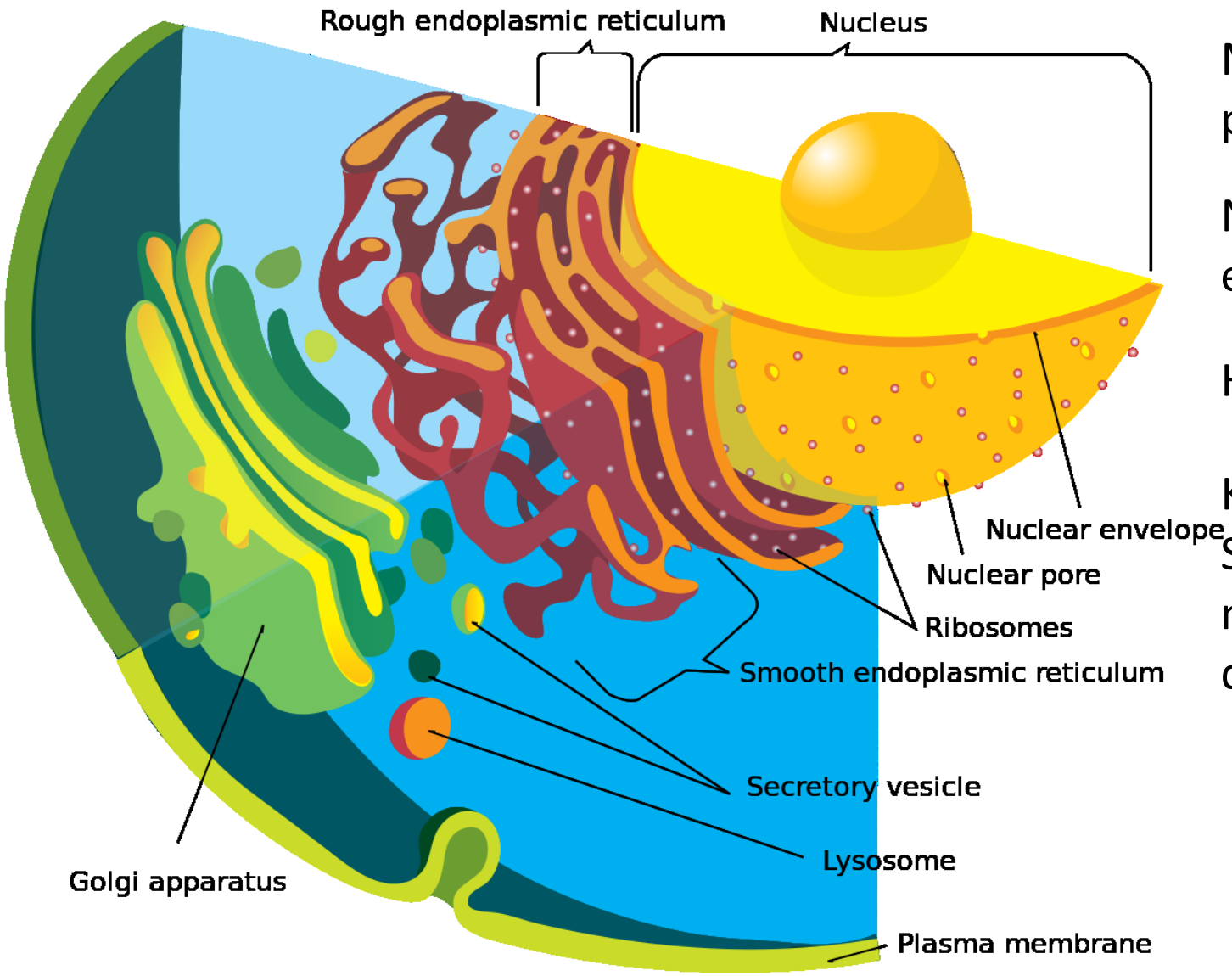
Munoz-Gomez et al., 2017

Proč zrovna mitochondrie?

U prvoků i archaeí jsou symbiózy velmi časté, vznik semiautonomních organel je ale výjimka

1. Efektivnjší metabolismus (2 ATP x 36ATP)
   - Takhle dobře to ale na začátku nefungovalo (pokud vůbec)
2. Nejdřív výměna metabolitů, pak viz bod 1.
   - Hodně obecné, těžko pro i proti.
3. OxTox ochrana před toxickým kyslíkem)
   - Asgard byli nejspíš aerobní
   - Navíc ROS produkované mitochondrií jsou mnohem toxičtější
4. Zprvu parazit, výhodný byl až později
   - Většinou obráceně, nejprve symbiont, pak parazit.

Endomembránový systém



Membránová dědičnost - kontinuita při přenosu na potomstvo

Nové útvary pouze odškrcením existujících membrán, ne *de novo*

Homologie s bakteriálními membránami

Komplikovaná teorie vzniku (Cavallier-Smith) předpokládá ztrátu kompatibility mezi PM a ER/jádrem neschopností vázat docking protein u PM… ???

Jádro

Vznik společne s EMS

U prokaryot se DNA váže na PM, eukaryota původne na EMS, z něj vzniklo jádro

Ochrana DNA před ROS, kontrola mRNA a zamezení sestřihu nematurované RNA

Jaderné póry nejprve volně, pak selektivně prostupné

Vznik meiózy a mitozy podnítil reorganizaci chromozomů a vznik chromatinu

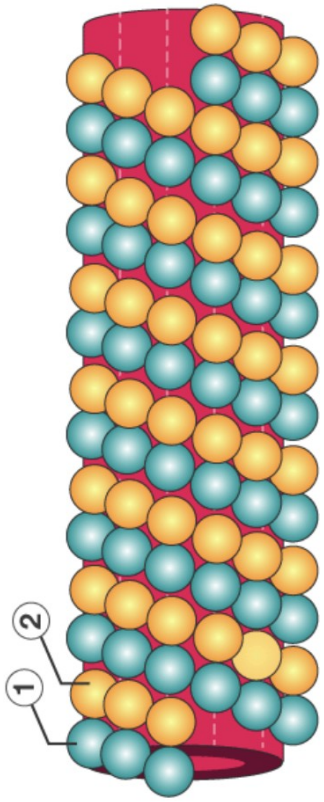
H1 histony z eubakterií, H3 a H4 archaea, H2 a H2b eukaryotická novinka

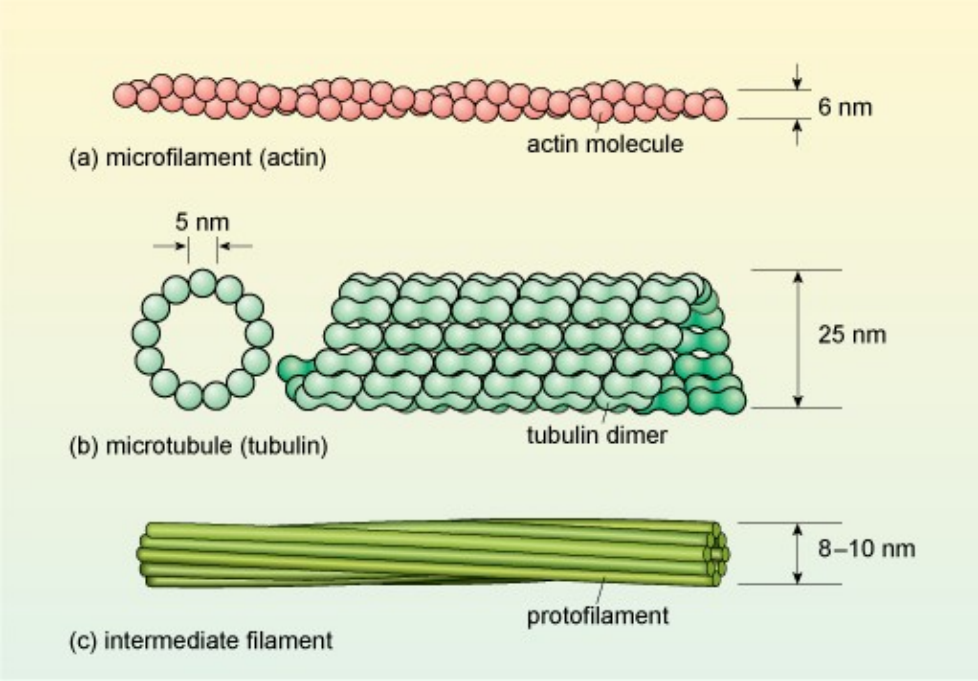
Cytoskelet

Důležitá primárně asi pro buněčné dělení, pak vnitřní organizace, transport a pohyb

Aktin a tubulin

- Původně považovány za čistě eukaryotické
- Tubulin i u eubacterií (verrucomicrobia), ale asi LGT od eukaryot
- Později homology objeveny i u Asgard archaeí





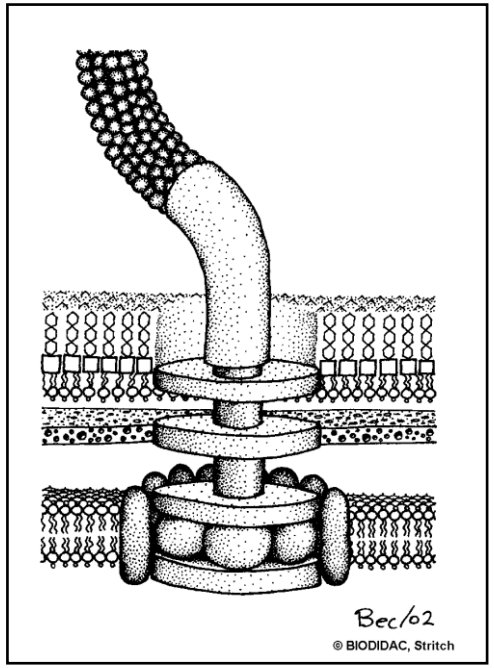
Bičík

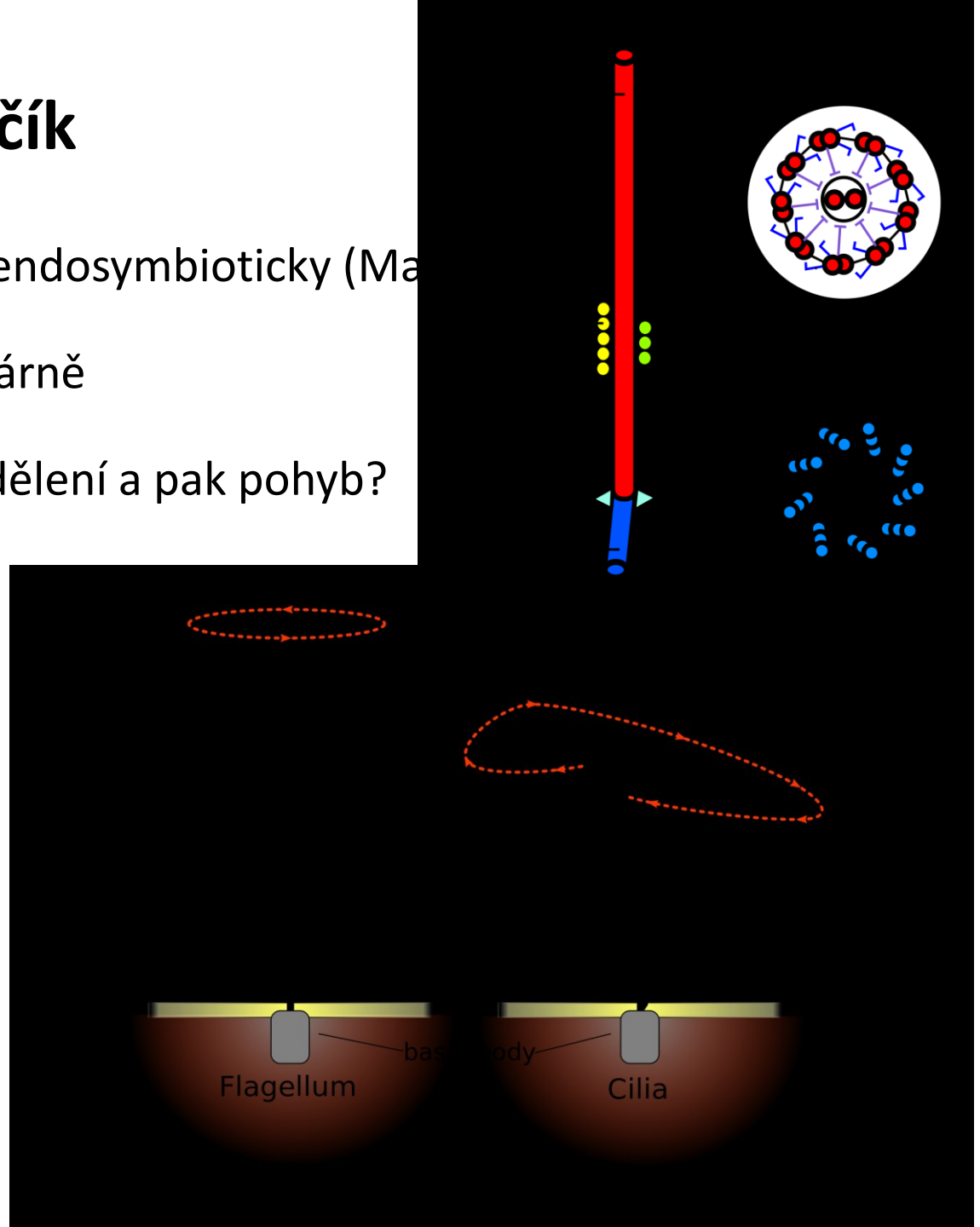
Prokaryotický vs eukaryotický bičík

Evoluční novinka eukaryot, vznik endogenně vs endosymbioticky (Ma

Podobně jako mitochondrie chybí pouze sekundárně

Bazální tělísko homologní s centriolou, nejprve dělení a pak pohyb?





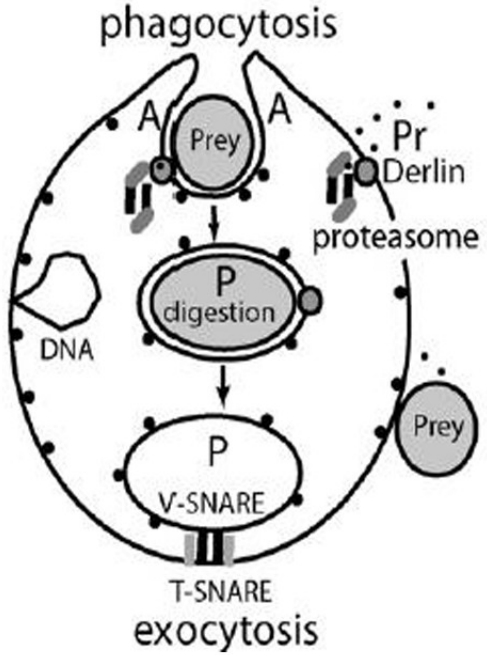
Fagocytóza

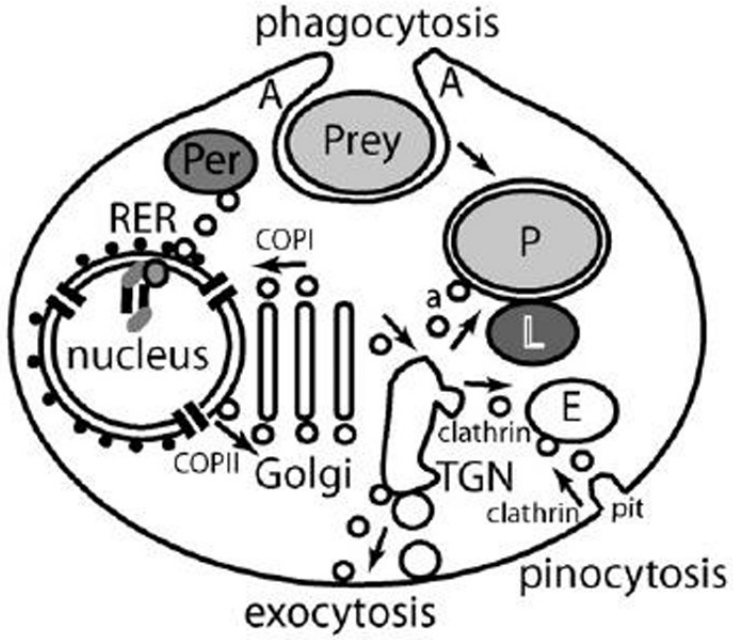
Pohlcení částic v okolí buňky vchlípením membrány a uzavřením do váčků - následný transport buňkou

Receptory, enzymy, cytoskeleton a EMS – eukarytická novinka částečně z prokaryotických prekurzorů

Známá i u bakterií (planktomyceta *Uabimicrobium amorphum*), podobný mechanismus, jiné současti

Komplikovaná teorie vzniku (opět Cavallier-Smith) 1. extracelulární trávení 2. nasátí natrávených proteinů Derlin kanálen, trávení proteasomem (obojí eukaryotické novinky) 3. částečná invaginace natrávené kořisti 4. úplné uzavření a transport buňkou





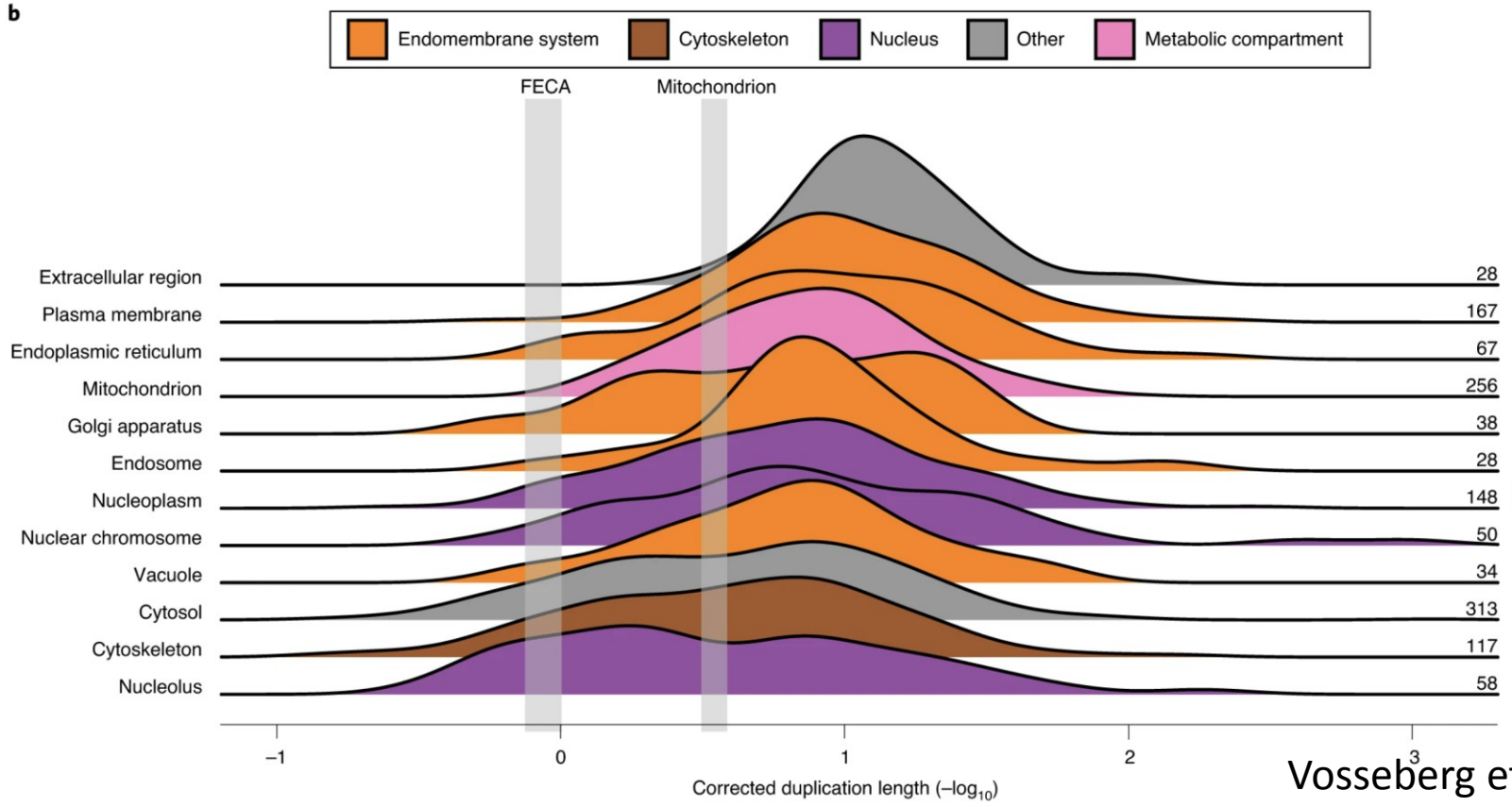
Časování vzniku eukaryot

Fosílie vs. Molekulární datování vs. porovnání stáří duplikací

-2700 mil. let – vznik eukaryot podle datování

-2000 mil. Let – vzink mitochondrie

-1500 mil let - první jasně eukaryotické fosílie



Vosseberg et al., 2021 Nat Ecol Evol

Nejprve vzniklo jádro, cytoskeleton a endocytóza, pak mitochondrie a EMS?