

L'évolution des Eucaryotes



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20 septembre 2012

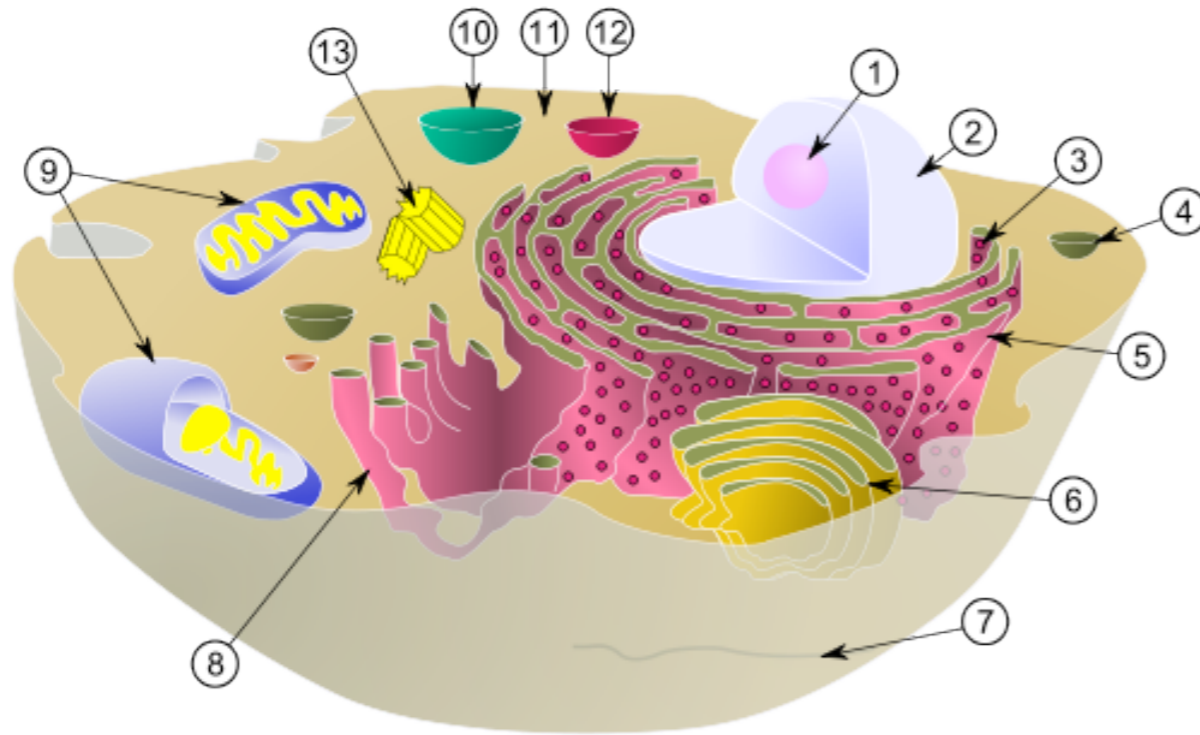
Plan de l'exposé

1. Qu'est-ce qu'un Eucaryote ?
2. Quelle est la diversité des Eucaryotes ?
3. Quelles sont les relations de parenté entre les grands groupes d'Eucaryotes ?
4. D'où viennent les Eucaryotes ?



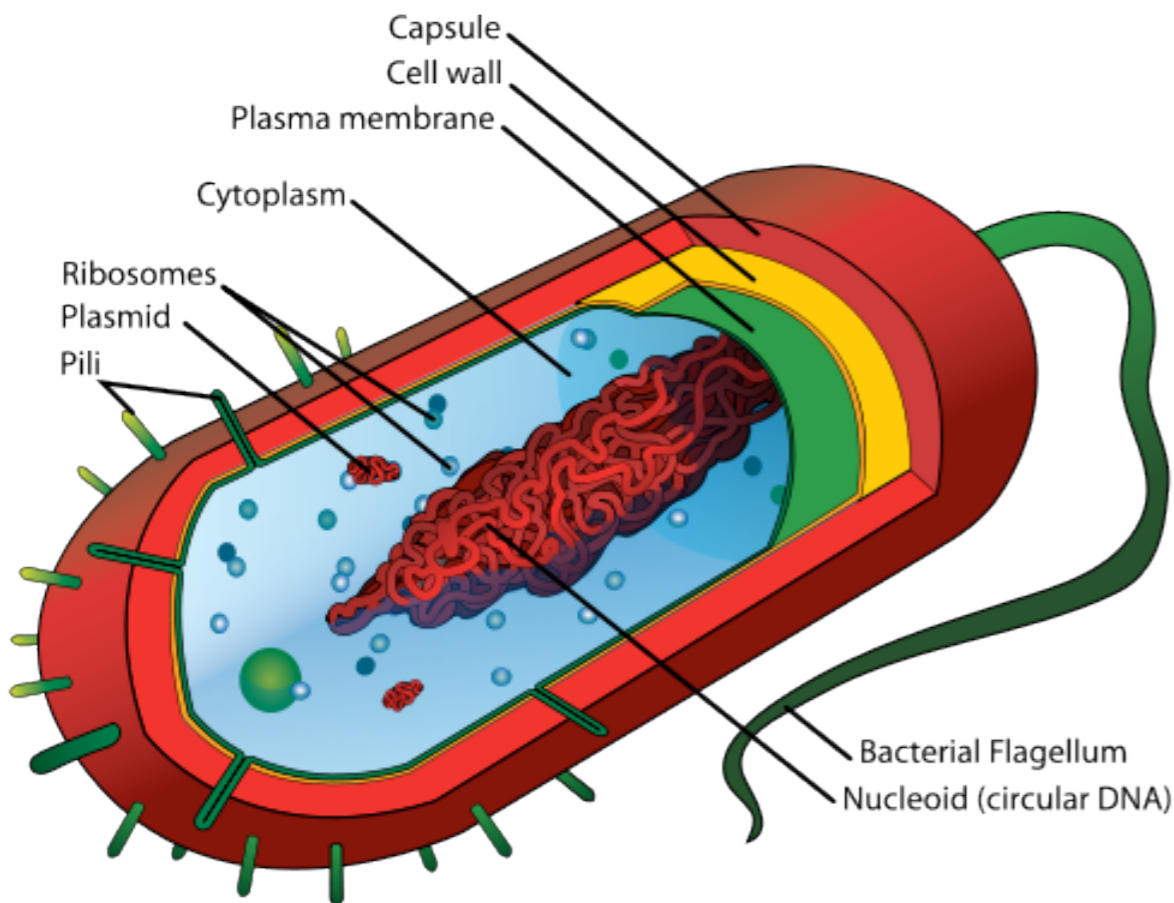
Qu'est-ce qu'un Eucaryote ?

Eukaryotic Cells

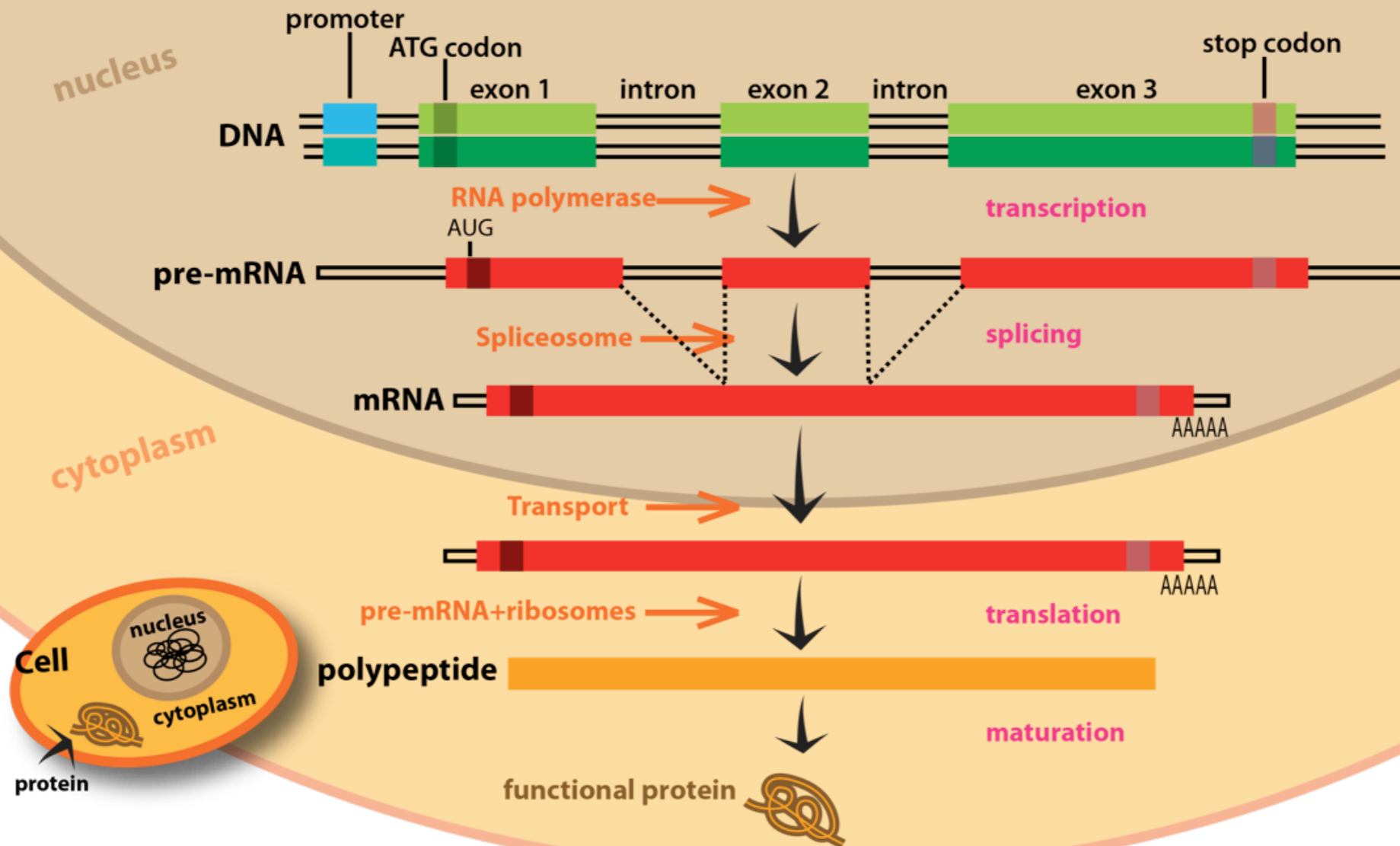


définition ultrastructurale :
organelles spécifiques

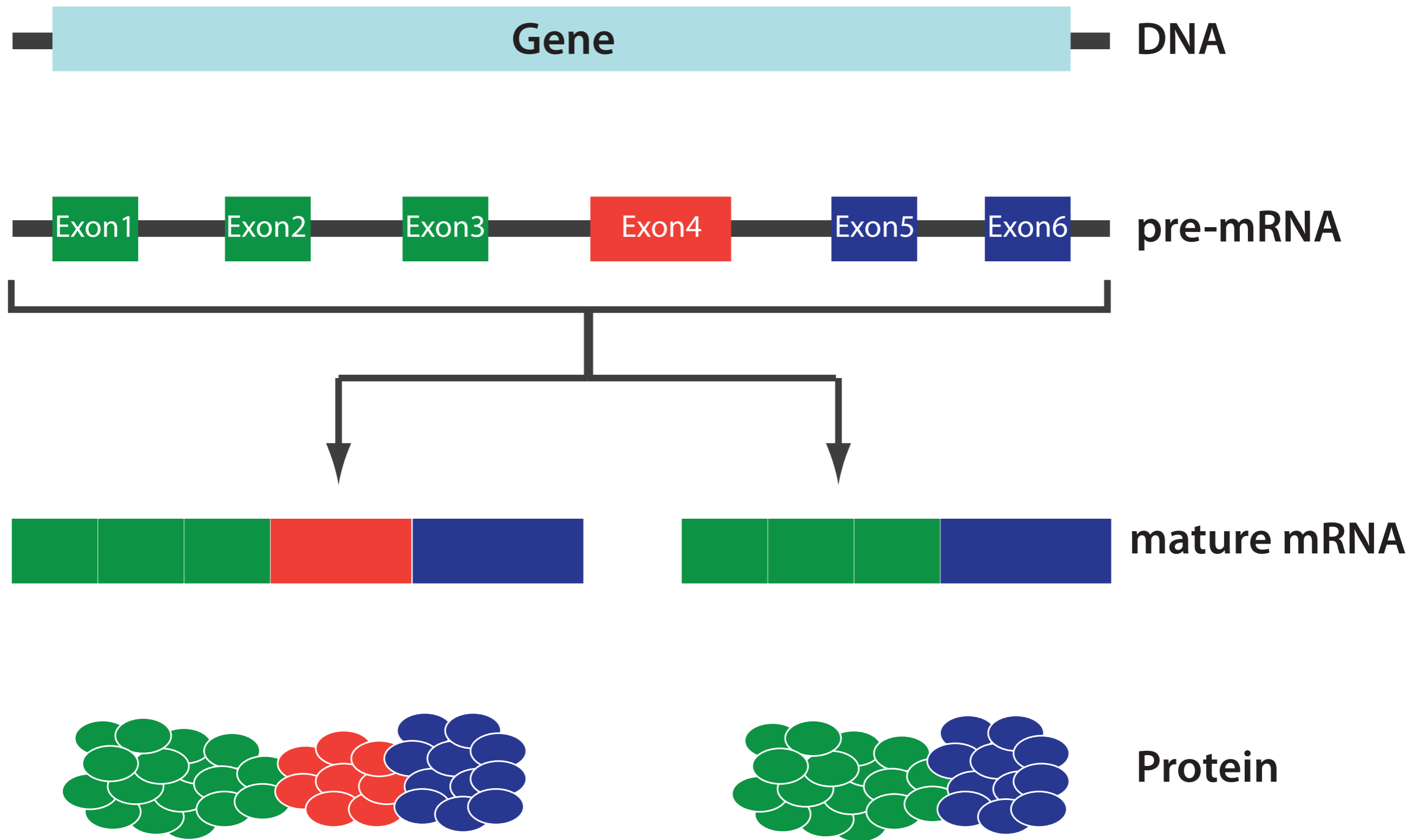
- **noyau** (1)
- nucléole (2)
- RE (5, 8)
- Golgi (6)
- centriole(s) (13)
- **mitochondrie(s)** (9)
- **chloroplaste(s)**
- ...



Simple diagram of transcription, splicing and translation



A eukaryotic gene is arranged in a patchwork of coding (exons) and non-coding sequences (introns). Introns are eliminated while exons are spliced together to yield the mature mRNA used for protein synthesis.



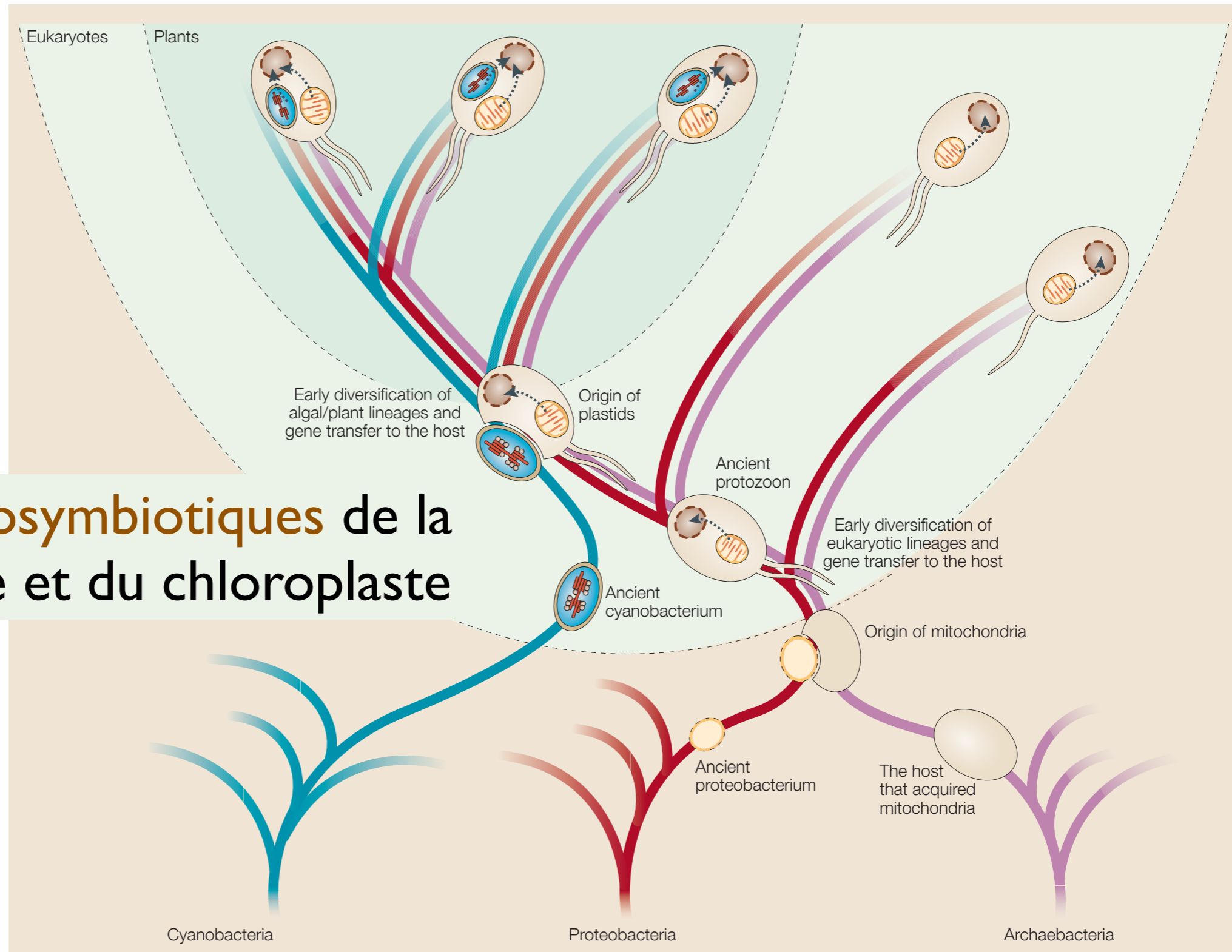
In many Eukaryotes, almost all genes can lead to different proteins through a process termed alternative splicing.

Endosymbiotic Organelles



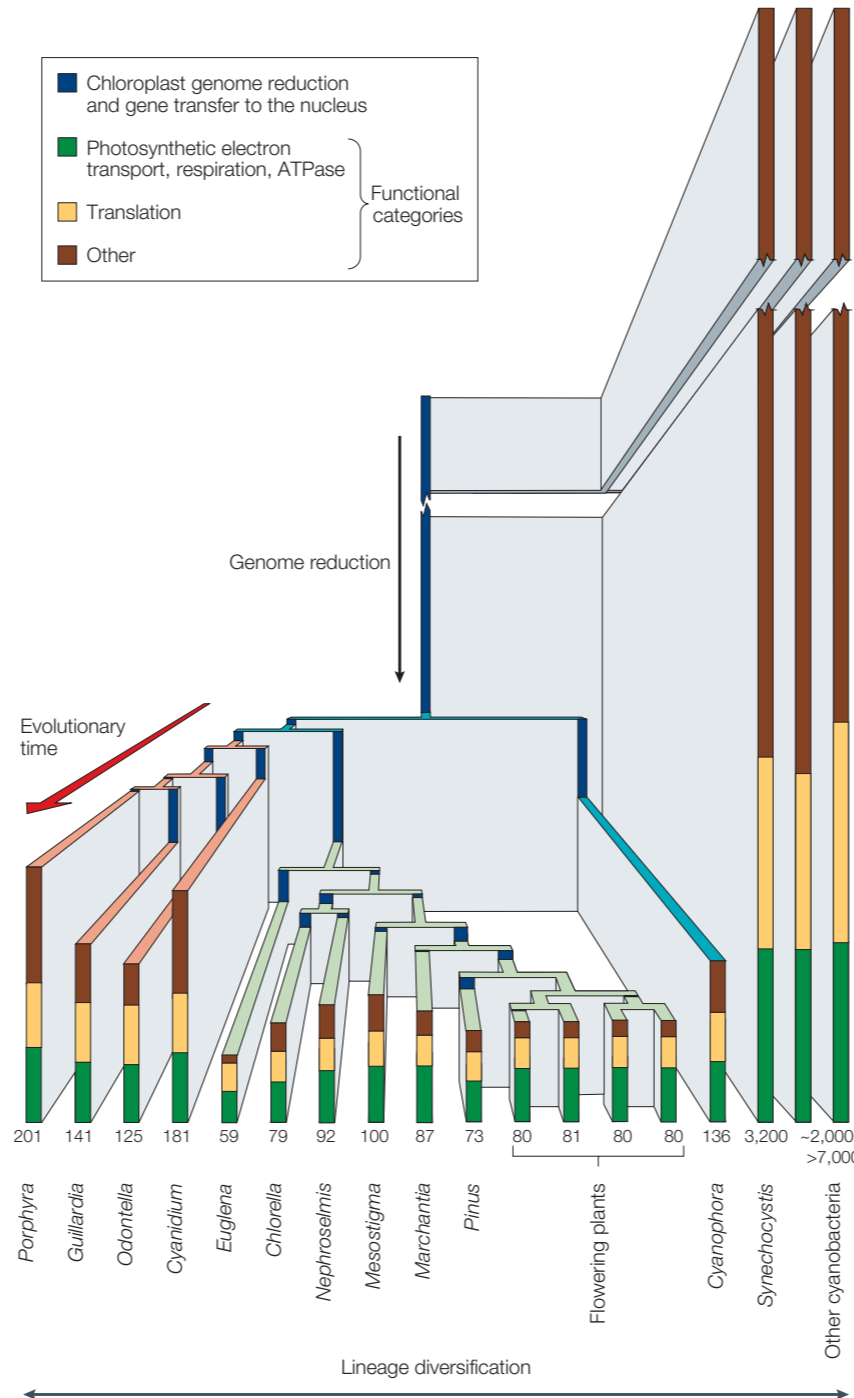
Lynn Margulis

origines **endosymbiotiques** de la mitochondrie et du chloroplaste



Genome Reduction

Gene code	Protein function
<i>accA,B,D</i>	Acetyl-CoA carboxylase
<i>acpP</i>	Acyl carrier protein
<i>apcA,B,D,E,F</i>	Allophycocyanin phycobilisome
<i>argB</i>	Acetylglutamate kinase
<i>atpA,B,D,E,F,G,H,I</i>	ATP synthase
<i>basI</i>	Thiol-specific antioxidant protein
<i>bioY</i>	Biotin synthase
<i>carA</i>	Carbamoyl phosphate synthetase
<i>cbbX</i>	Red type Calvin cycle operon
<i>ccsA</i>	Heme attachment to plastid cytochrome <i>c</i>
<i>cemA</i>	Envelope membrane protein
<i>chlB,I,L,N</i>	Protochlorophyllide reductase
<i>clpC/P</i>	Caseinolytic-like protease (Clp)
<i>cpcA,B,G</i>	Phycocyanin phycobilisome
<i>cpeA,B</i>	Phycocerythrin
<i>crtE</i>	Geranylgeranyl pyrophosphate synthetase
<i>cysA,T</i>	Probable transport proteins
<i>dfr</i>	Drug sensory protein
<i>dnaB</i>	DNA-replication helicase
<i>dnaK</i>	Hsp 70-type chaperone
<i>dsbD</i>	Thiol:disulfide interchange protein
<i>fabH</i>	β -Ketoacyl-acyl carrier protein synthase III
<i>fdx</i>	2[4Fe-4S] ferredoxin
<i>frbB</i>	Ferredoxin-thioredoxin reductase
<i>ftsH,W</i>	Division proteins
<i>glnB</i>	Nitrogen regulatory protein
<i>gltB</i>	Glutamate synthase (GOGAT)
<i>groEL,ES</i>	Chaperonins 60 and 10 kDa
<i>hemA</i>	5-Aminolevulinic acid synthase
<i>hisH</i>	Histidinol-phosphate aminotransferase
<i>I-CvuI</i>	DNA endonuclease
<i>ilvB,H</i>	Acetohydroxyacid synthase
<i>infA,B,C</i>	Translational initiation factors
<i>minD,E</i>	Homologues of bacterial cell division regulators
<i>mntA,B</i>	Manganese transport system proteins
<i>moeB</i>	Molybdopterin biosynthesis protein
<i>nadA</i>	Quinolinate synthase
<i>nblA</i>	Phycobilisome degradation protein
<i>ndhA-J</i>	NADH-plastoquinone oxidoreductase
<i>ndhK</i>	NADH-ubiquinone oxidoreductase
<i>ntcA</i>	Global nitrogen transcriptional regulator
<i>odpA,B</i>	Pyruvate dehydrogenase E1 component
<i>pbsA</i>	Heme oxygenase
<i>petA,B,D,F,G,J,L,M</i>	Photosystem electron transport proteins
<i>pgmA</i>	Phosphoglycerate mutase
<i>preA</i>	Prenyl transferase
<i>psaA-M</i>	PSI proteins
<i>psbA-X</i>	PSII proteins
<i>rbcLg/r</i>	RUBISCO large subunit, green and red forms
<i>rbcR</i>	RUBISCO operon transcriptional regulator
<i>rbcSg/r</i>	RUBISCO small subunit, green and red forms
<i>rdpO</i>	Probable reverse transcriptase
<i>rne</i>	RNAseE
<i>rplI-36</i>	Large subunit ribosomal proteins
<i>rpoA,B,C1,C2</i>	RNA polymerase
<i>rps1-20</i>	Small subunit ribosomal proteins
<i>secA,Y</i>	Preprotein-translocase
<i>syfB</i>	Phenylalanine tRNA synthetase
<i>syh</i>	Histidine tRNA synthetase
<i>thiG</i>	Thiamine biosynthesis
<i>trpA</i>	Tryptophane synthase
<i>trpG</i>	Anthranilate synthase, glutamine amidotransferase
<i>trxA</i>	Thioredoxin
<i>tsf</i>	Translational elongation factor Ts
<i>tufA</i>	Translational elongation factor Tu
<i>upp</i>	Uracil phosphoribosyltransferase
<i>ycf</i>	Hypothetical proteins



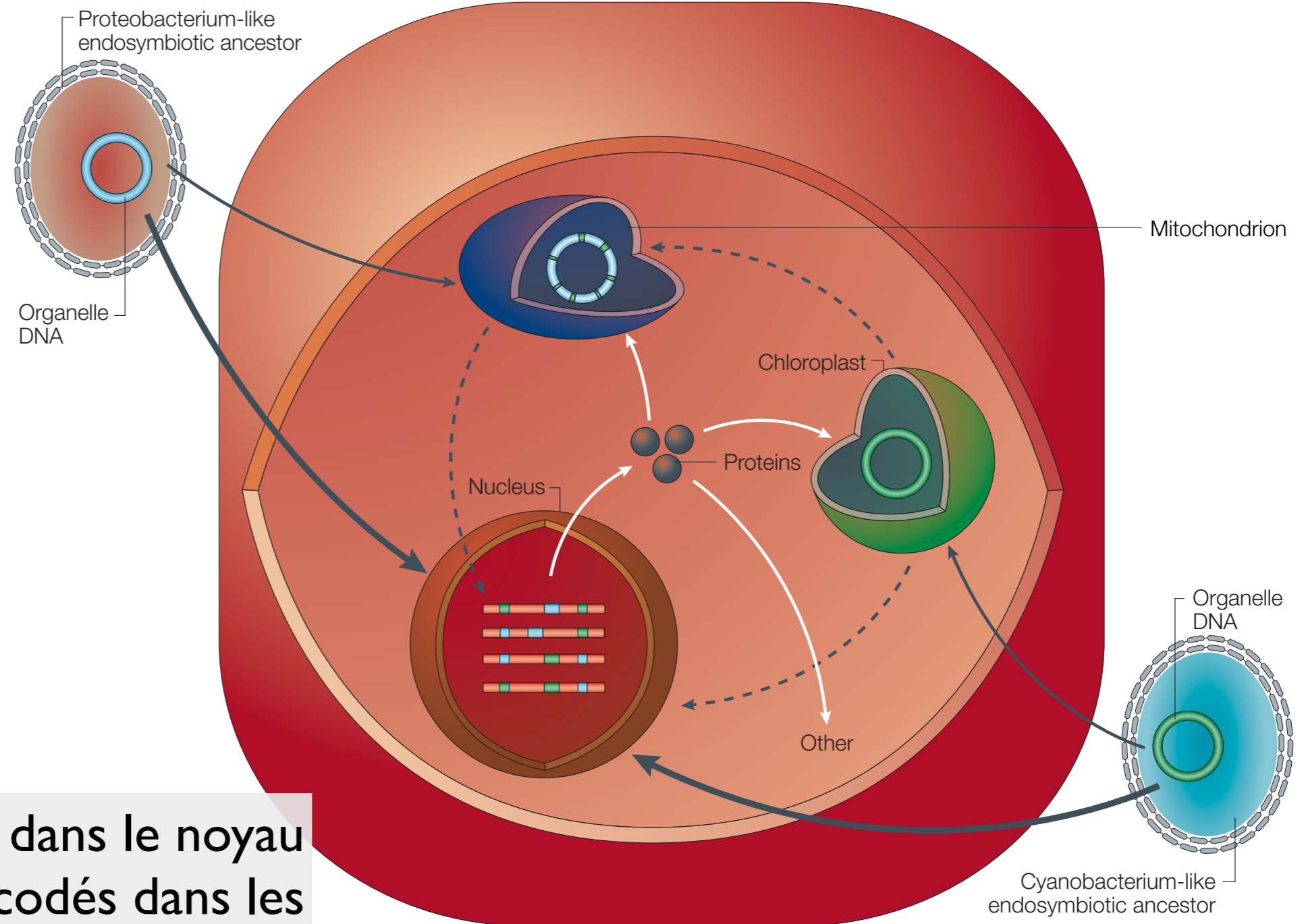
chloroplastes

1. gènes **inutiles** pour un endosymbionte
2. gènes **redondants** avec ceux du noyau
3. gènes **transférés** dans le noyau

Endosymbiotic Gene Transfer



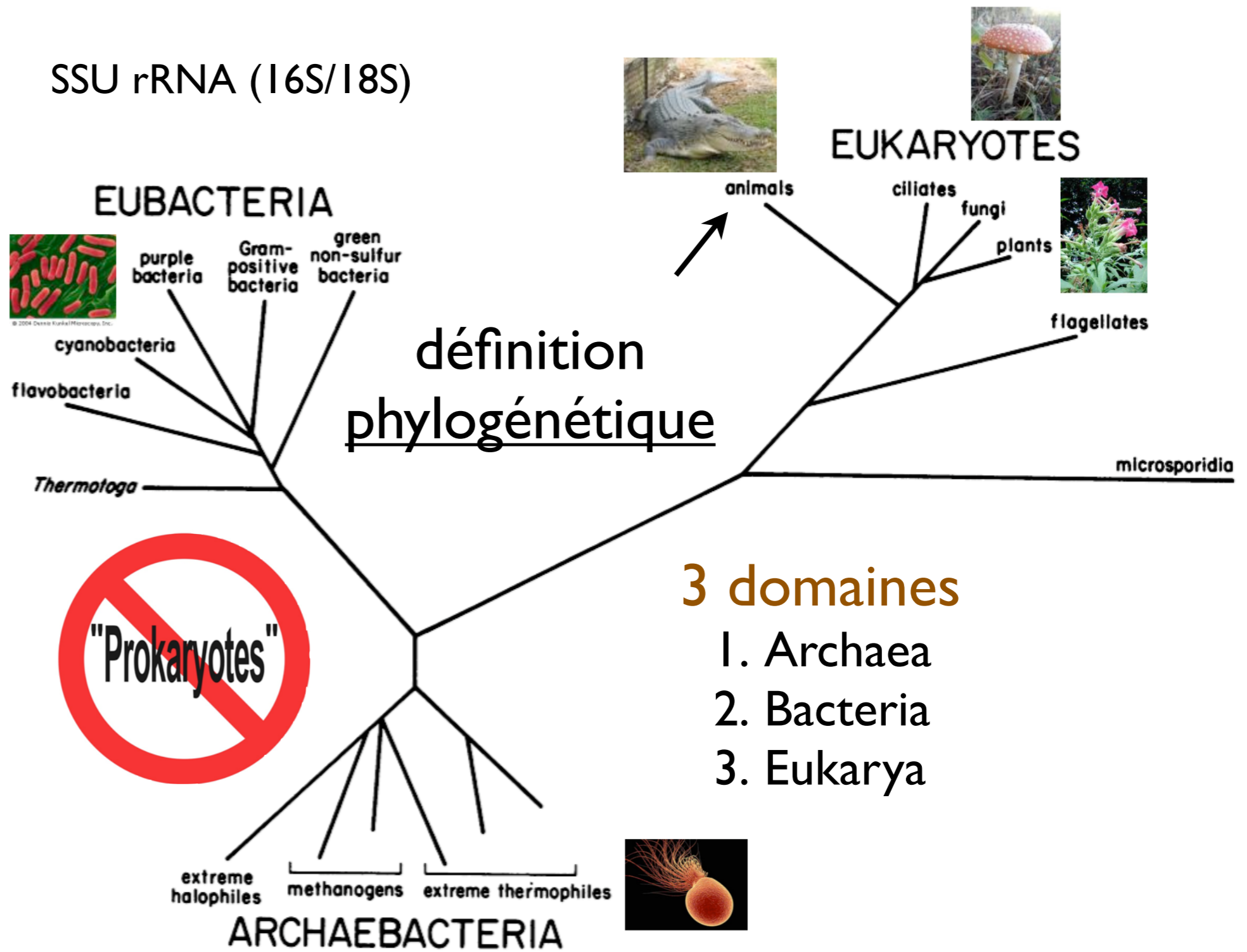
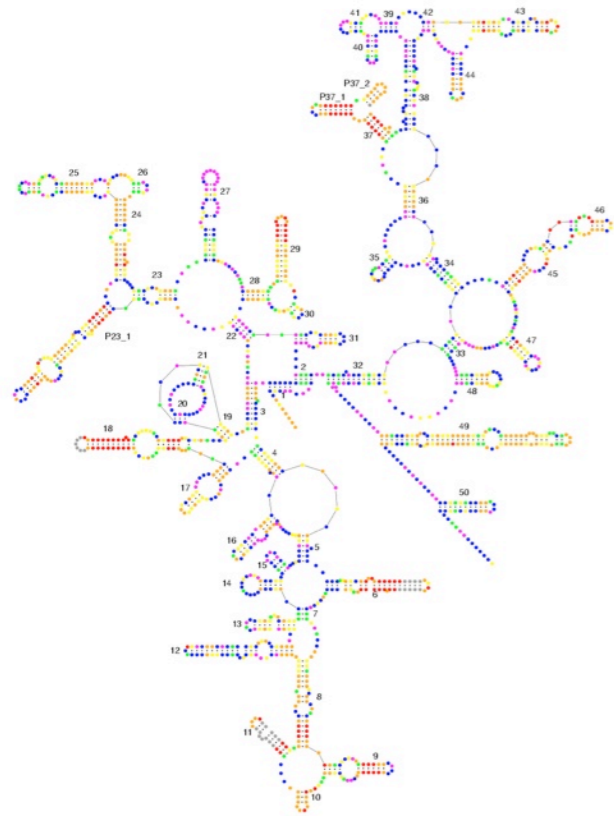
Bill Martin



relocalisation dans le noyau
des gènes encodés dans les
organelles endosymbiotiques

Woese's Tree of Life

SSU rRNA (16S/18S)

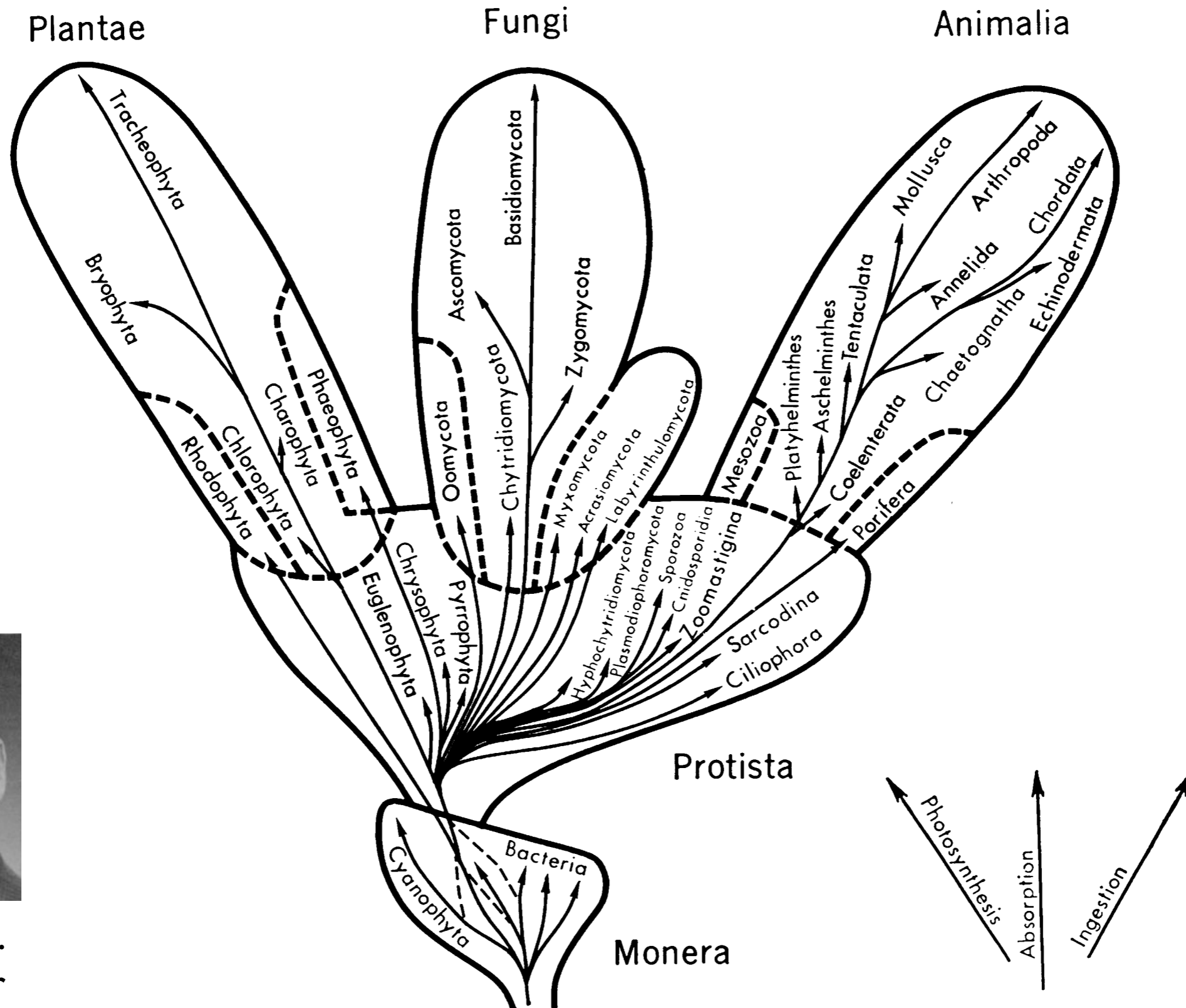


Carl Woese

A large, stylized number '2' in a brown color, positioned in the background of the slide.

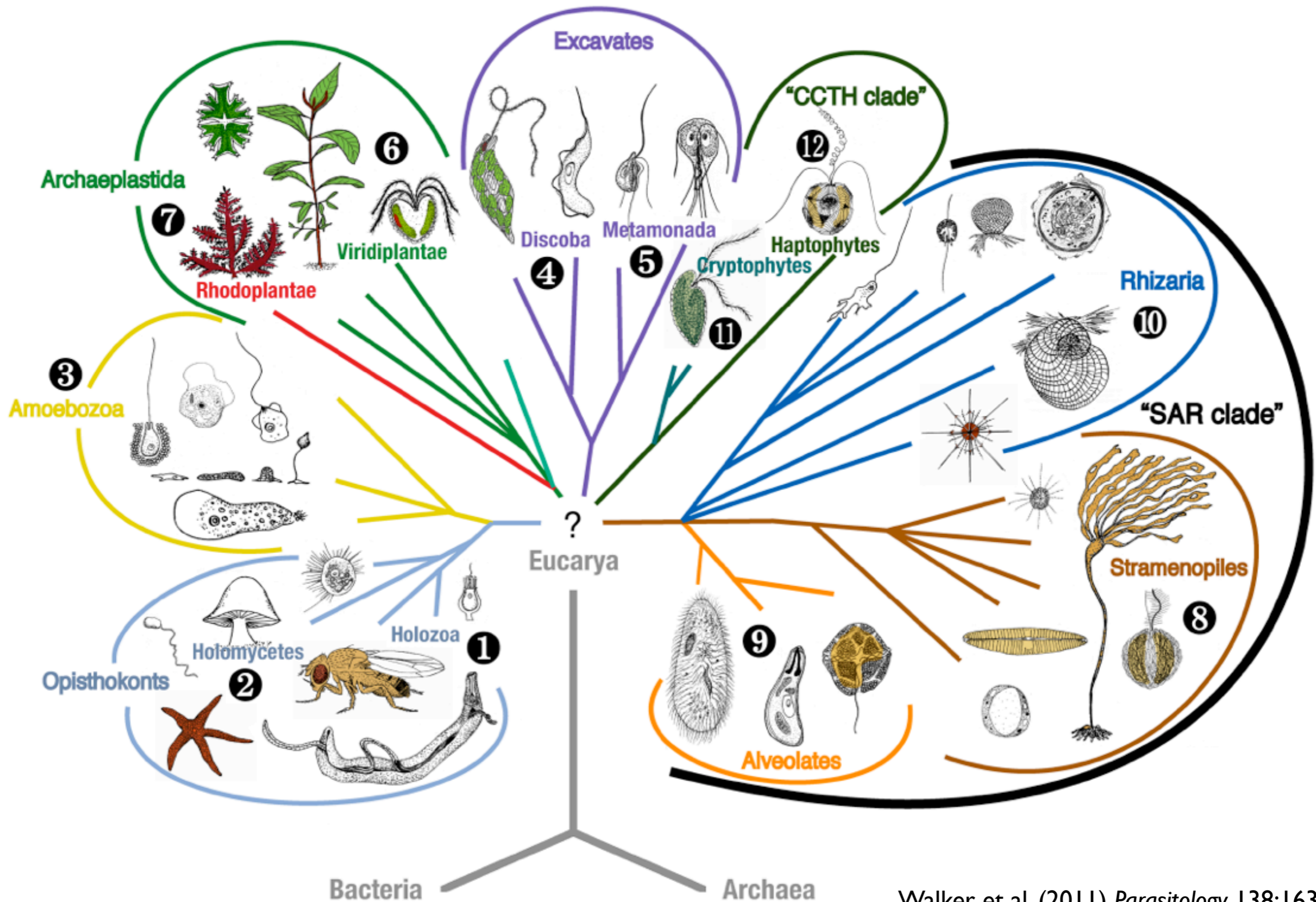
*Quelle est la diversité
des Eucaryotes ?*

Whittaker's System

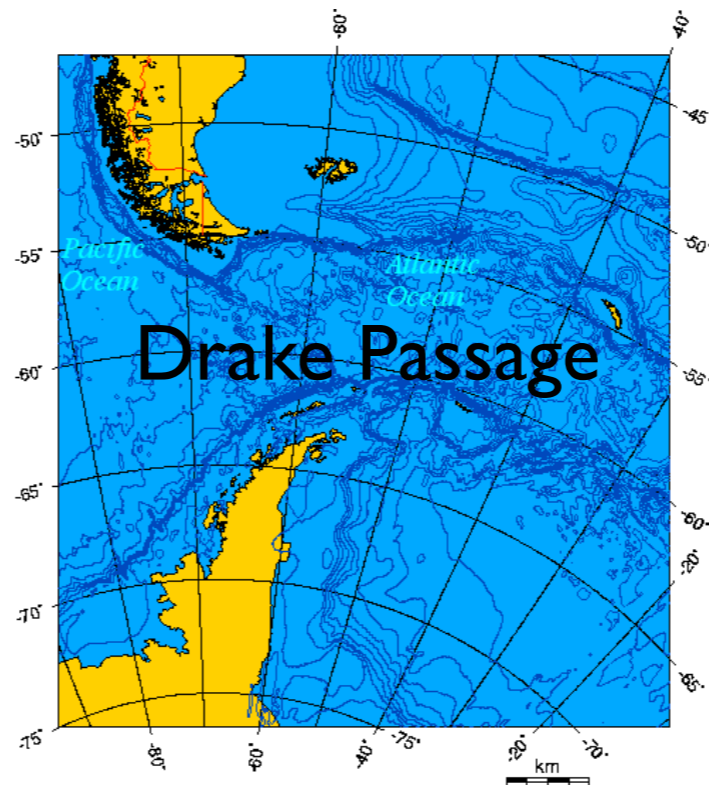
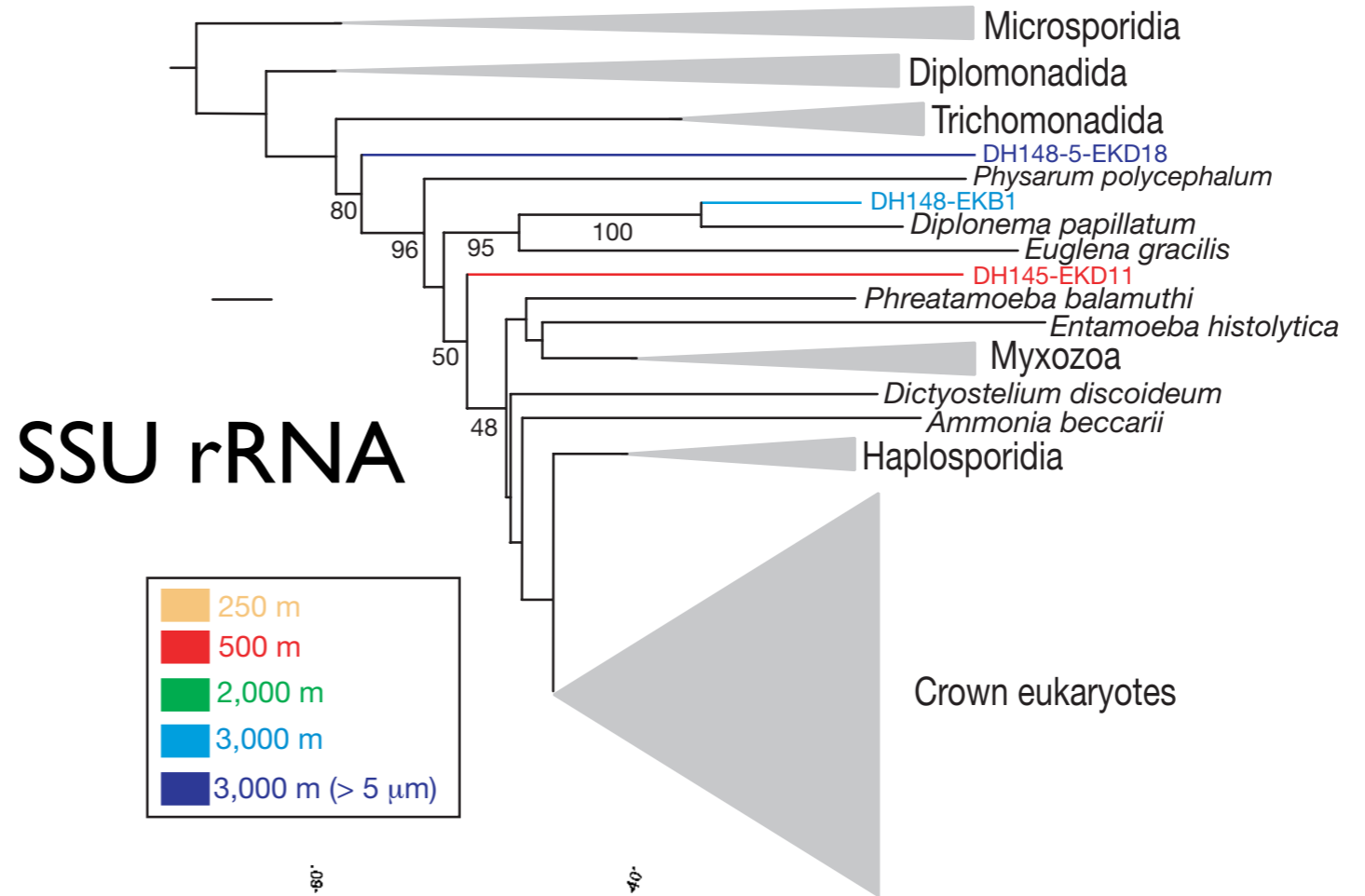
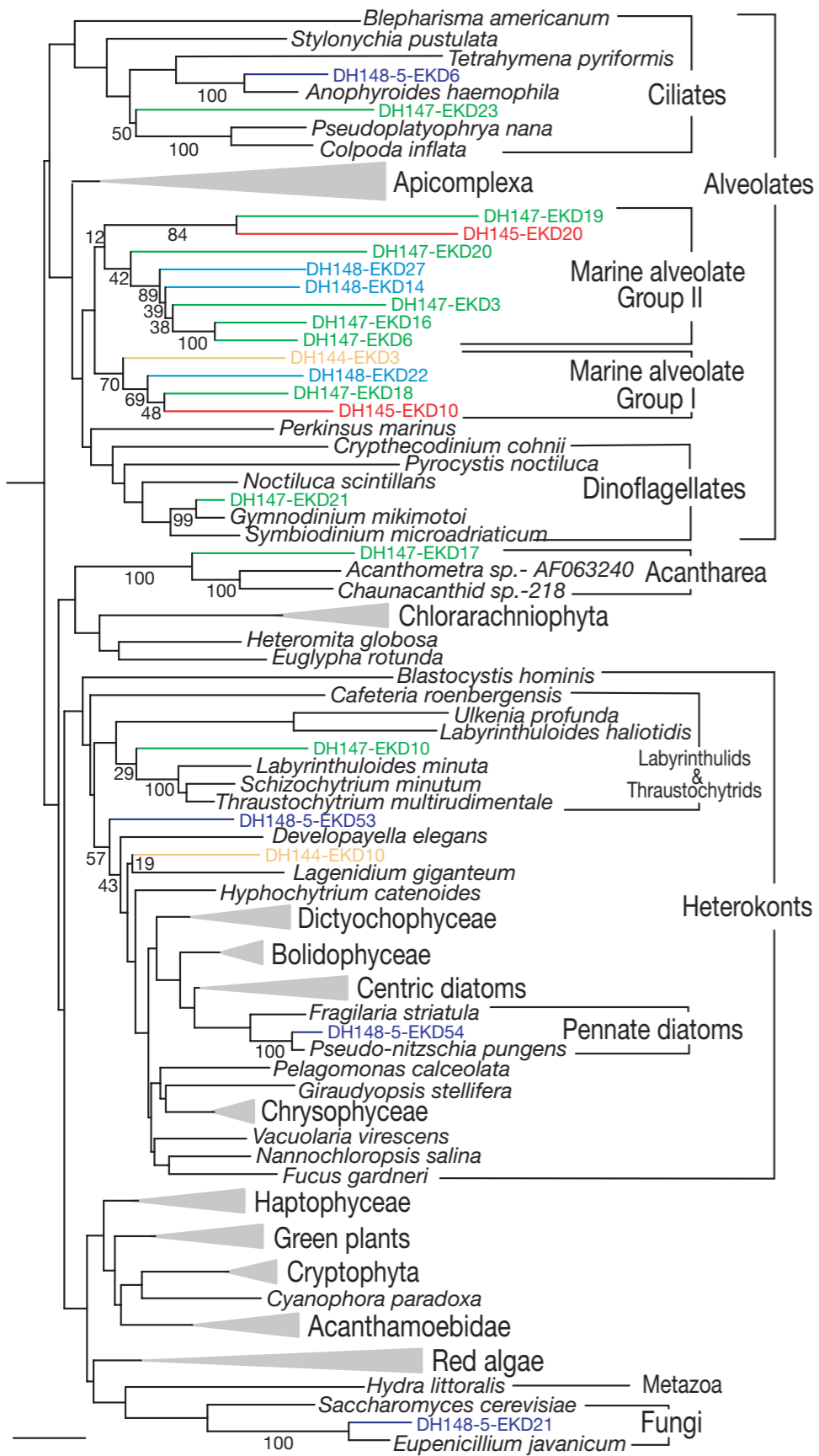


Robert H. Whittaker

Eukaryotic Diversity

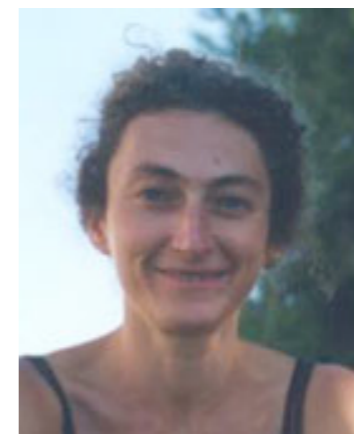


Environmental Surveys



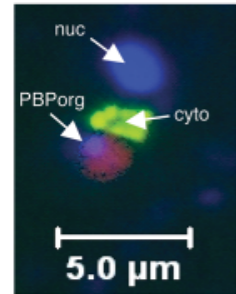
Purification
Lopez-Garcia

David Moreira

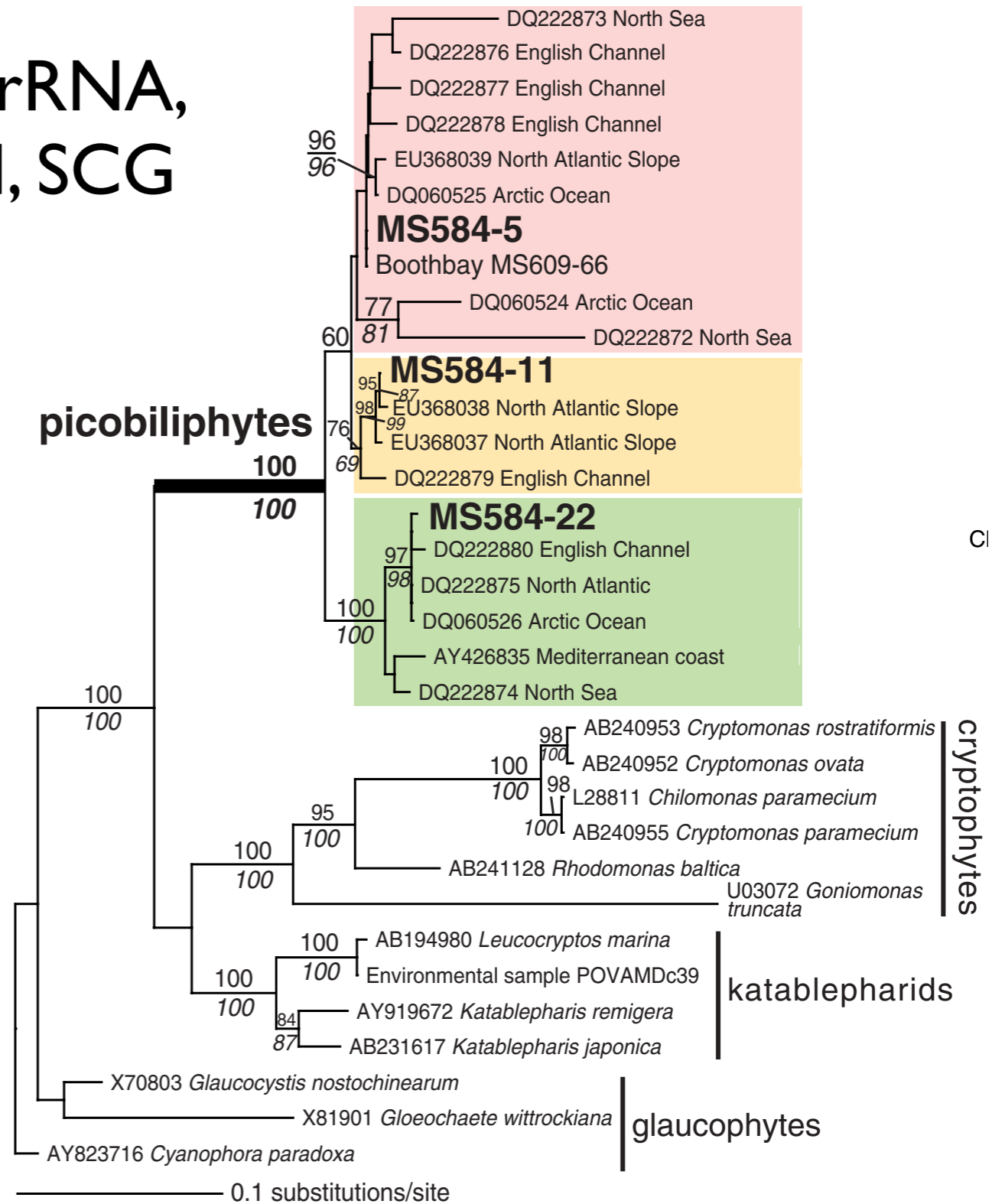
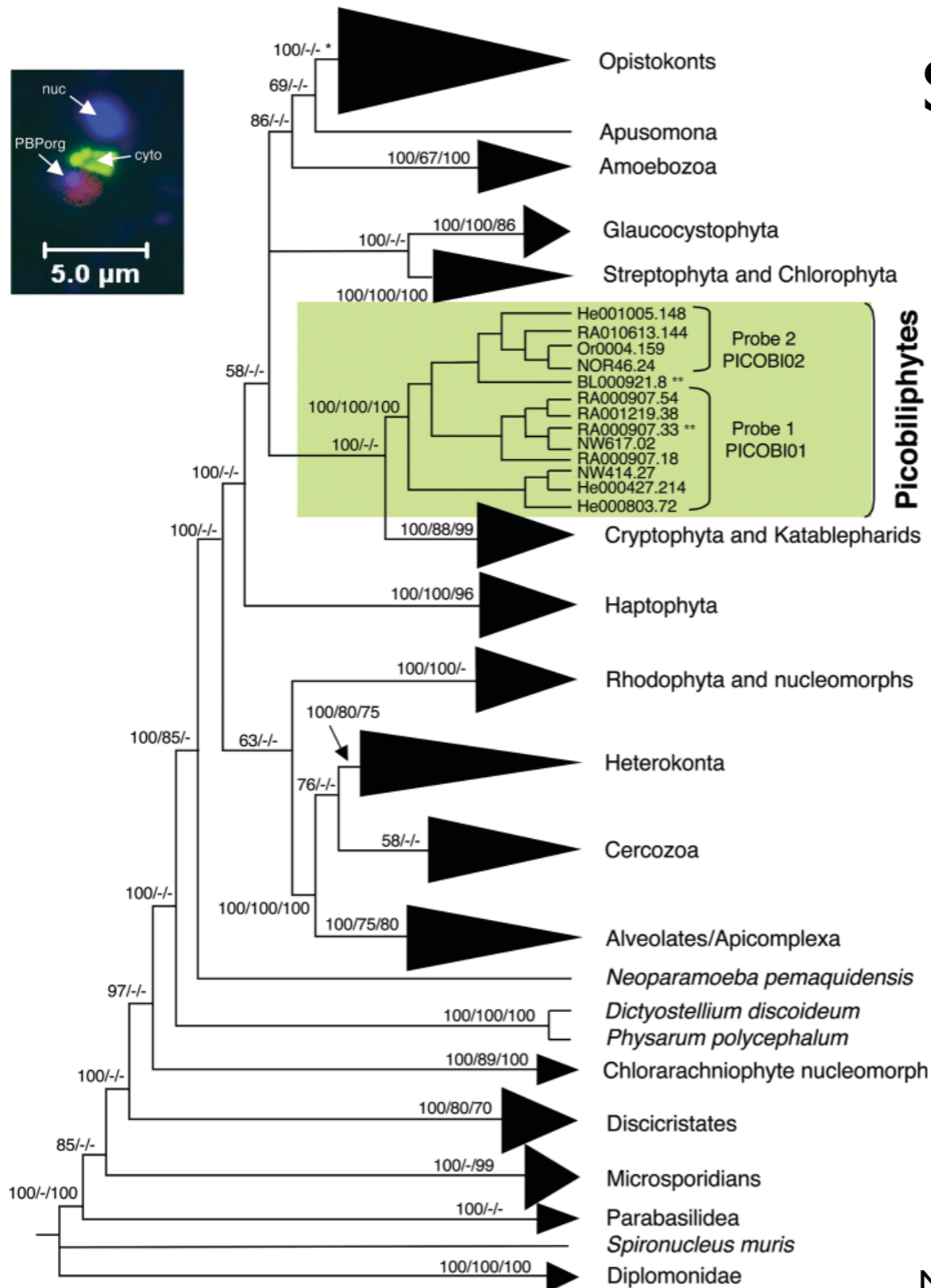


Lopez-Garcia et al. (2001) *Nature* 409:603-607

Phylum-level Findings (I)

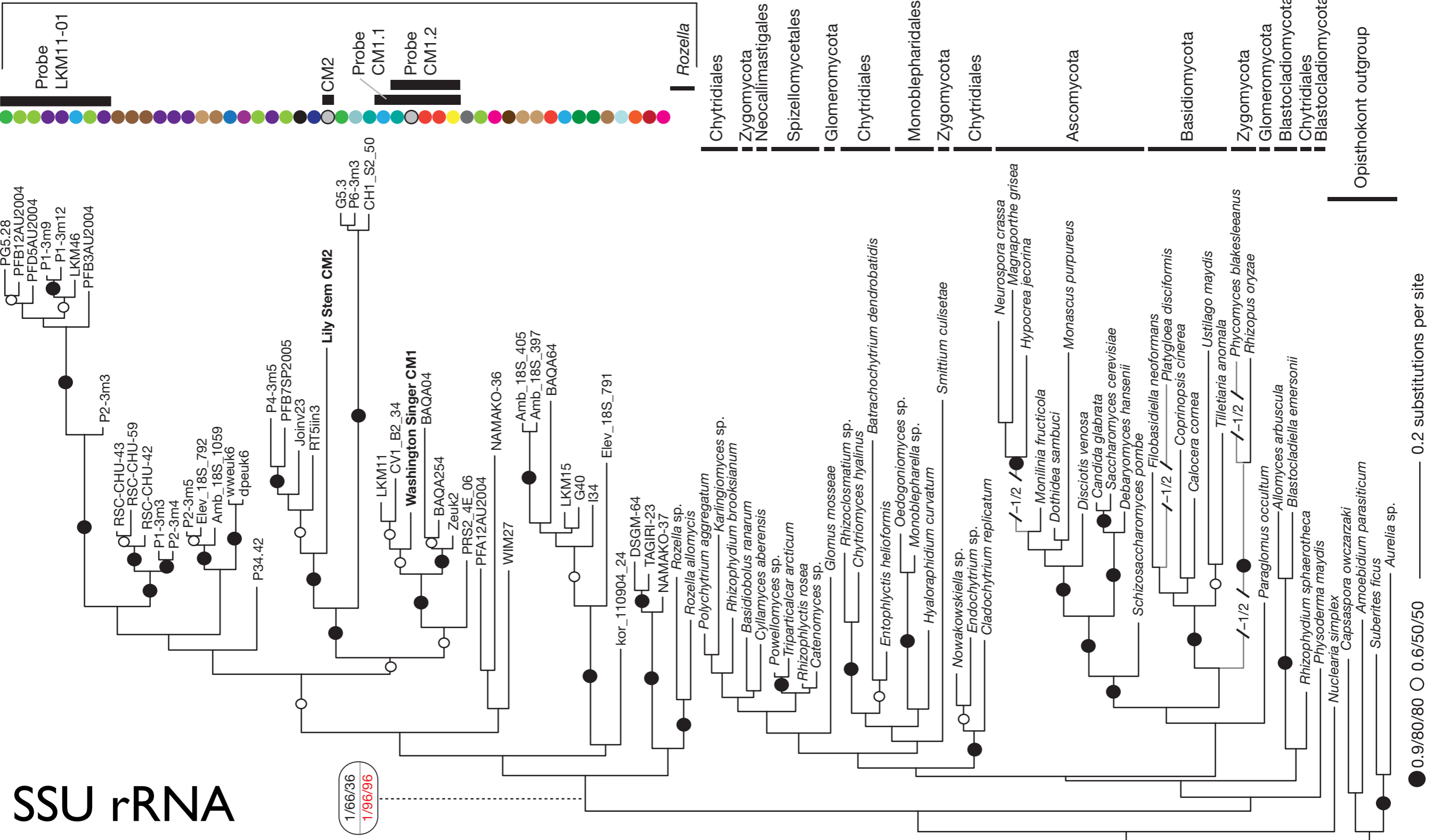


SSU rRNA,
FISH, SCG



Phylum-level Findings (2)

Cryptomycota



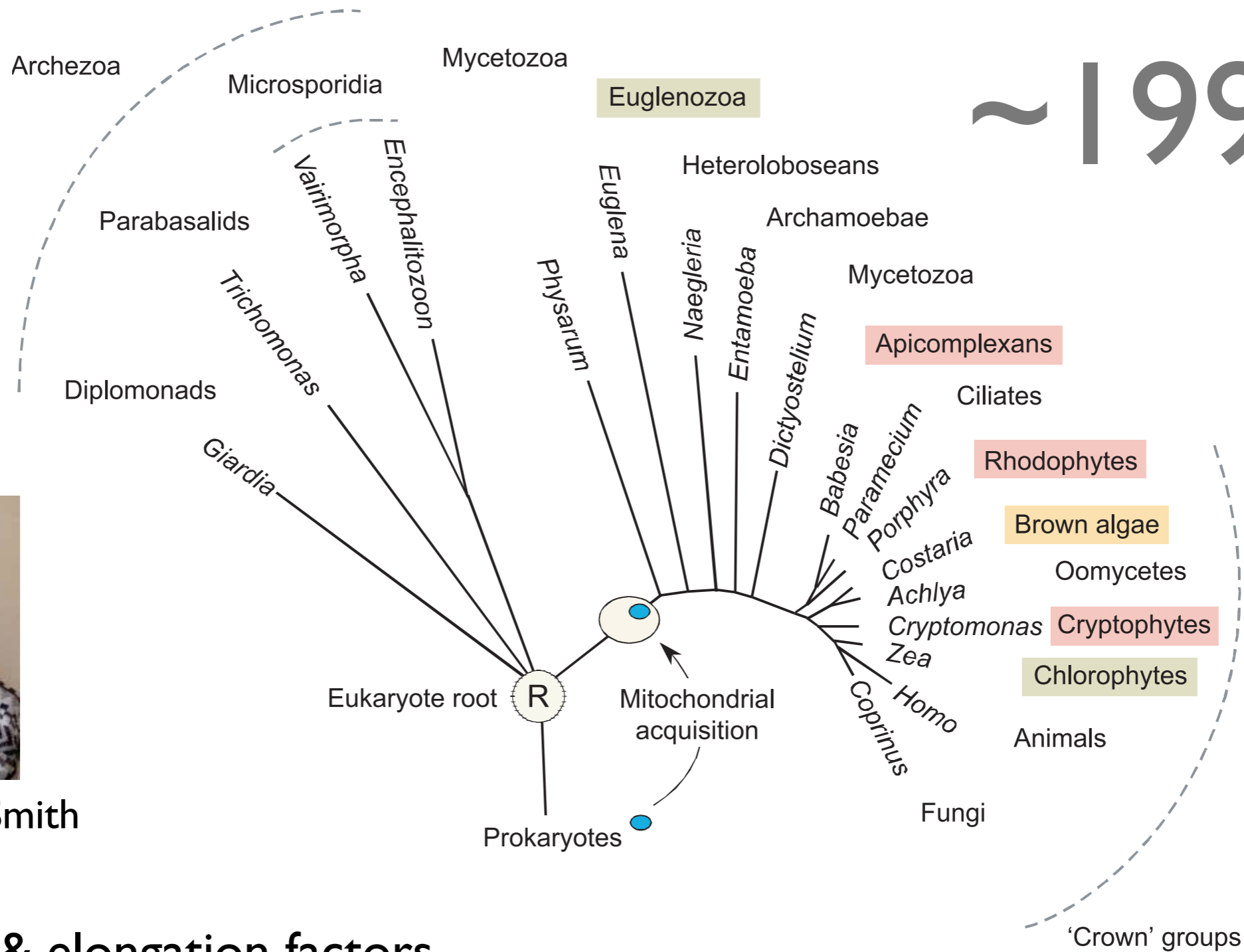
SSU rRNA



*Quelles sont les relations
entre les groupes d'Eucaryotes ?*

Archaezoa vs. 'Crown' groups

~1995



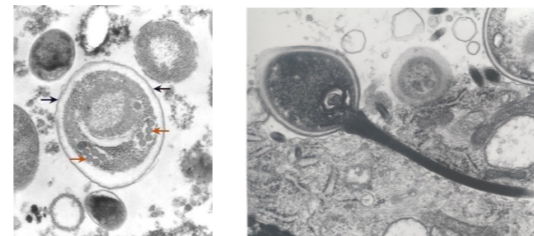
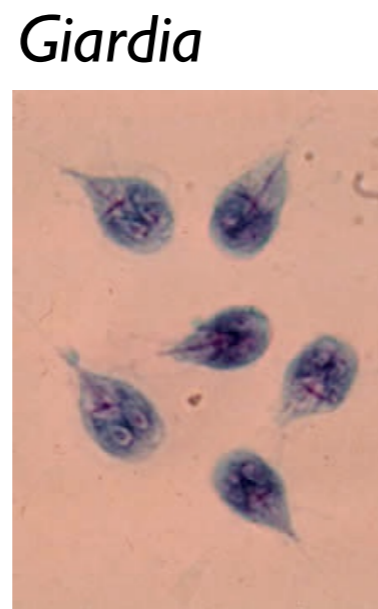
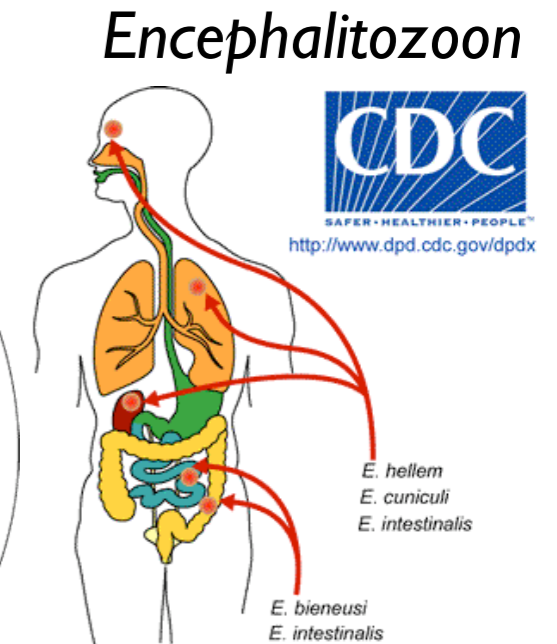
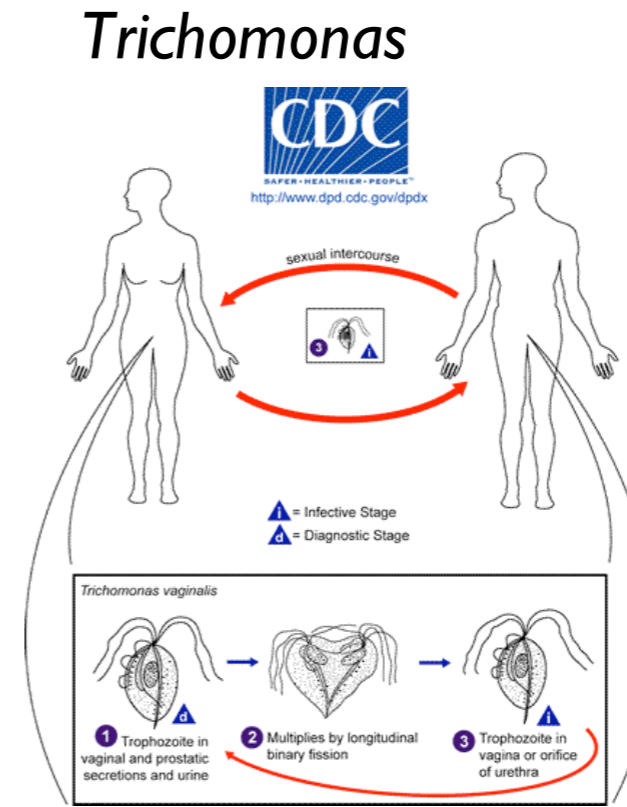
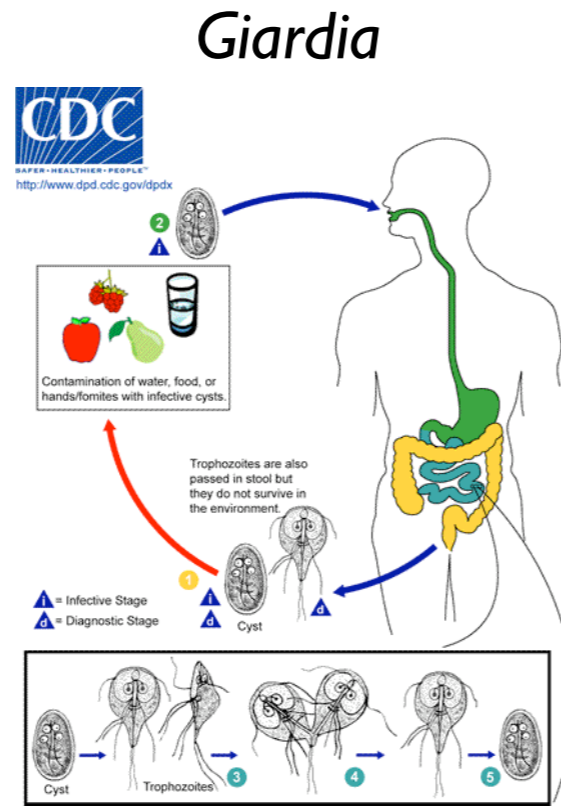
Tom Cavalier-Smith

SSU rRNA & elongation factors

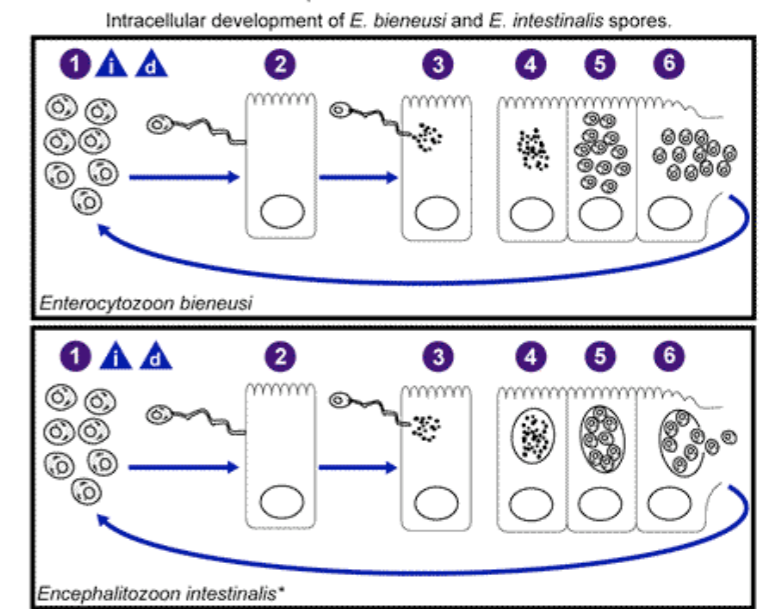
What are the Archezoa?

parasites
amitochondriaux

(ultrastructure simple,
pas de peroxysomes,
système endomembranaire
peu développé)



Encephalitozoon



*Development inside parasitophorous vacuole also occurs in *E. hellem* and *E. cuniculi*.

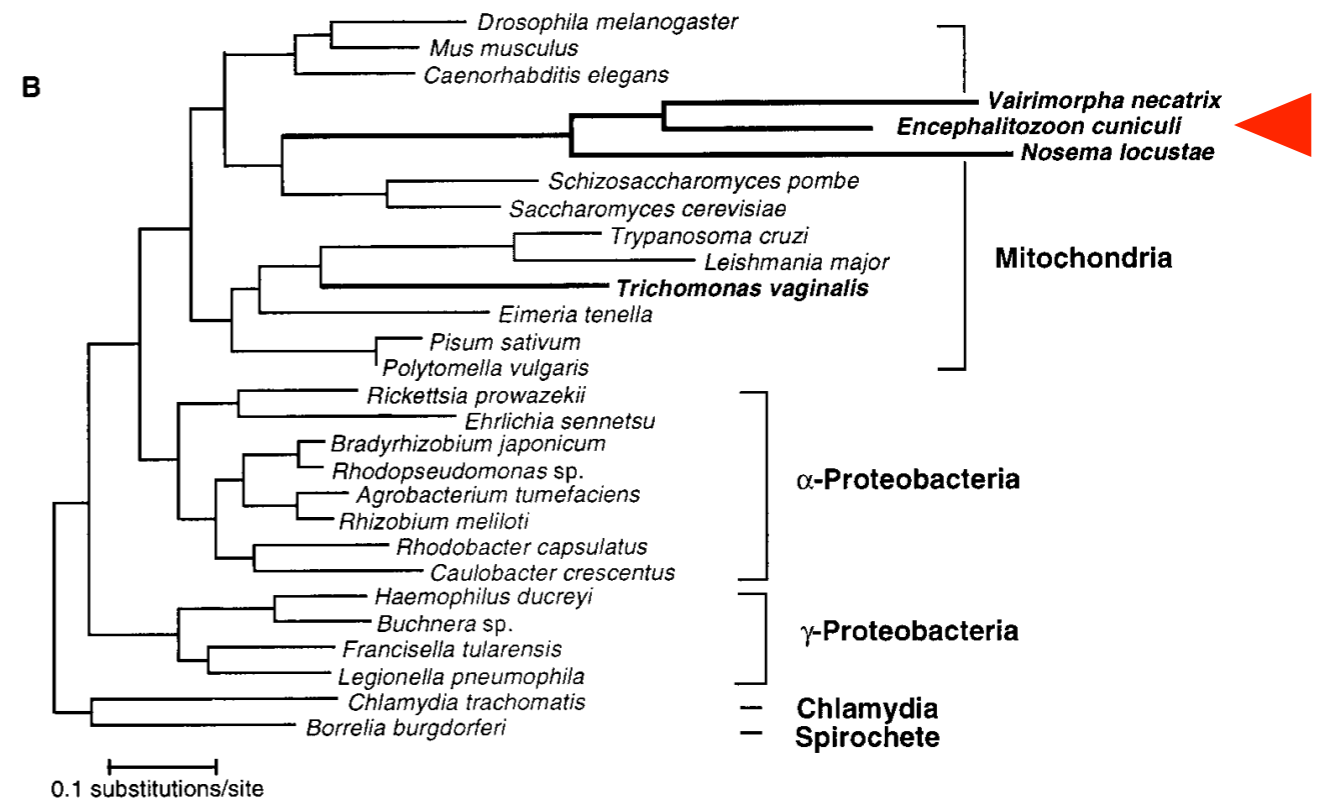
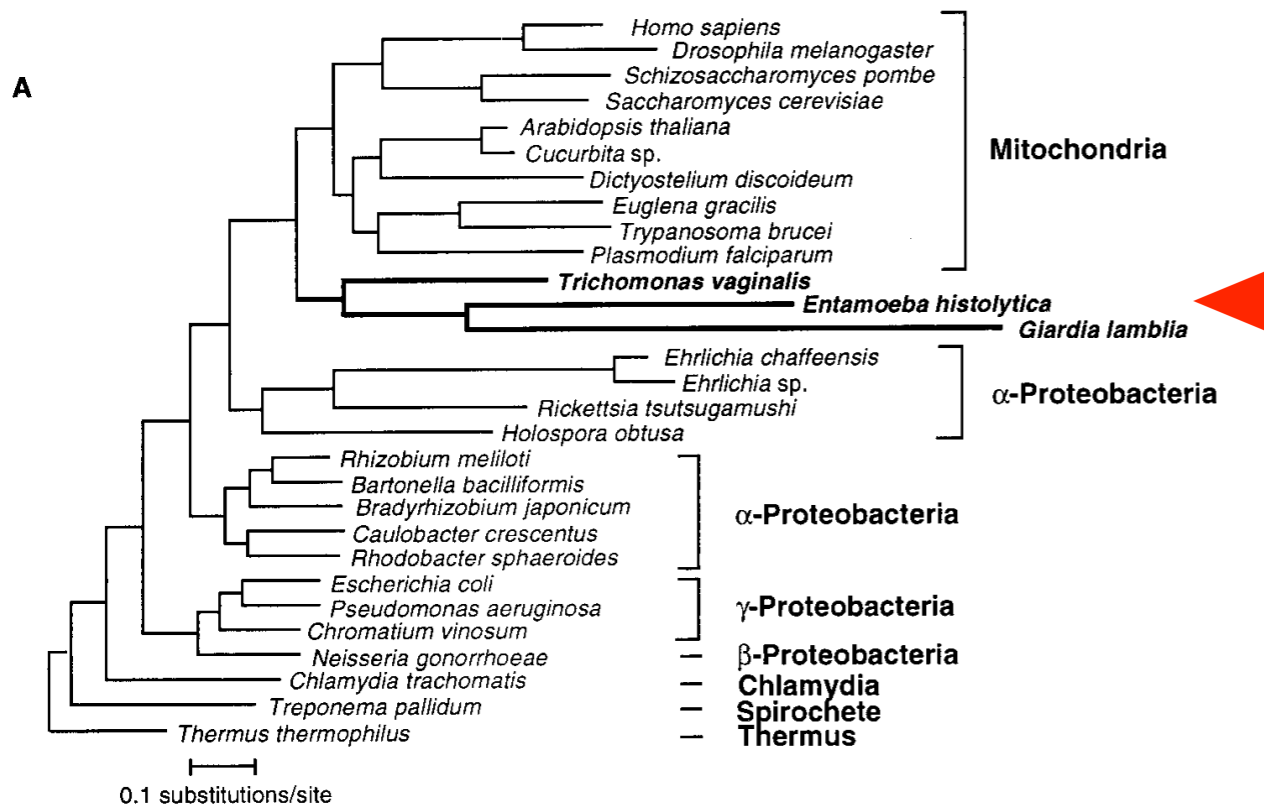
Not so Archezoa (I)



Andrew Roger

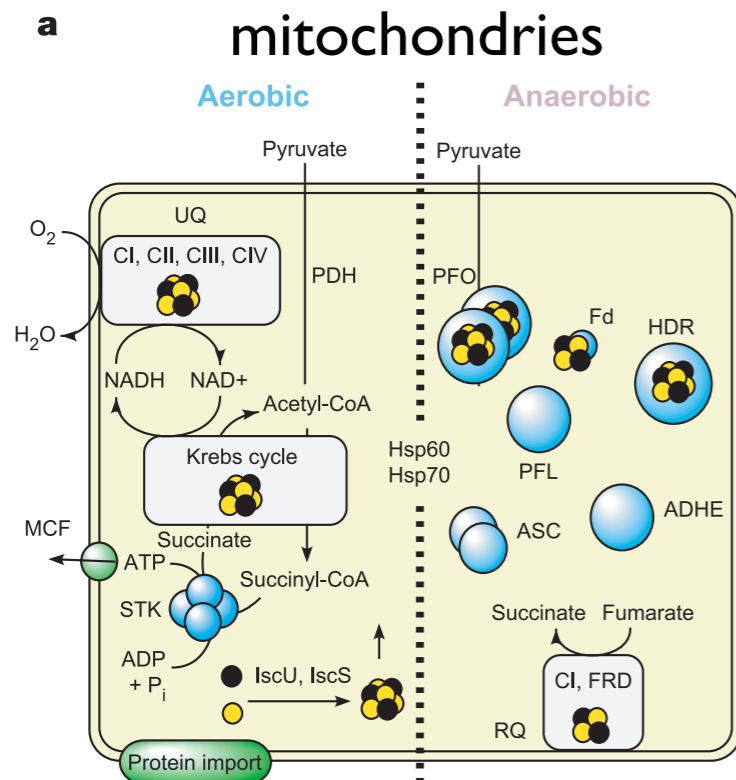
CPN60

HSP70



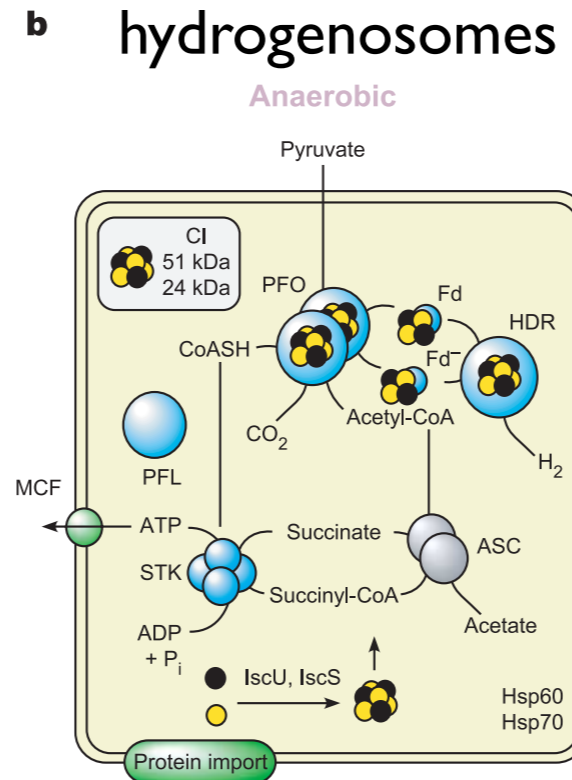
présence de gènes nucléaires d'origine mitochondriale dans les Archezoa

Not so Archezoa (2)

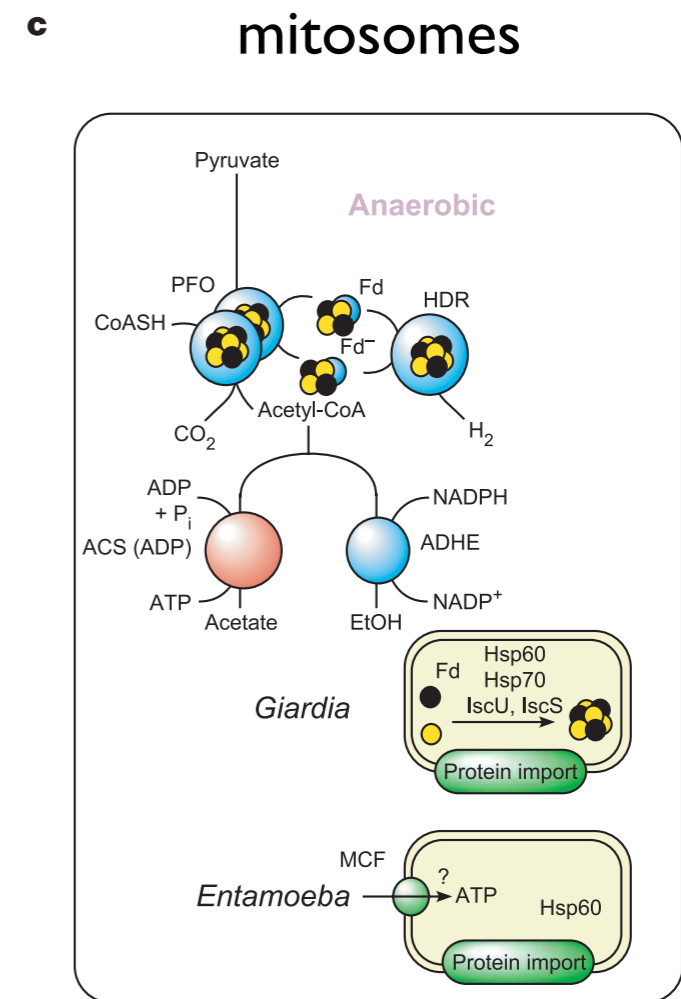


Krebs cycle and complex I, II, III and IV in most forms

PFO: *Euglena*
 HYD: *Nyctotherus*
 ADHE: *Chlamydomonas*
 PFL: *Chlamydomonas*
 ASC: *Trypanosoma*
 FRD: *Fasciola*
 RQ: *Fasciola* and *Euglena*



All except PFL: *Trichomonas*
 PFL: *Neocallimastix*



*Trachipleistophora**

Hsp70

Protein import

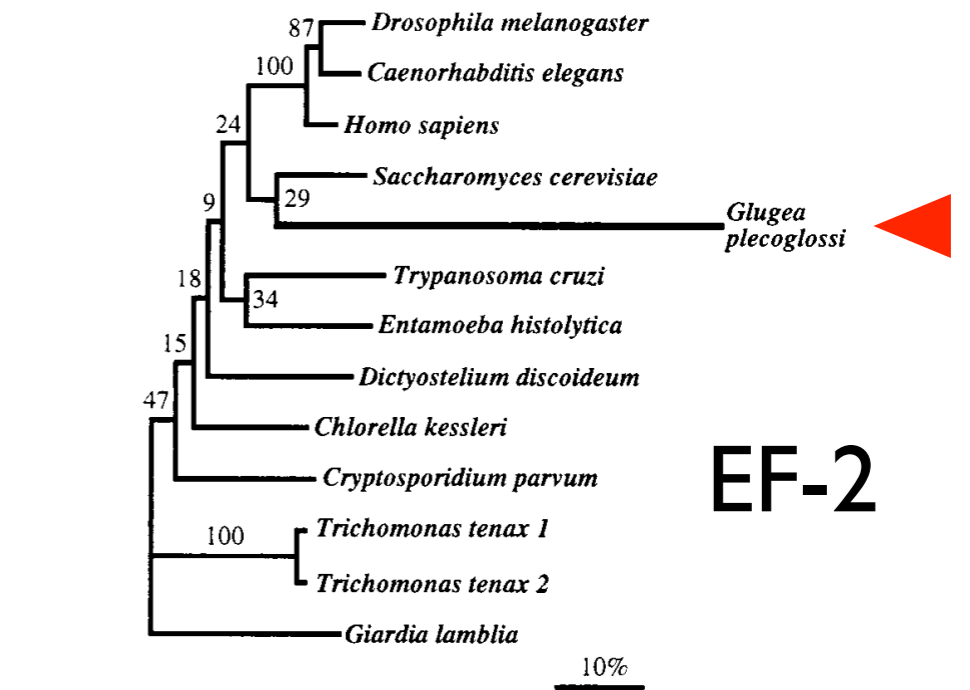
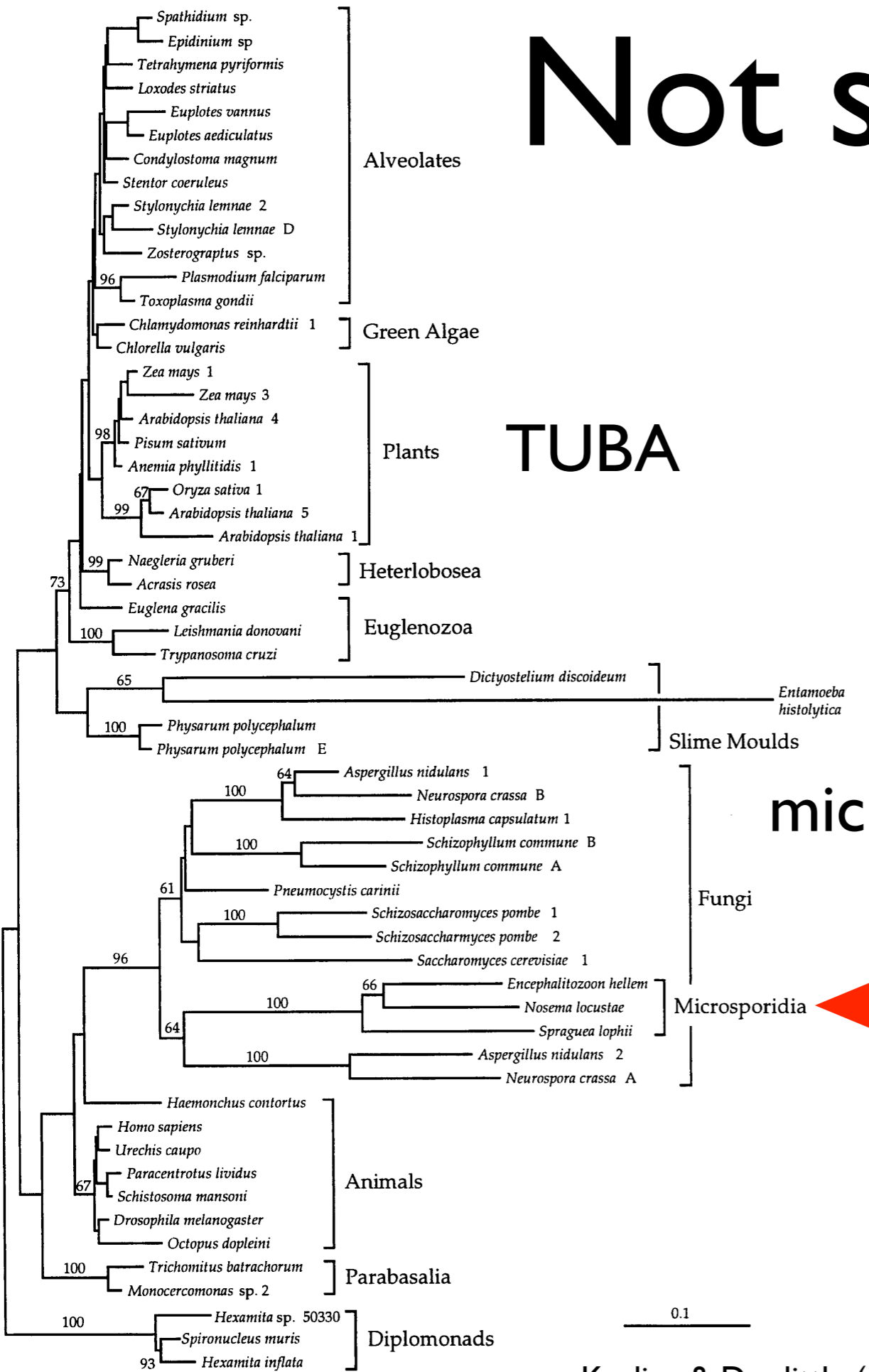
*Cryptosporidium**

Hsp60
Hsp70

Protein import

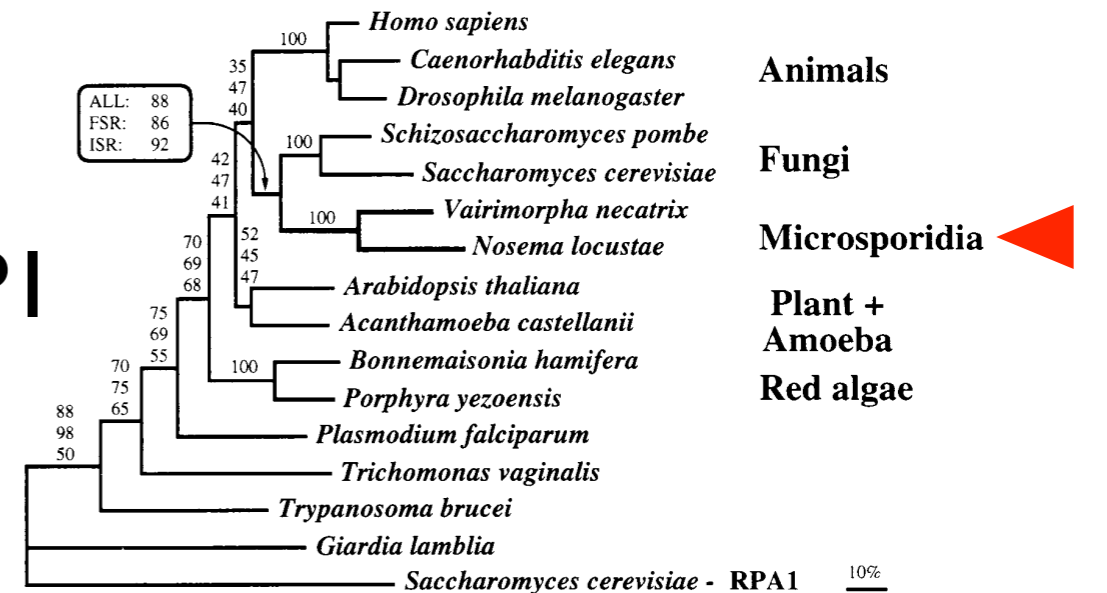
présence d'organelles homologues aux mitochondries dans les Archezoa

Not so Archezoa (3)



microsporidies = champignons dérivés

RBPI



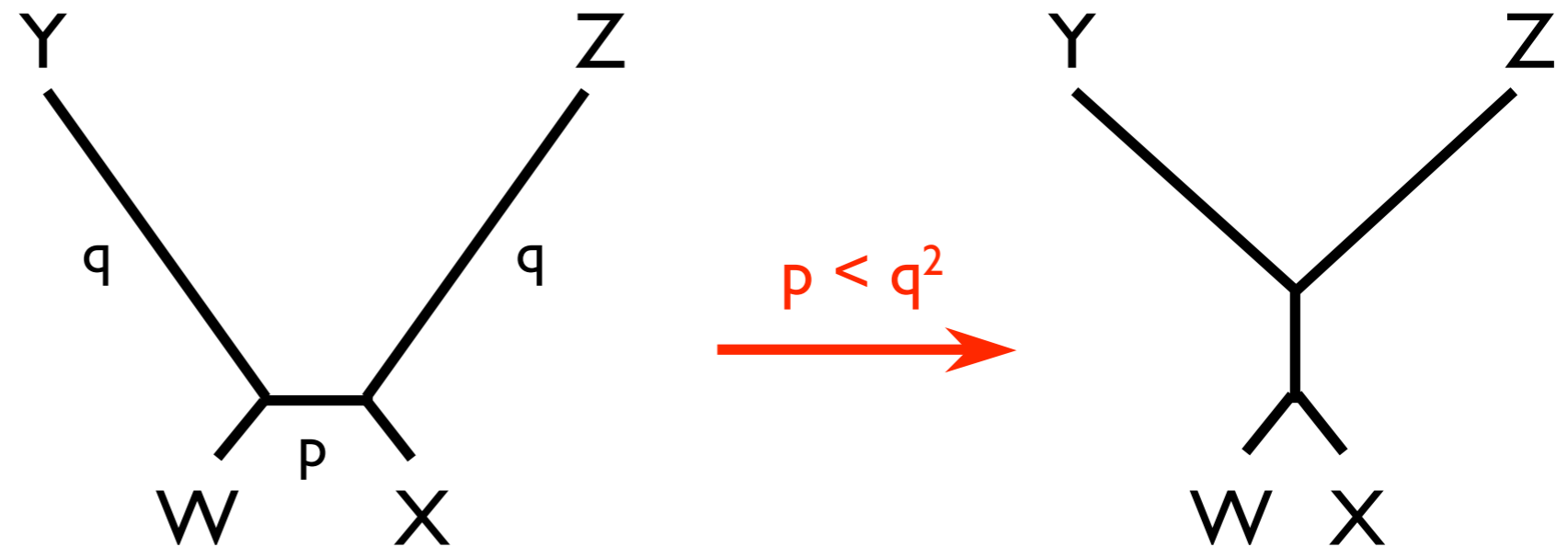
Long Branch Attraction



Joe Felsenstein

surtout en parcimonie, mais pas seulement

position artéfactuelle des Archezoa dans l'arbre de C. Woese

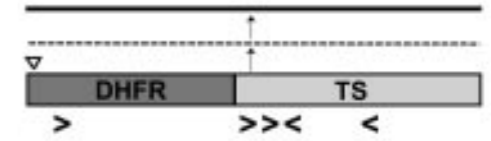


si Y est un outgroup phylogénétiquement éloigné

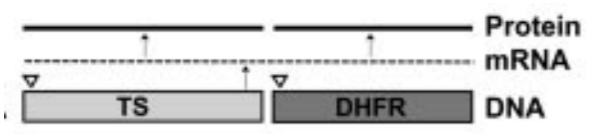
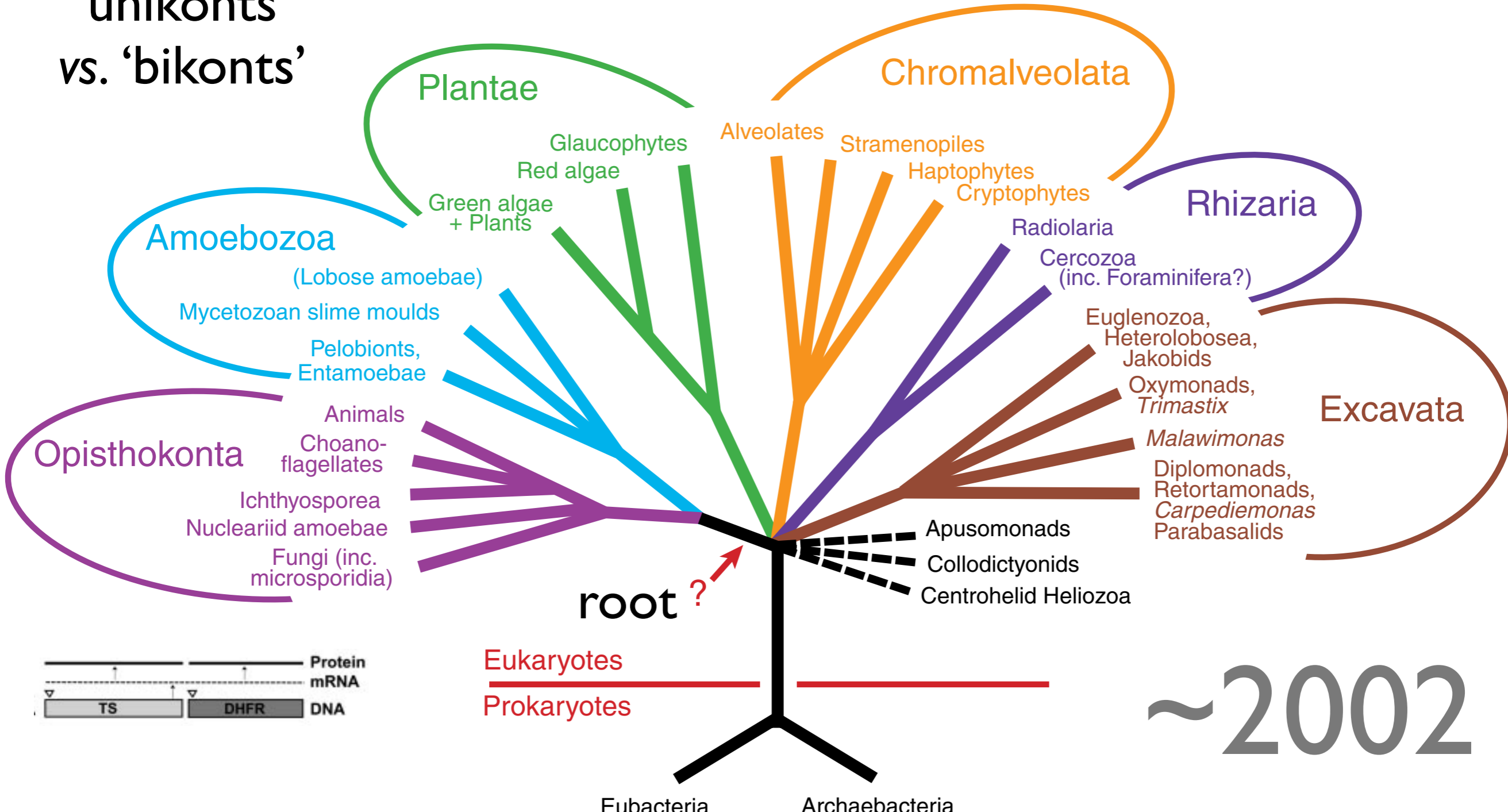


The Six Supergroups

DHFR-TS gene fusion

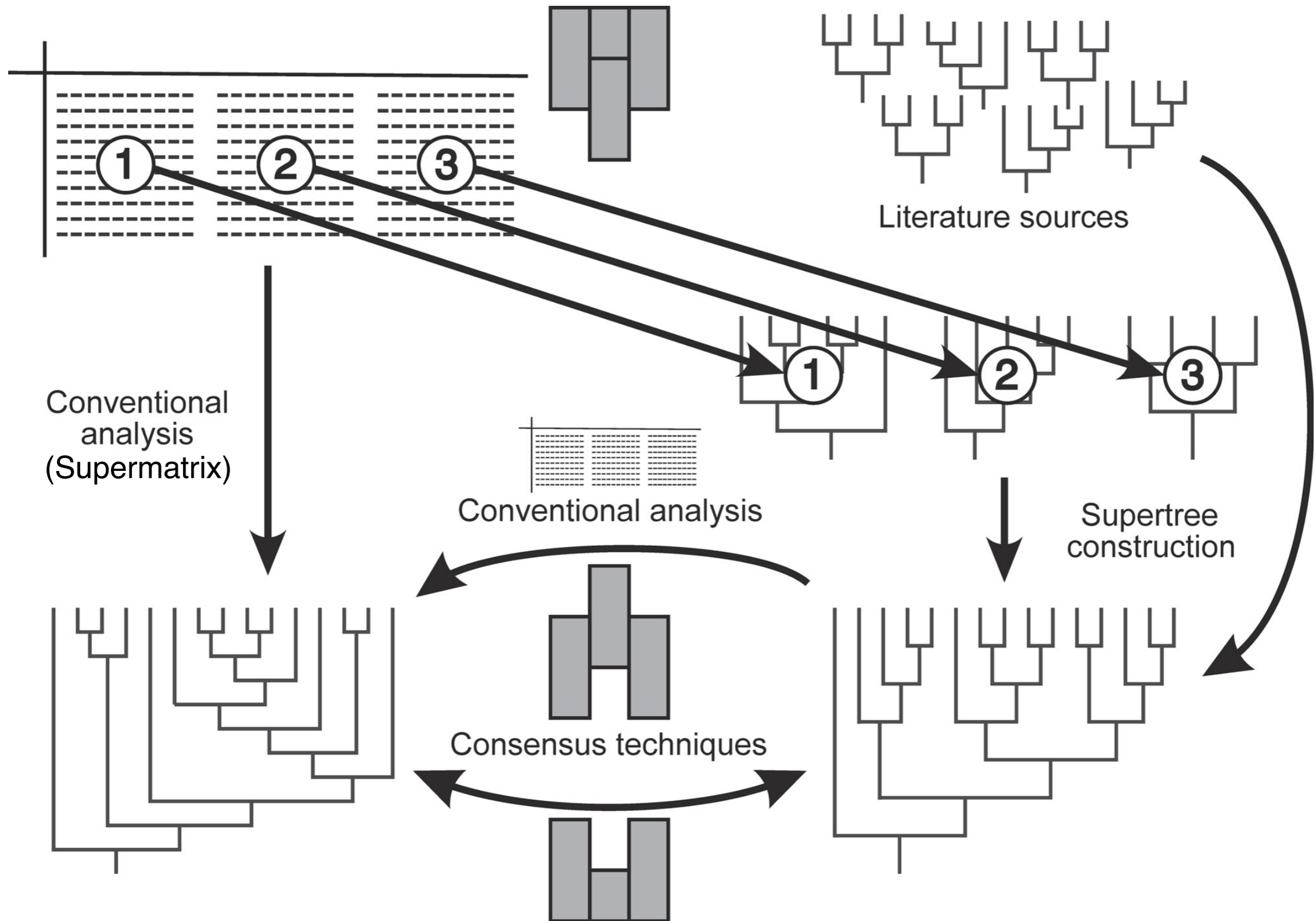


'unikonts'
vs. 'bikonts'



~2002

Phylogenomics

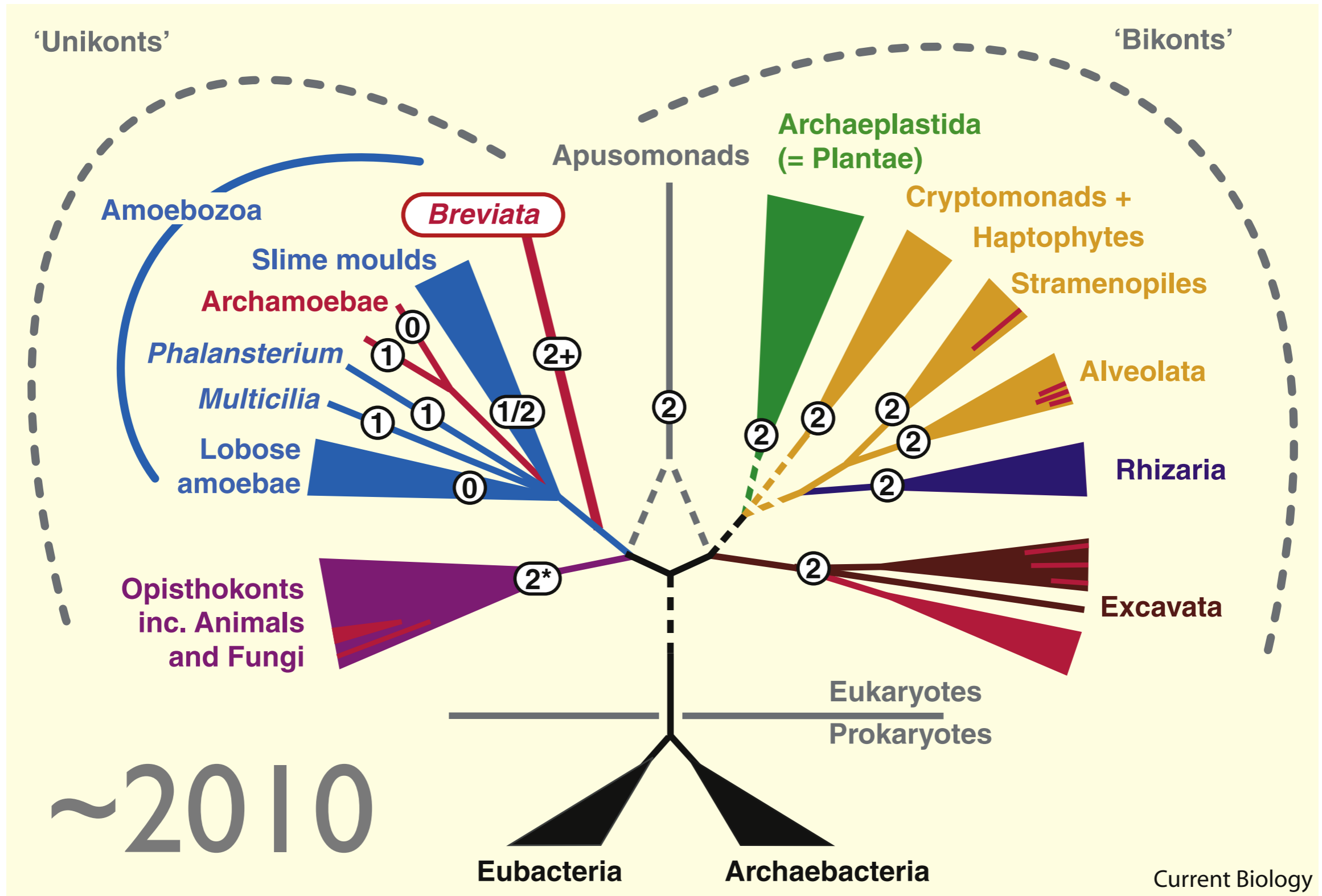


Supermatrix Assembly

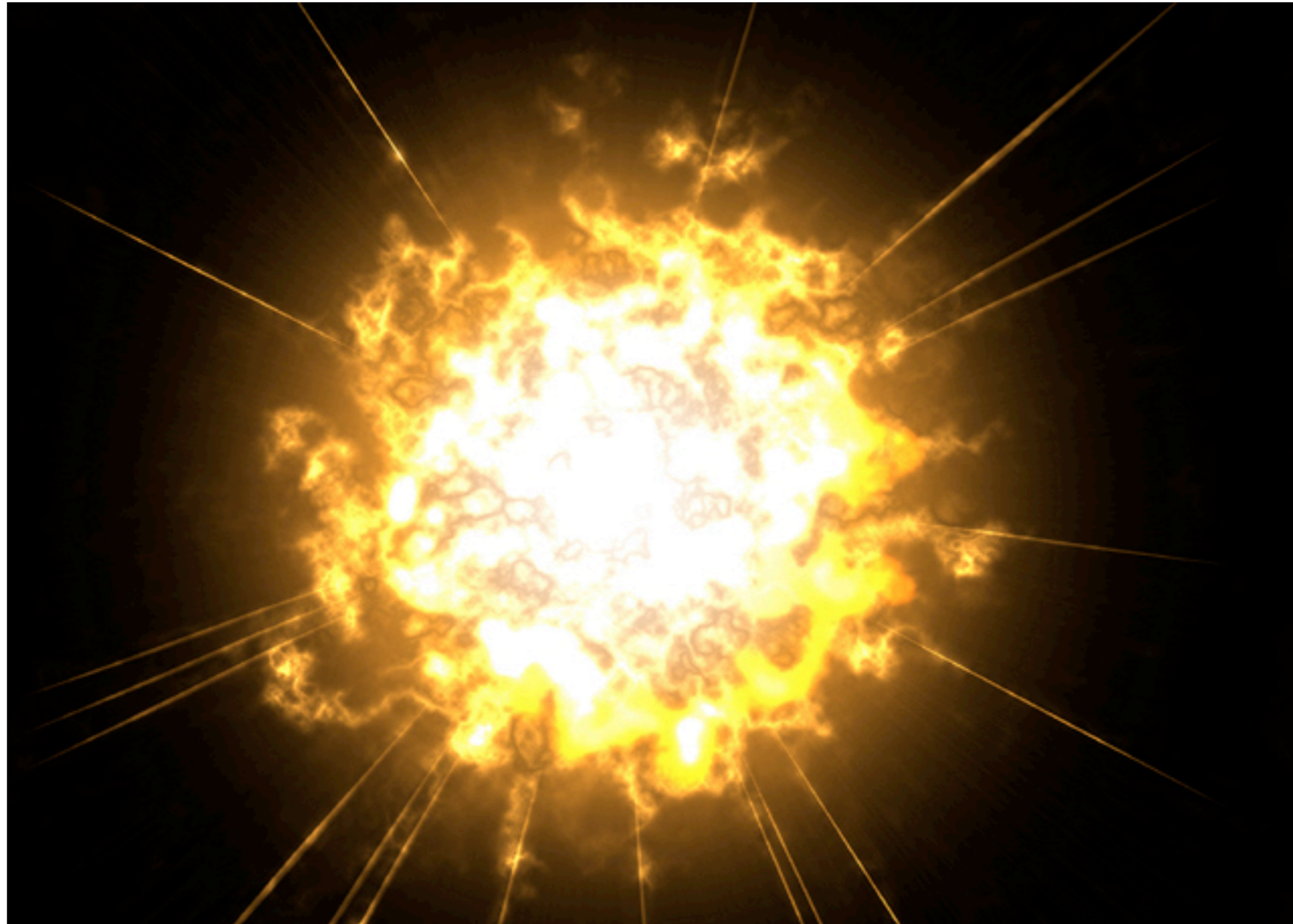
	<u>S¹</u>		<u>S²</u>		<u>S³</u>	
<i>S</i> ₁	A C G T C A A G		<i>S</i> ₁	T G G - - T	<i>S</i> ₁	C G G A C T A C G T
<i>S</i> ₂	A C - T C C A G		<i>S</i> ₃	A G C T C C	<i>S</i> ₄	C C C T - - - - G G
<i>S</i> ₃	A C - T C G A C		<i>S</i> ₄	A G C T C G	<i>S</i> ₅	C G T T C G A C G T

	<u>S¹</u>	<u>S²</u>	<u>S³</u>
<i>S</i> ₁	A C G T C A A G	T G G - - T	C G G A C T A C G T
<i>S</i> ₂	A C - T C C A G
<i>S</i> ₃	A C - T C G A C	A G C T C C
<i>S</i> ₄	A G C T C G	C C C T - - - - G G
<i>S</i> ₅	C G T T C G A C G T

Lack of Resolution



Issues (I)



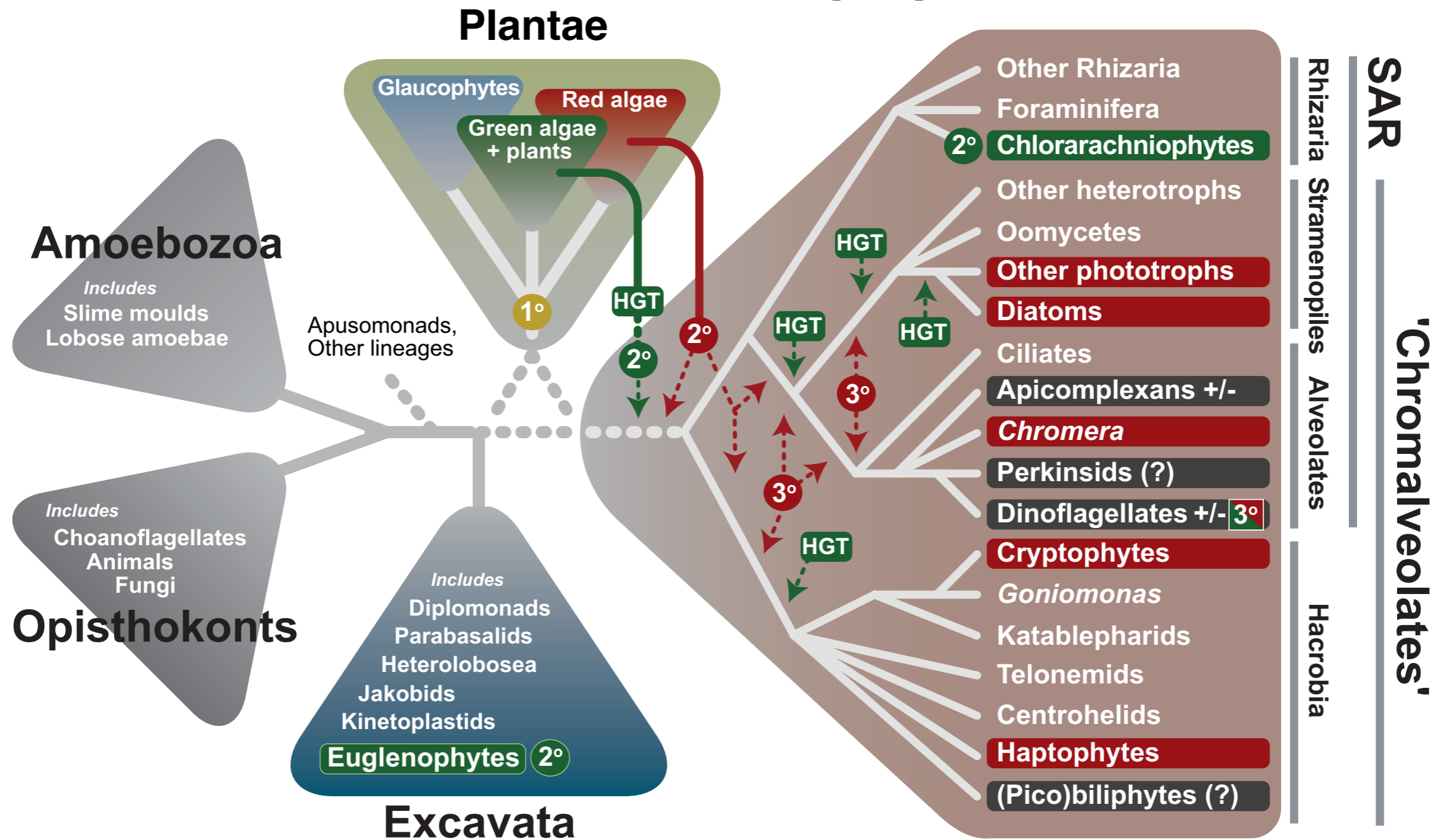
possible 'big-bang' radiation of Eukaryotes
(worsened by phylogenetic artefacts)

Issues (2)



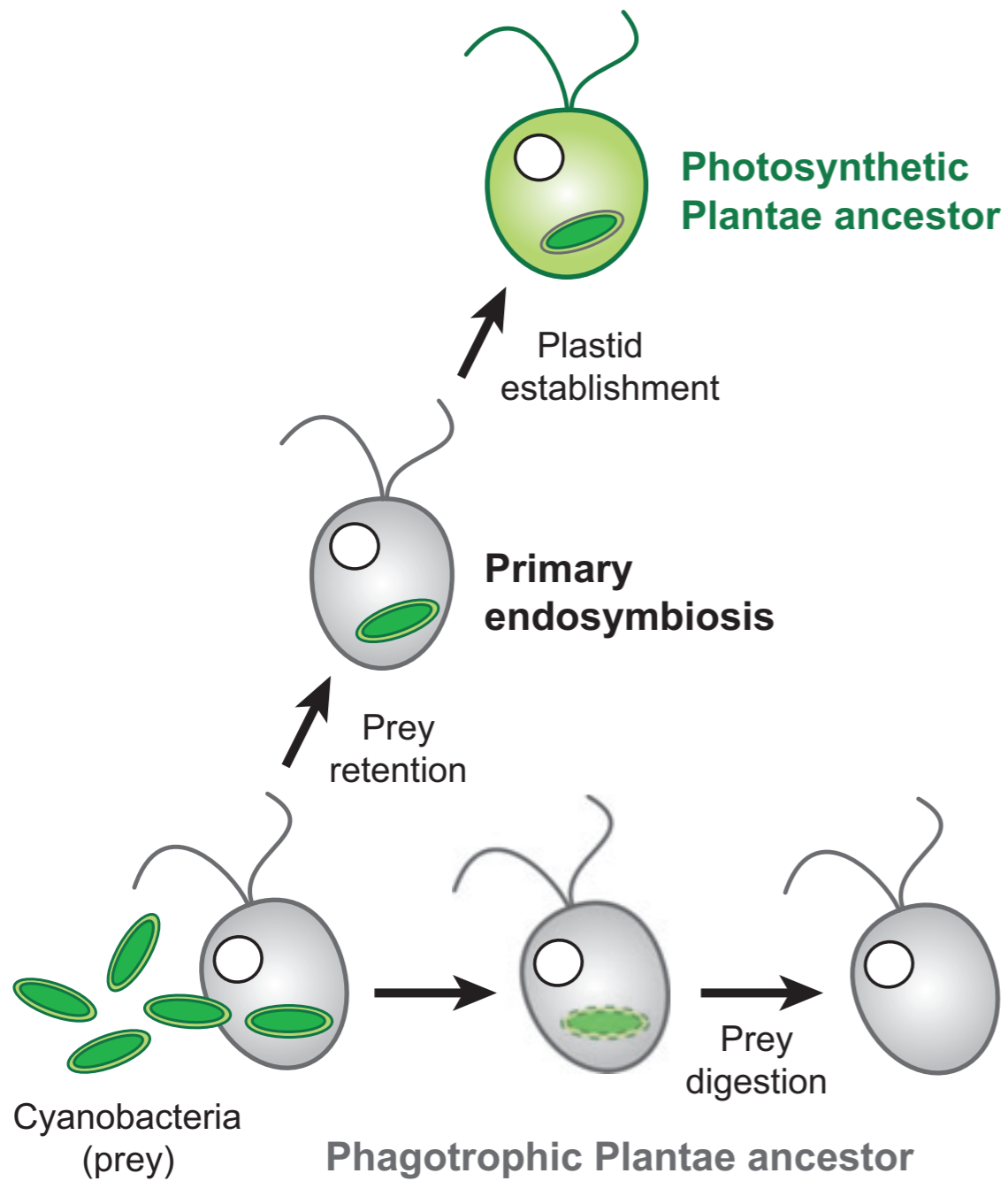
horizontal gene transfer (HGT) due to
« You are what you eat »

Issues (3)

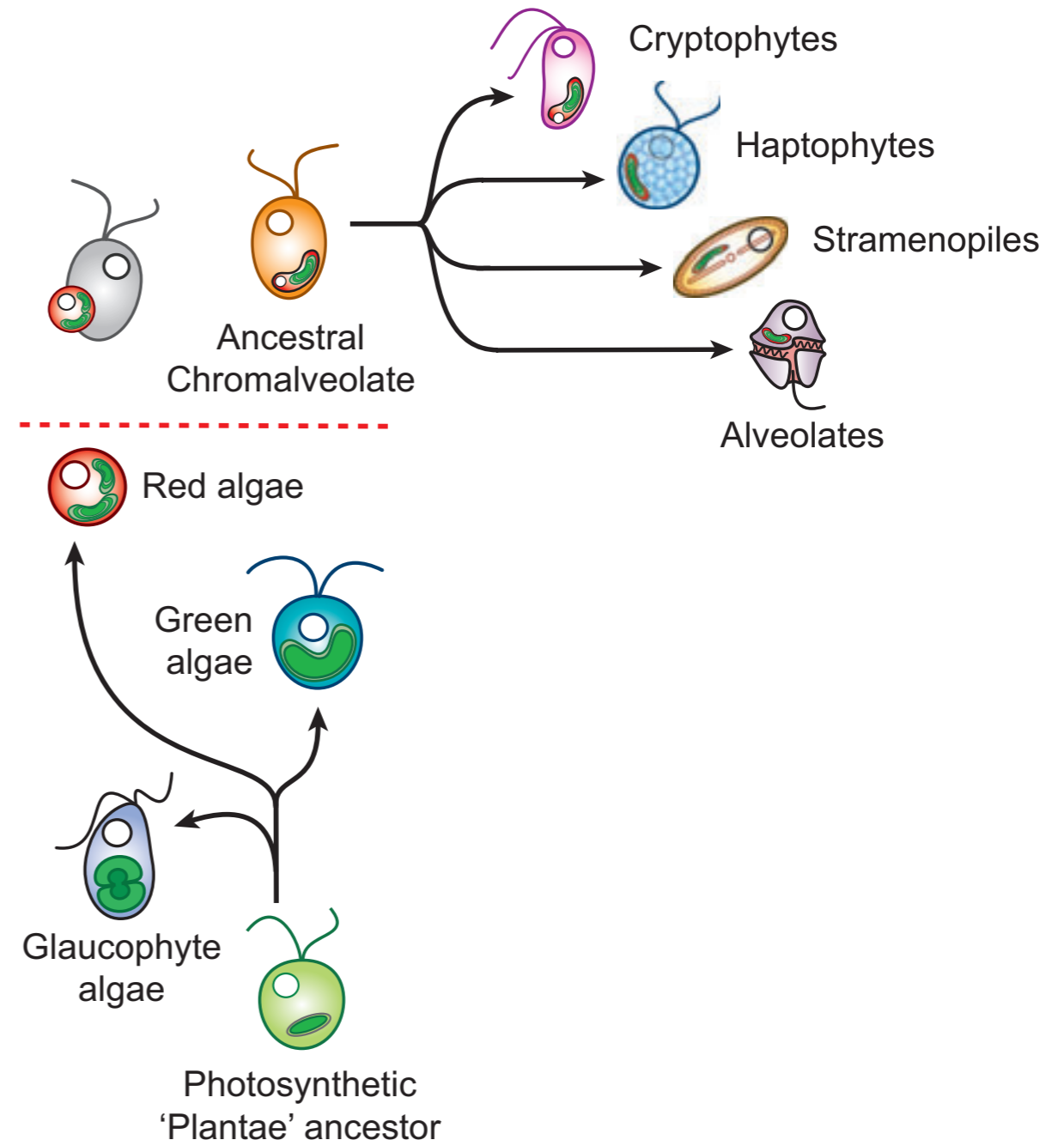


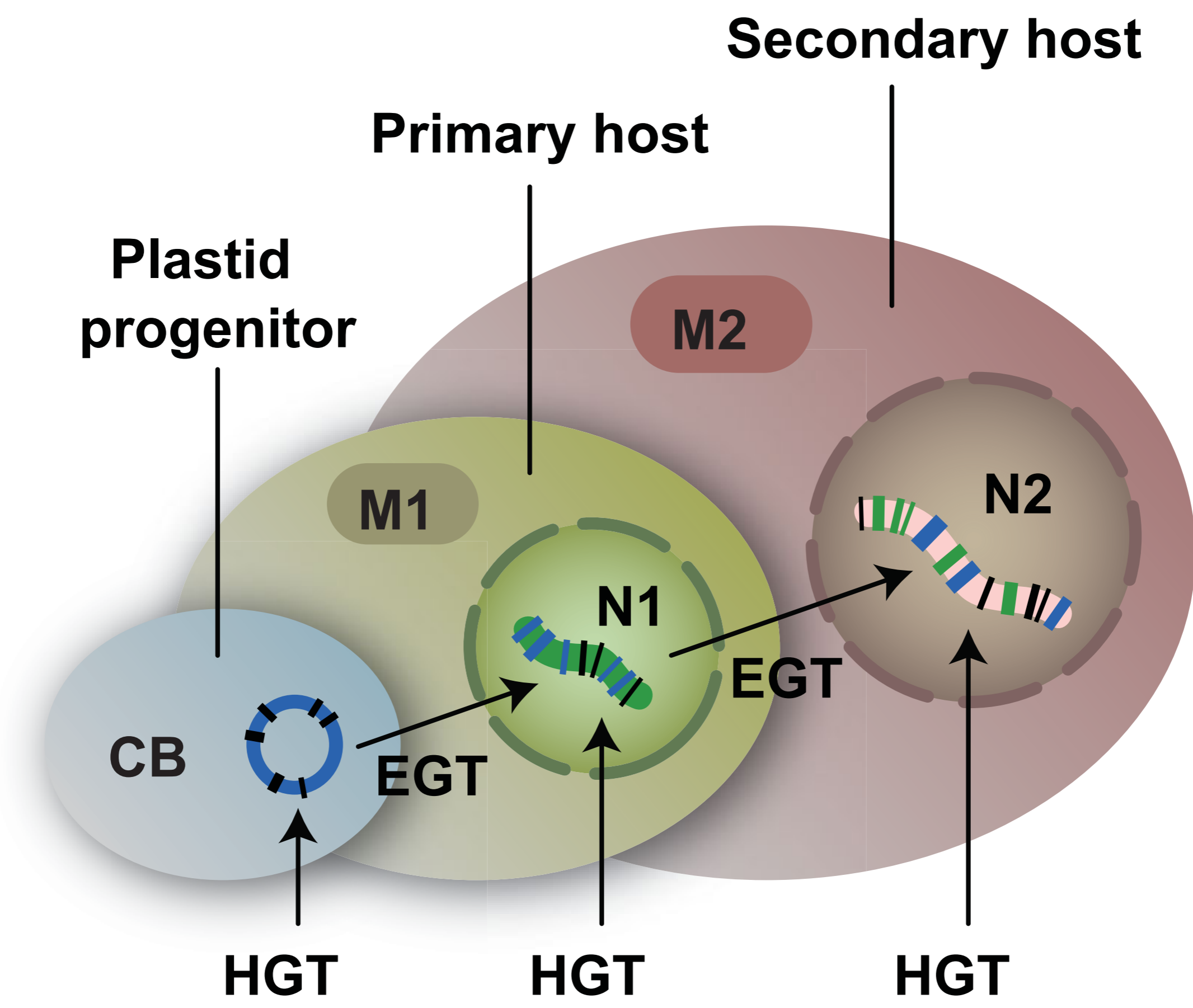
endosymbiotic gene transfer (EGT) due to multiple plastid transfers

endosymbiose primaire Plantae



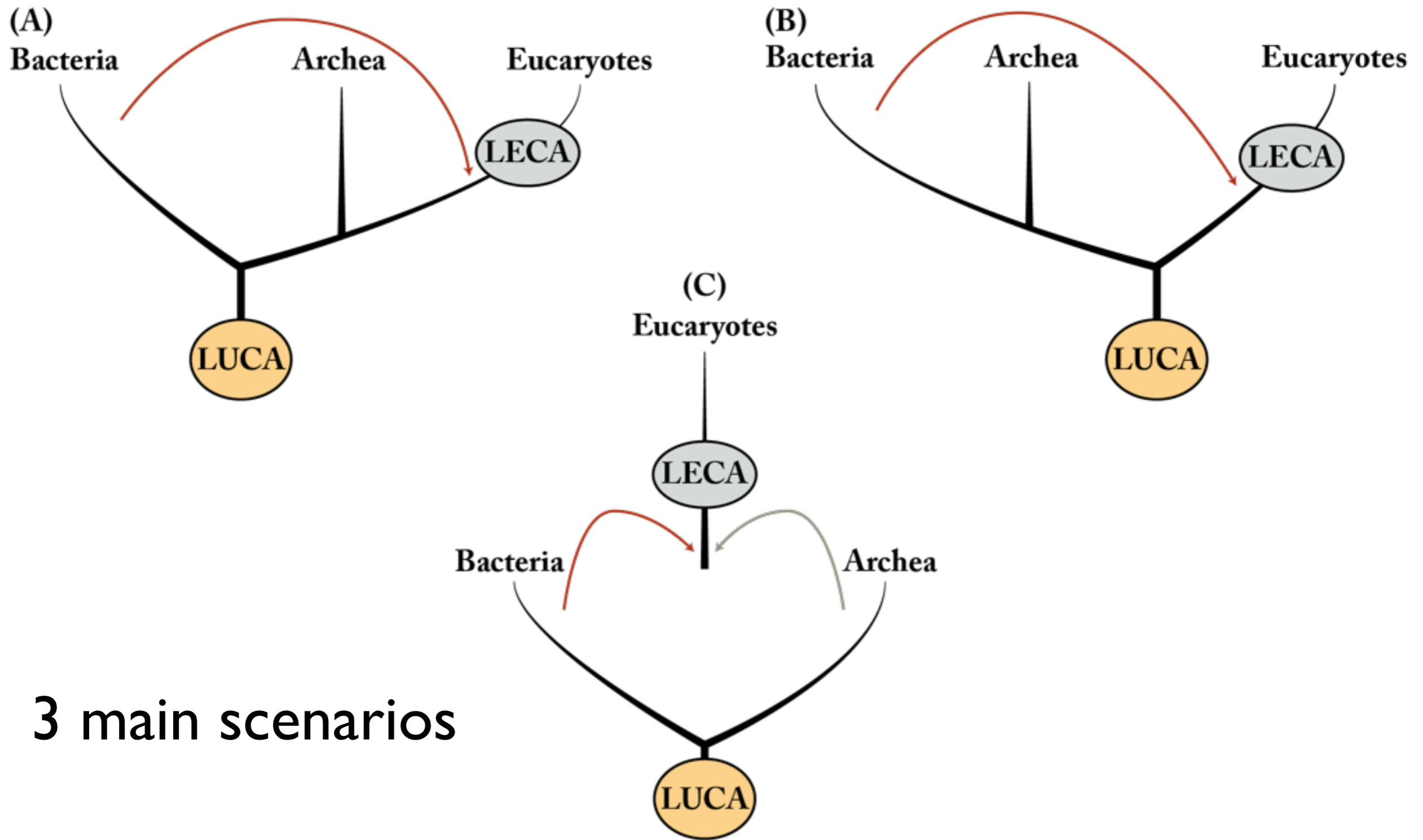
endosymbiose secondaire « Chromalveolés »





*D'où viennent les
Eucaryotes ?*

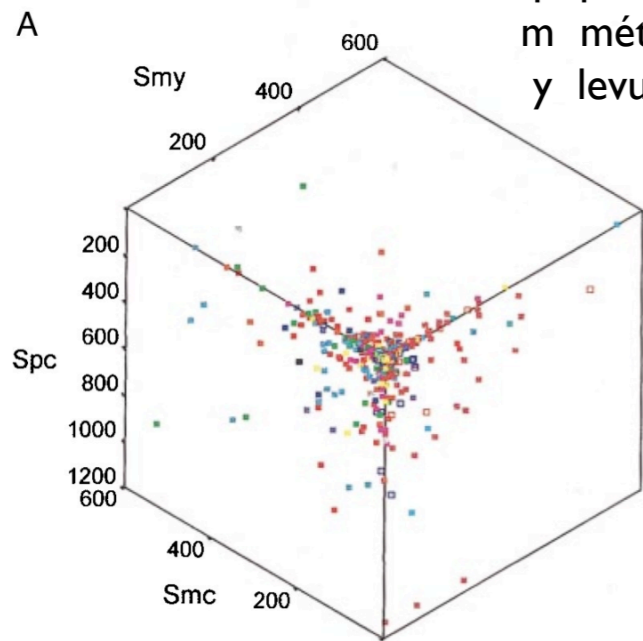
Eukaryotic Origins



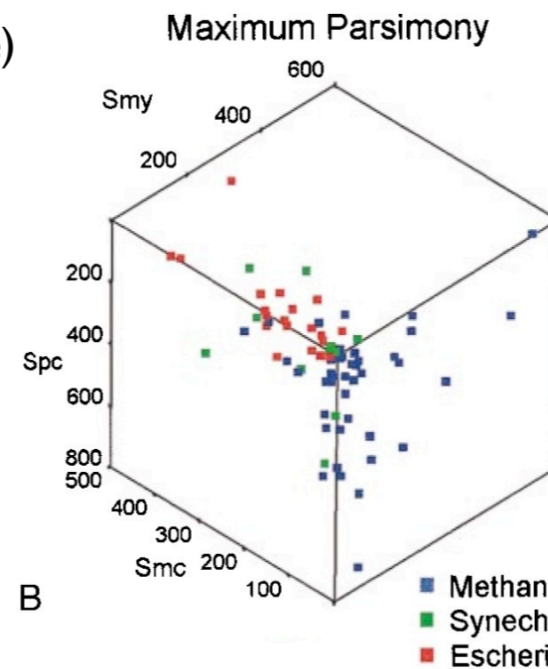
3 main scenarios

Chimeric Eukaryotes (I)

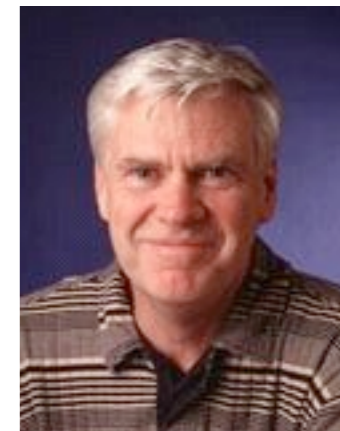
c cyanobactérie (eubactérie)
 p protéobactérie (eubactérie)
 m méthanogène (archéobactérie)
 y levure (Eucaryote)



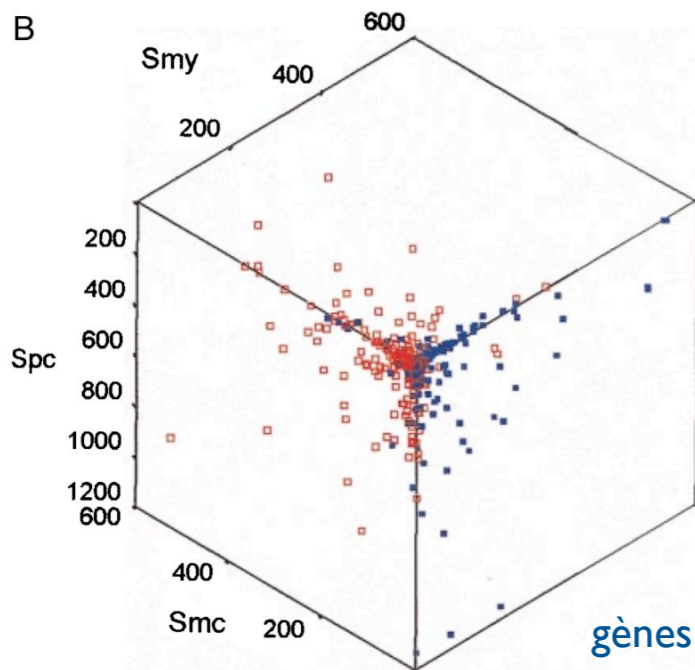
628 gènes



513 gènes

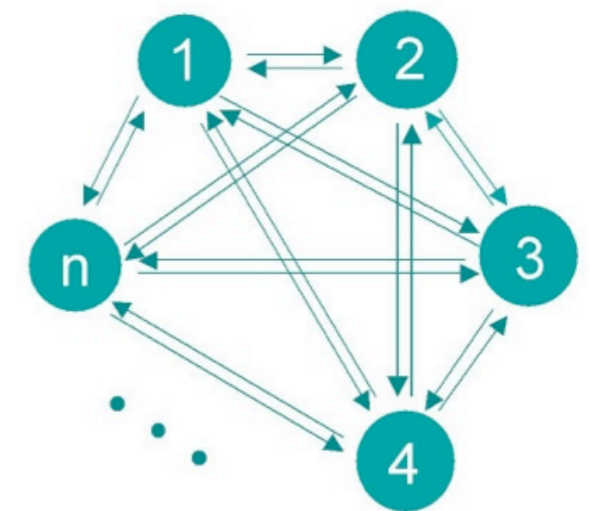
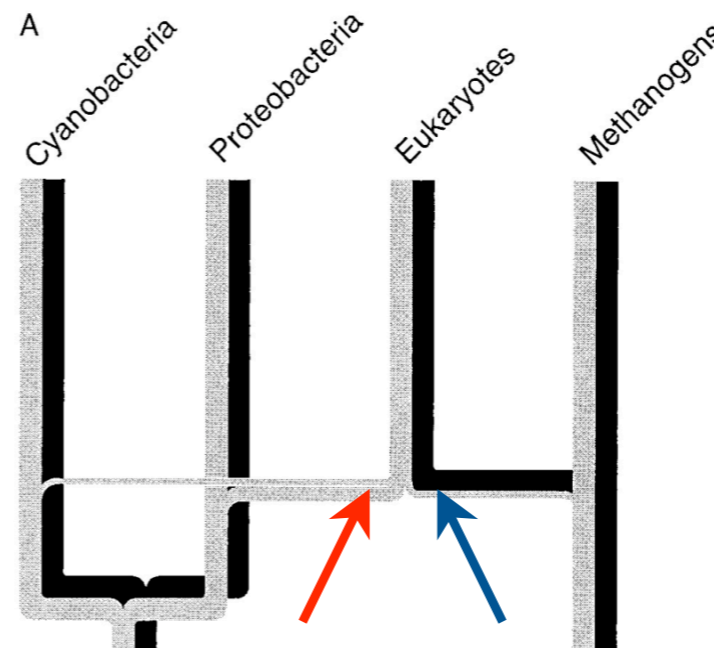


James Lake



628 gènes

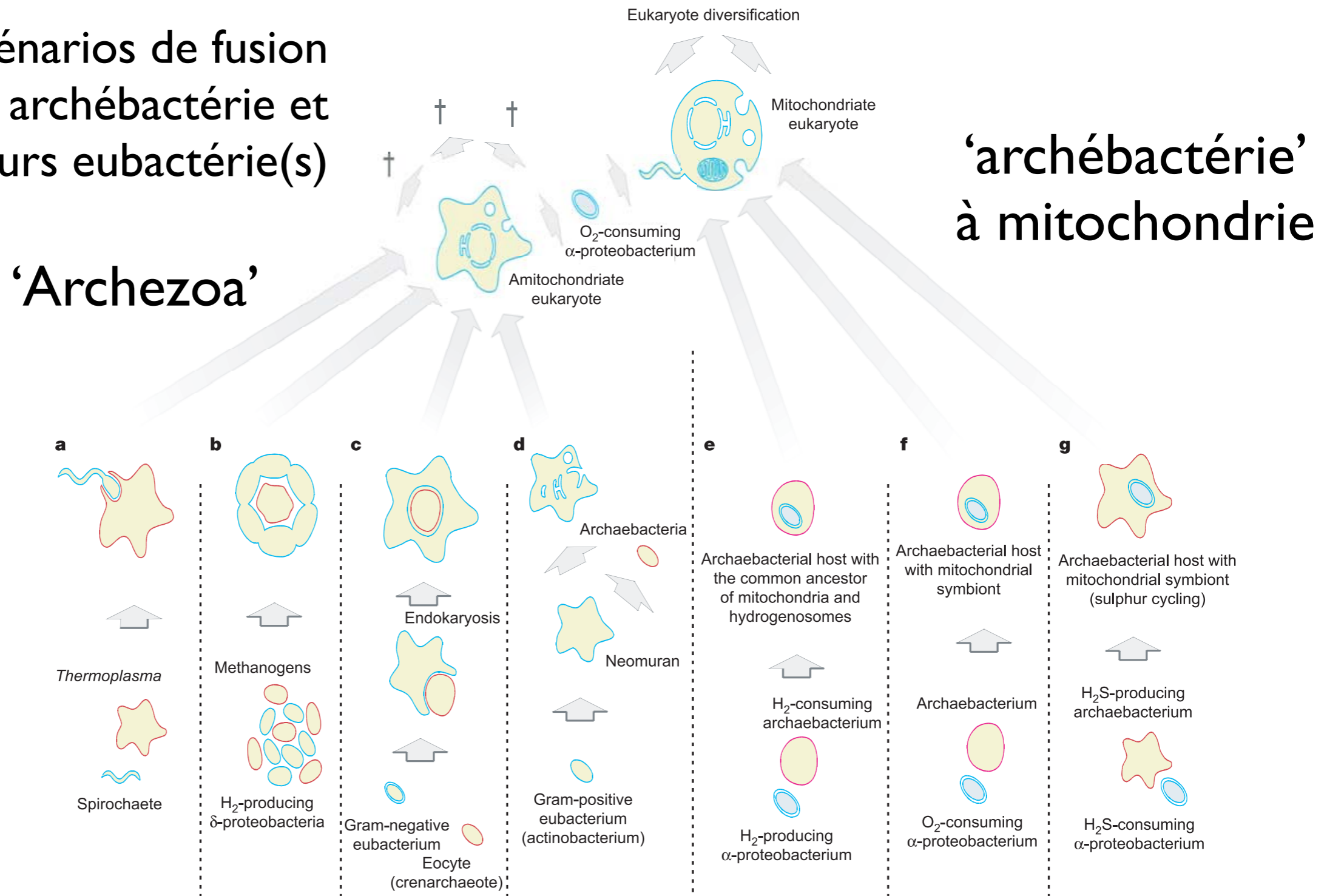
gènes informationnels
 gènes opérationnels



BLAST BRH
 (best reciprocal hits)

Chimeric Eukaryotes (2)

nombreux scénarios de fusion
entre une archéobactérie et
une ou plusieurs eubactérie(s)



Martin Embley

Eukaryotic Signature Proteins

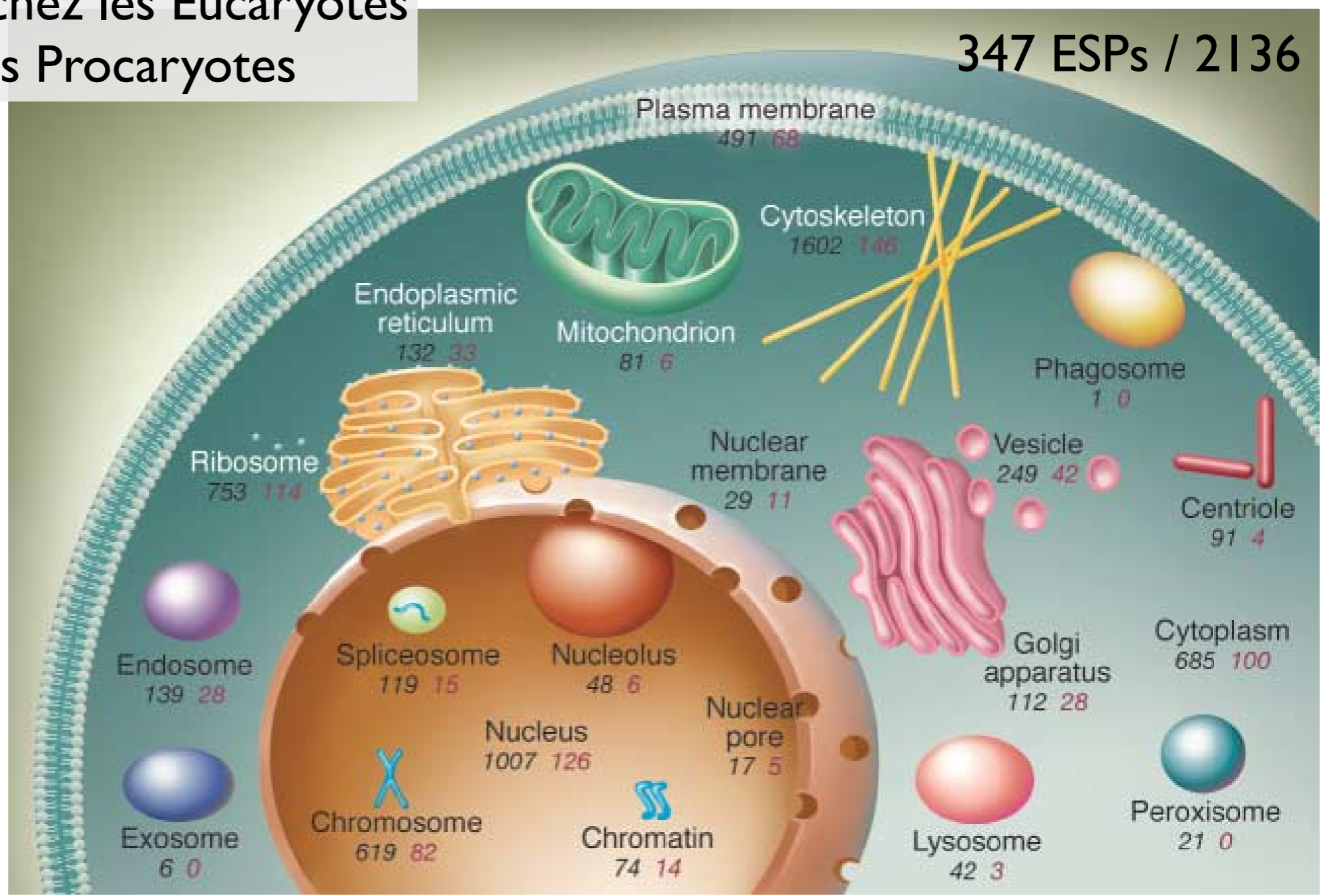
- 1. inventées chez les Eucaryotes
- 2. très modifiées chez les Eucaryotes
- 3. perdues chez les Procaryotes



Giardia lamblia

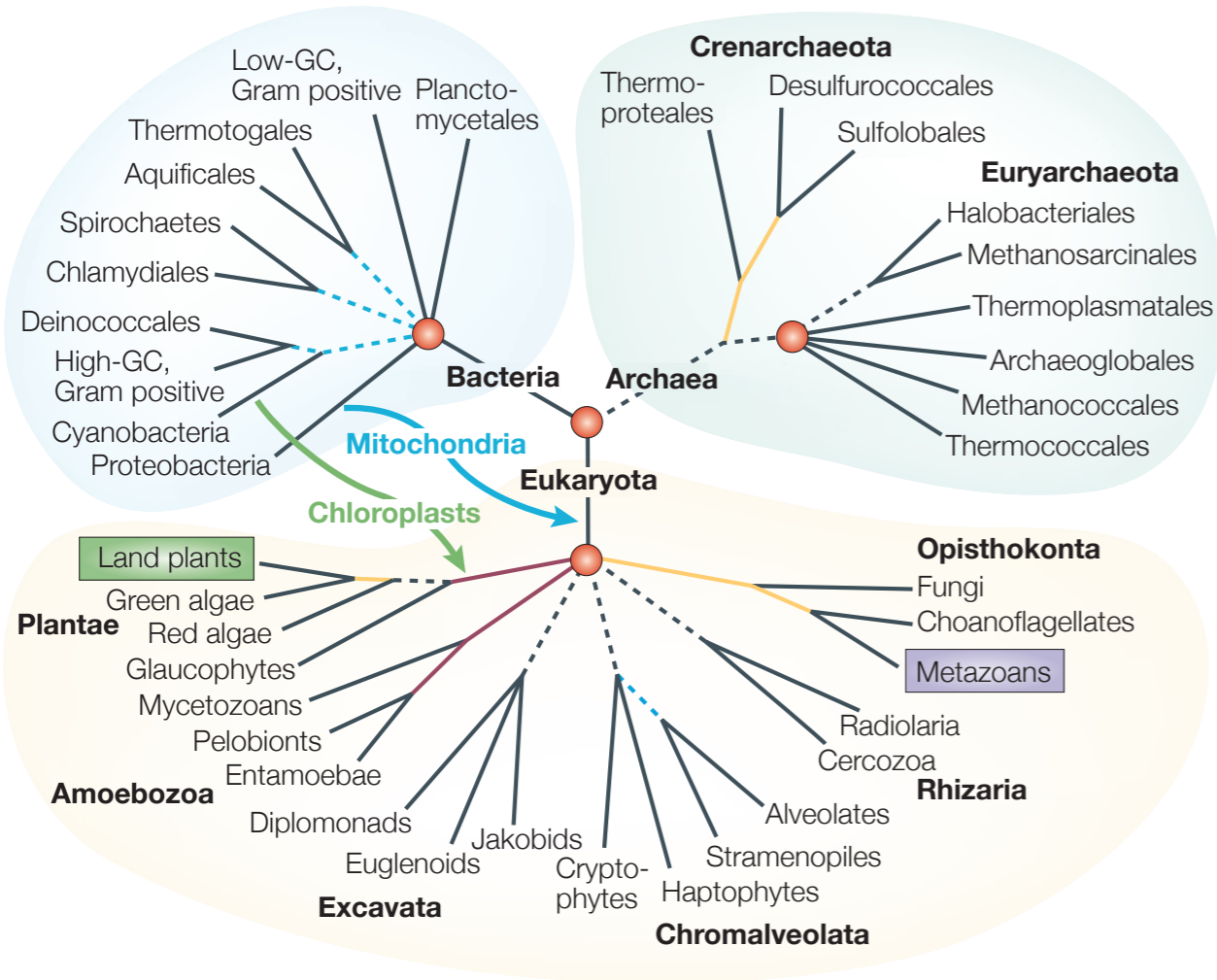


Charles Kurland



Life Roots

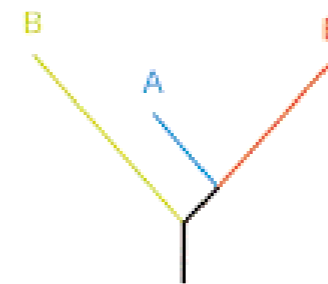
Tree of Life



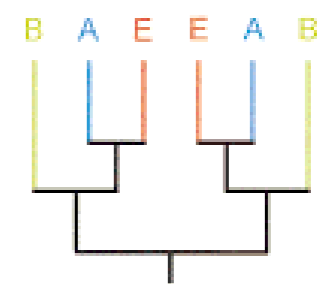
Patrick Forterre



Hervé Philippe

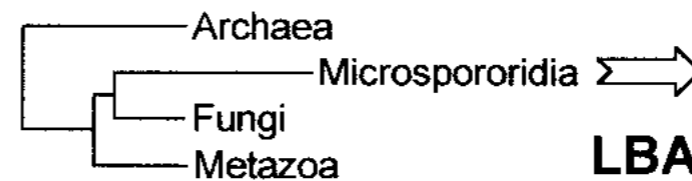


SSU rRNA

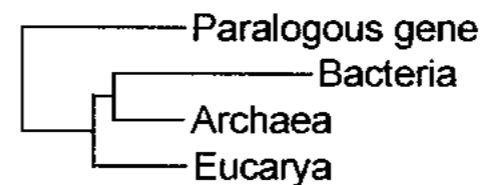
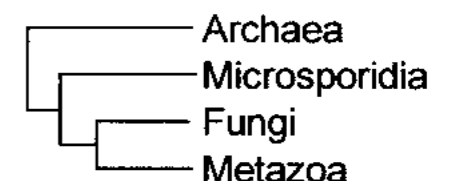


protéines dupliquées

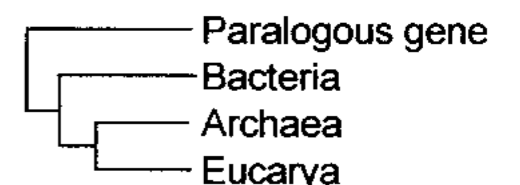
racine eubactérienne artificielle ?



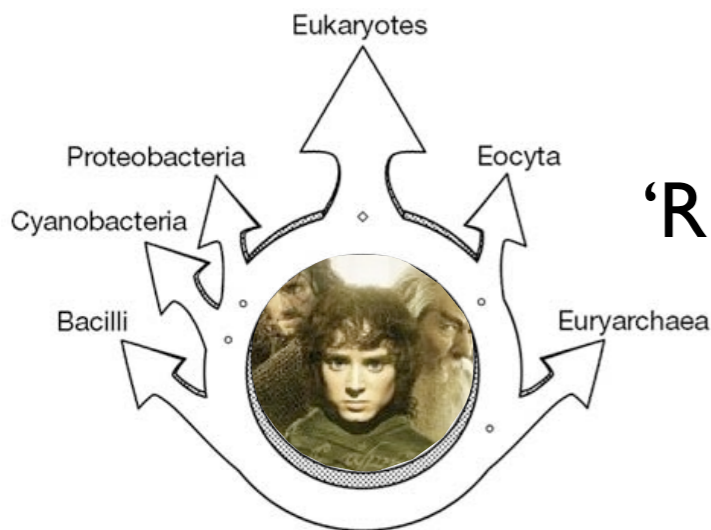
LBA



LBA



'Ring of Life'



Secondary Simplification

