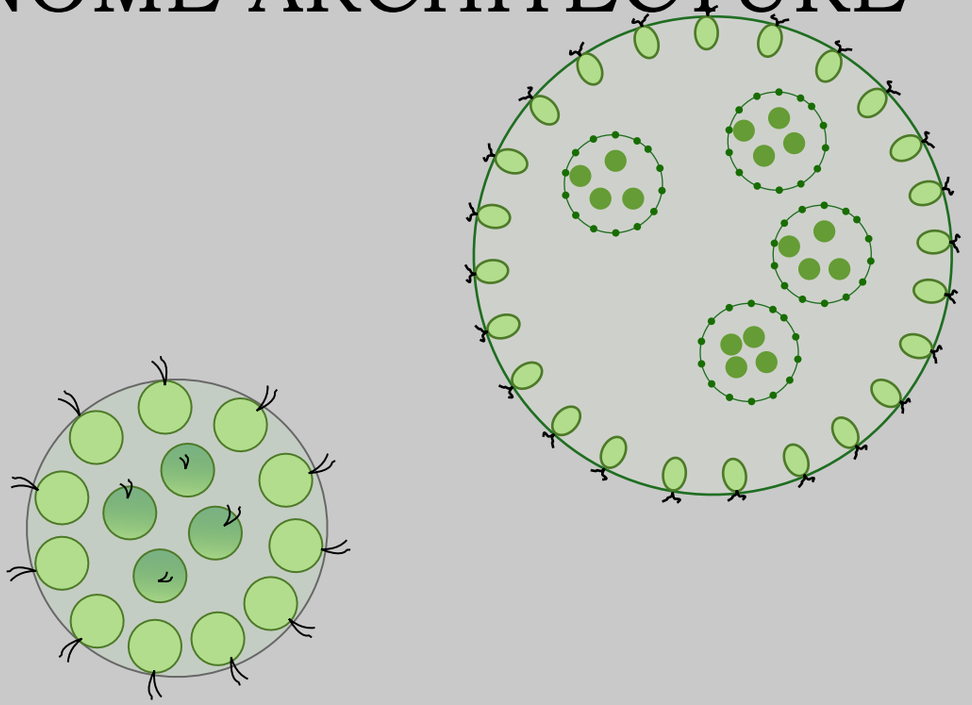
EVOLUTIONARY TRANSITIONS *& THEIR IMPACT ON* VOLVOCALEAN ORGANELLE GENOME ARCHITECTURE



DAVID SMITH, POSTDOC
BIODIVERSITY RESEARCH CENTRE
UNIVERSITY OF BRITISH COLUMBIA
KEELING LAB

ME • YOU

ME • YOU

genome architecture

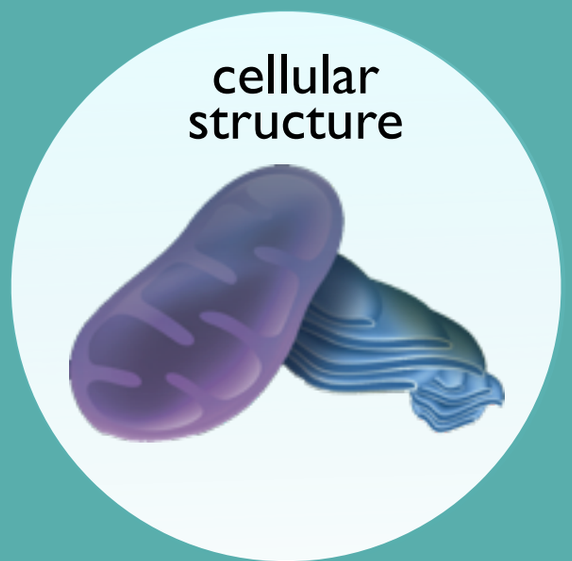
structure

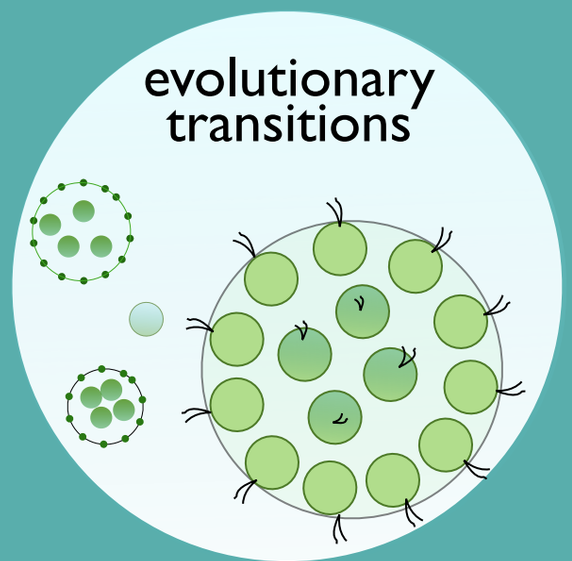
size

content

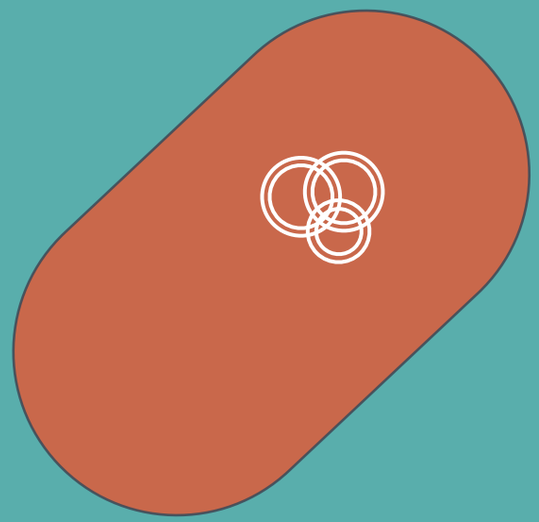
ME • YOU

genome architecture





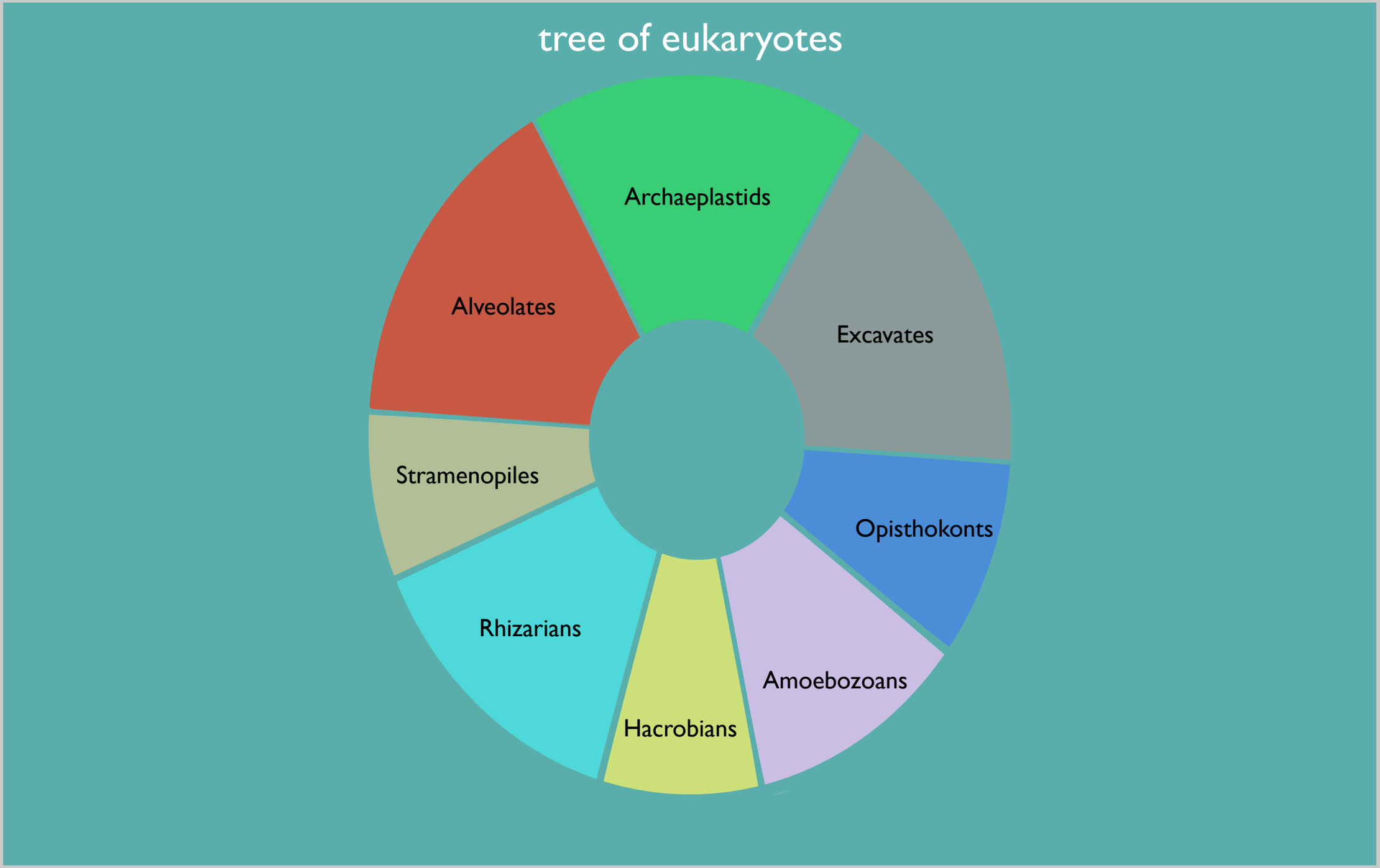
ME • YOU



mitochondrion

chloroplast

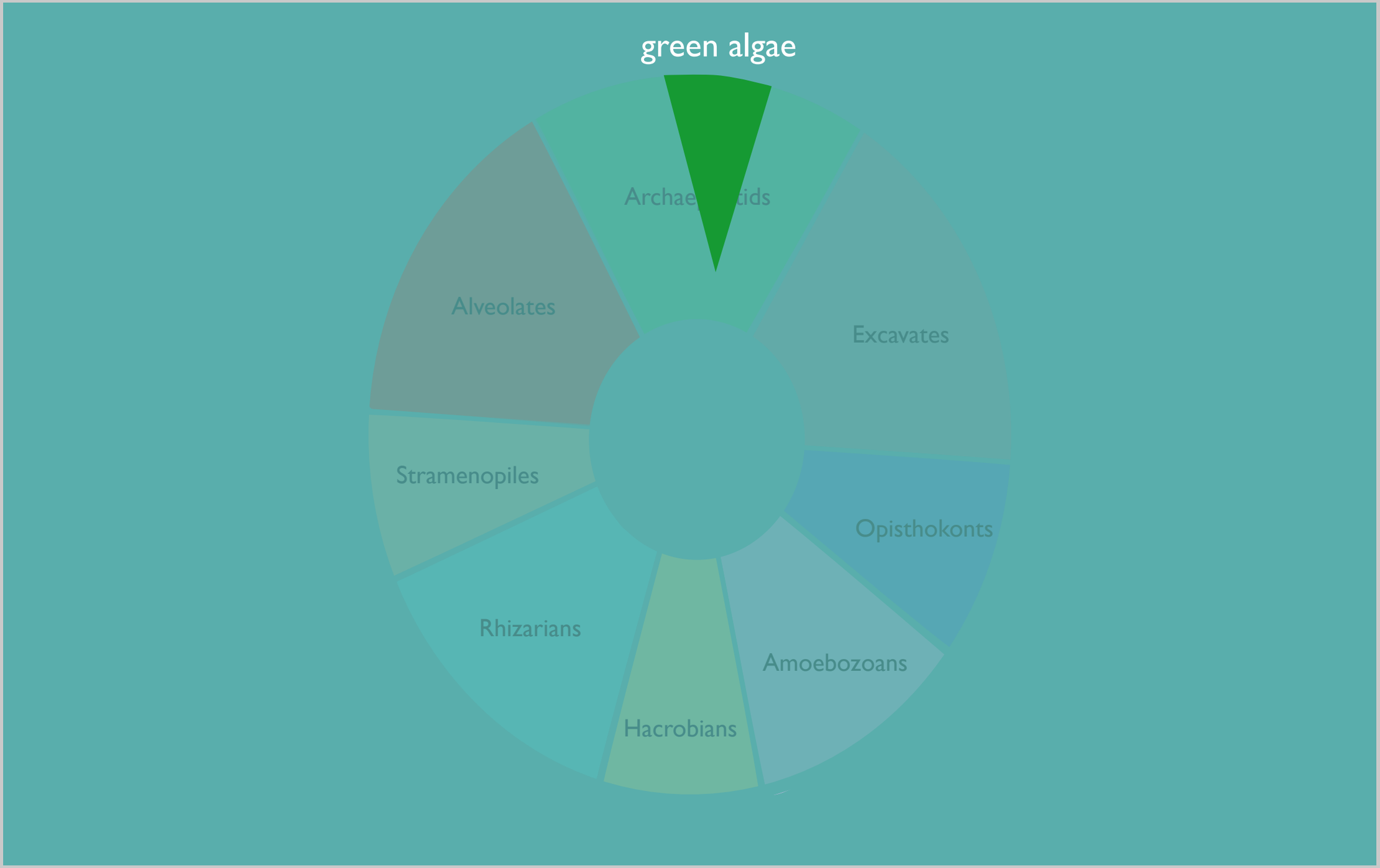
ME • YOU


tree of eukaryotes
Archaeplastids
Alveolates
Excavates
Stramenopiles
Opisthokonts
Rhizarians
Amoebozoans
Hacrobians

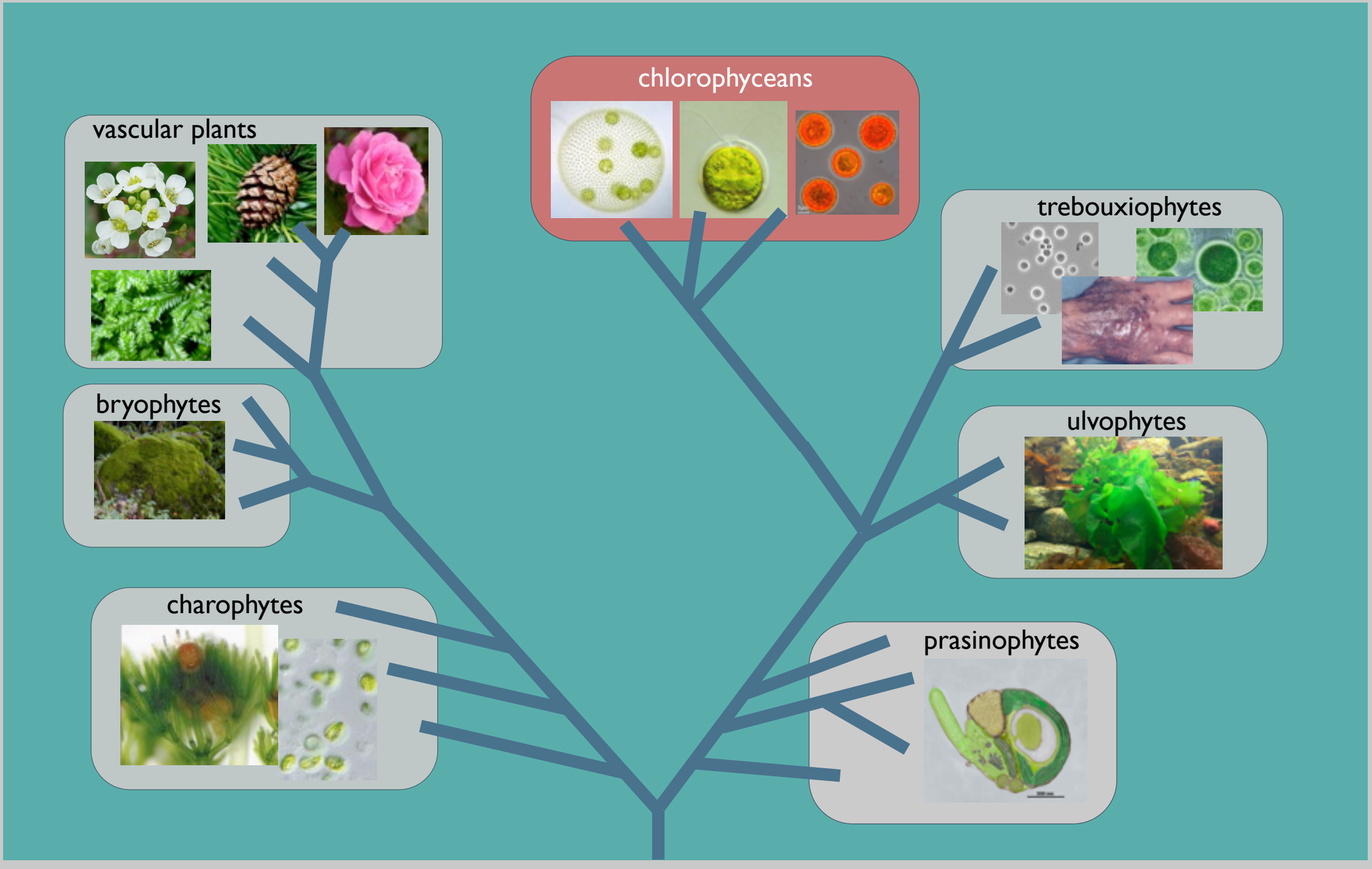
ME • YOU


Archaeplastids
Alveolates
Excavates
Stramenopiles
Opisthokonts
Rhizarians
Amoebozoans
Hacrobians

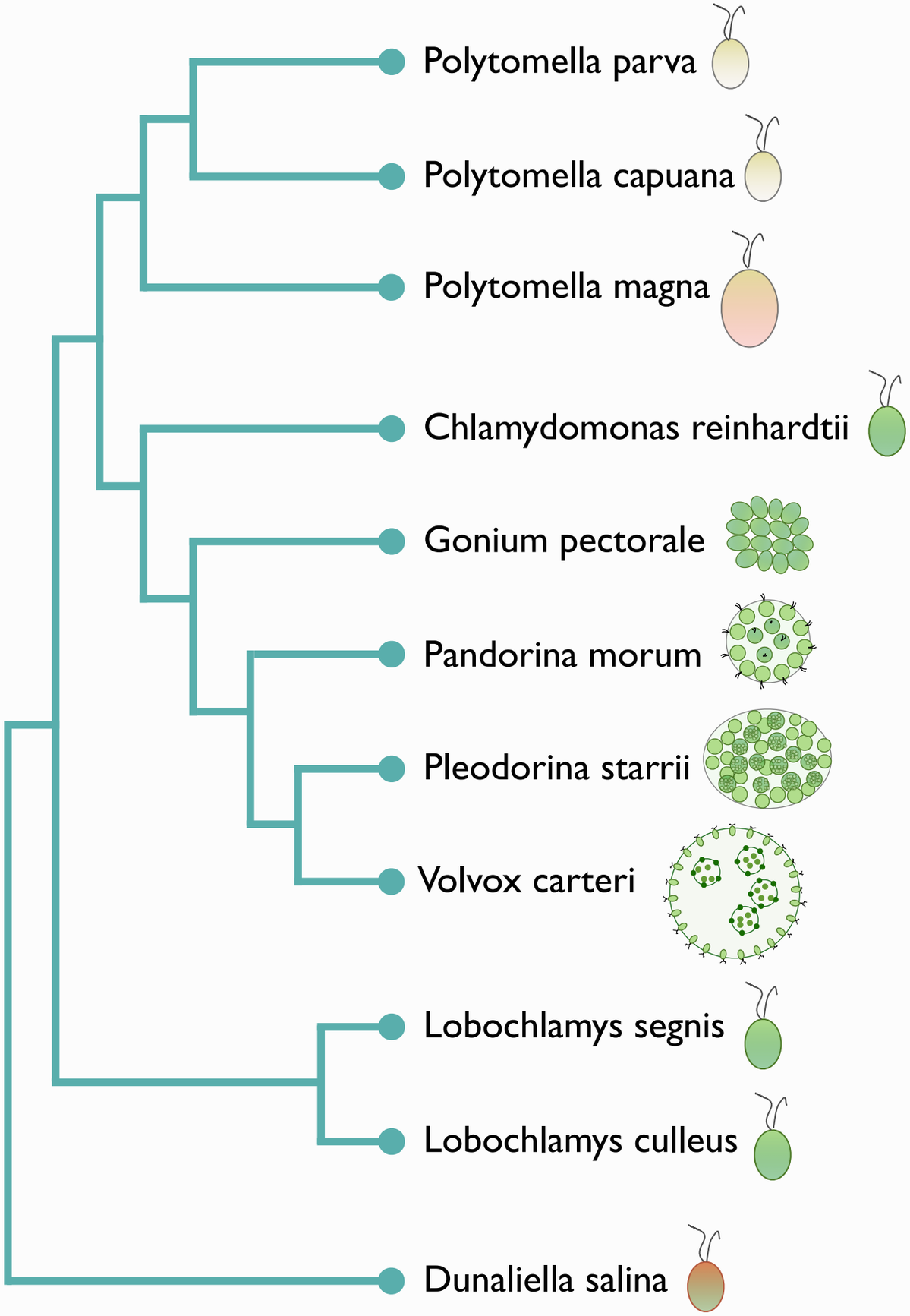
ME • YOU


green algae
Archaeplastids
Alveolates
Excavates
Stramenopiles
Opisthokonts
Rhizarians
Amoebozoans
Hacrobians

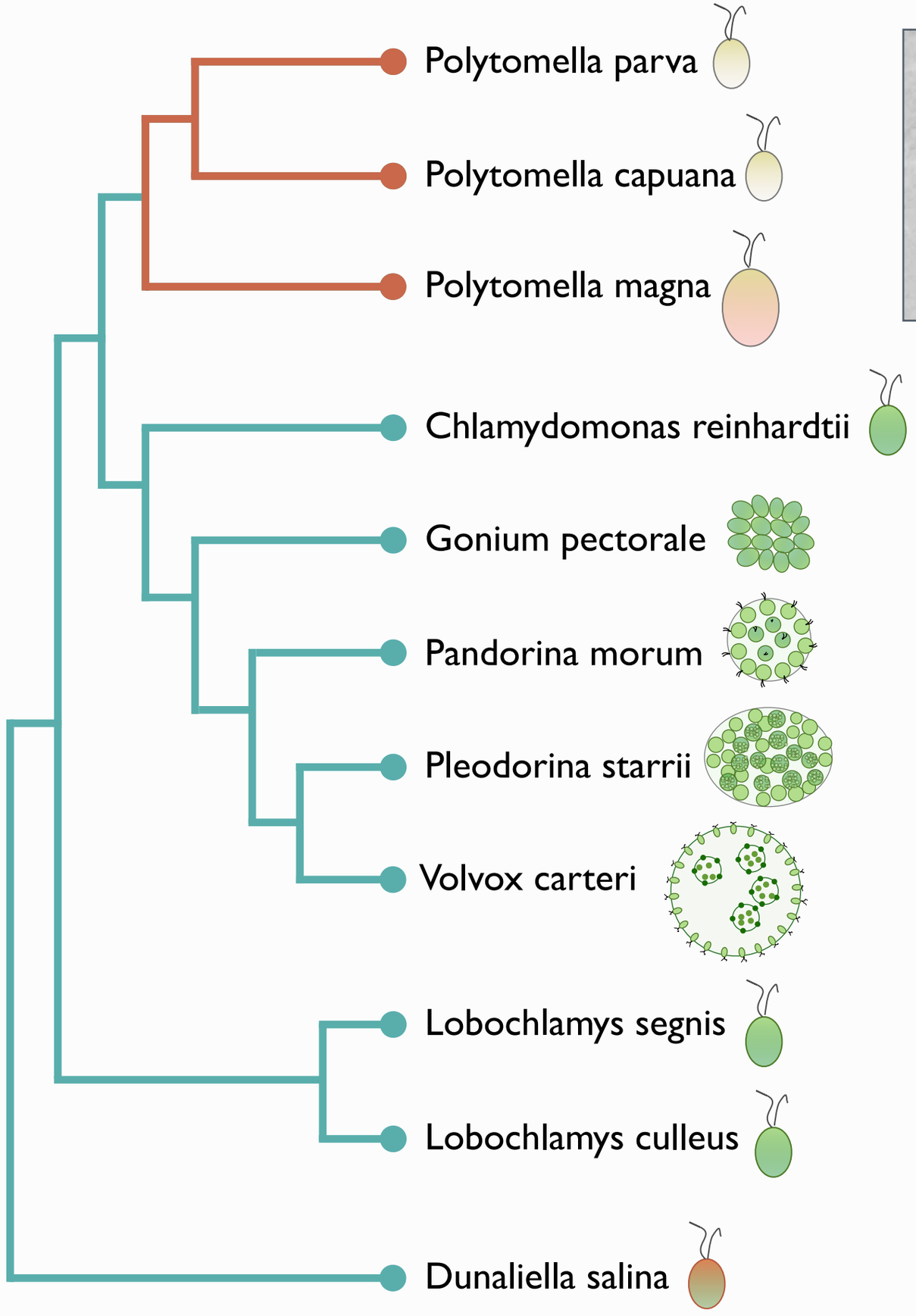
THE GREEN LINEAGE

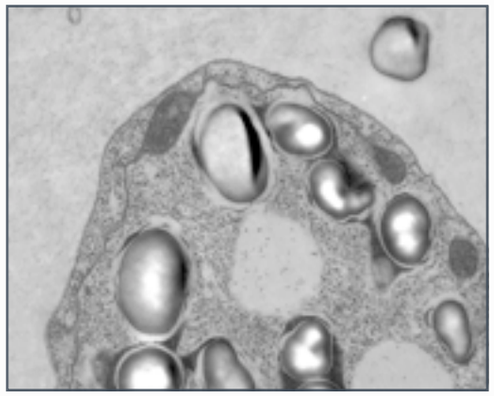


THE VOLVOCALES

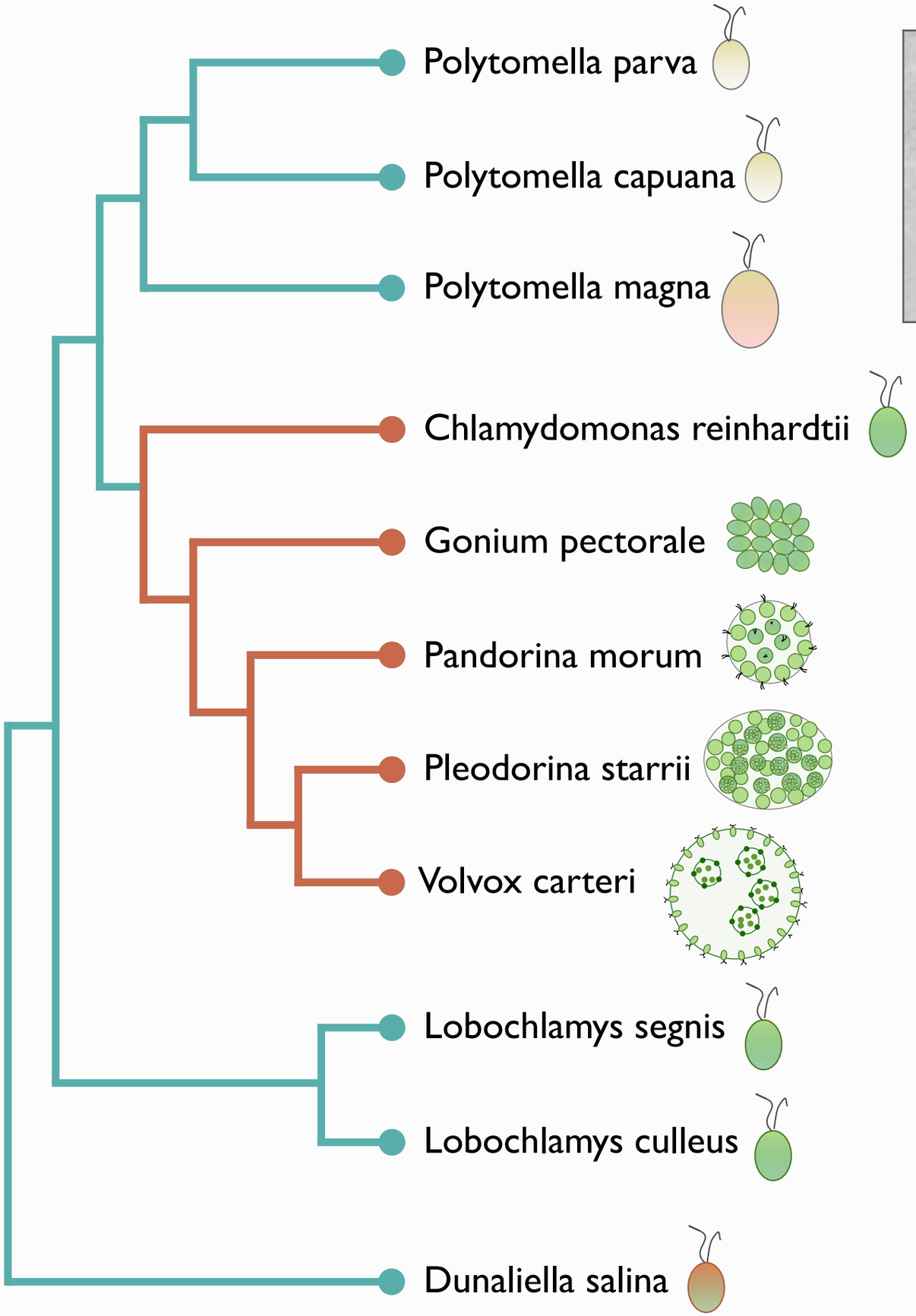


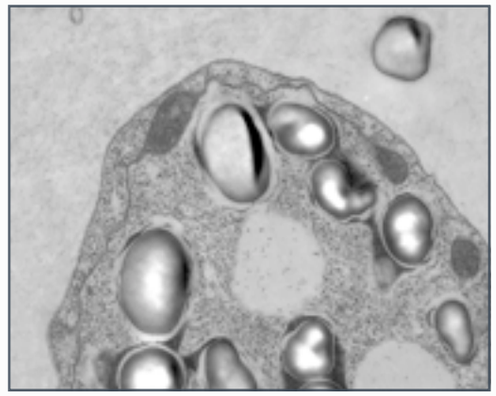
THE VOLVOCALES





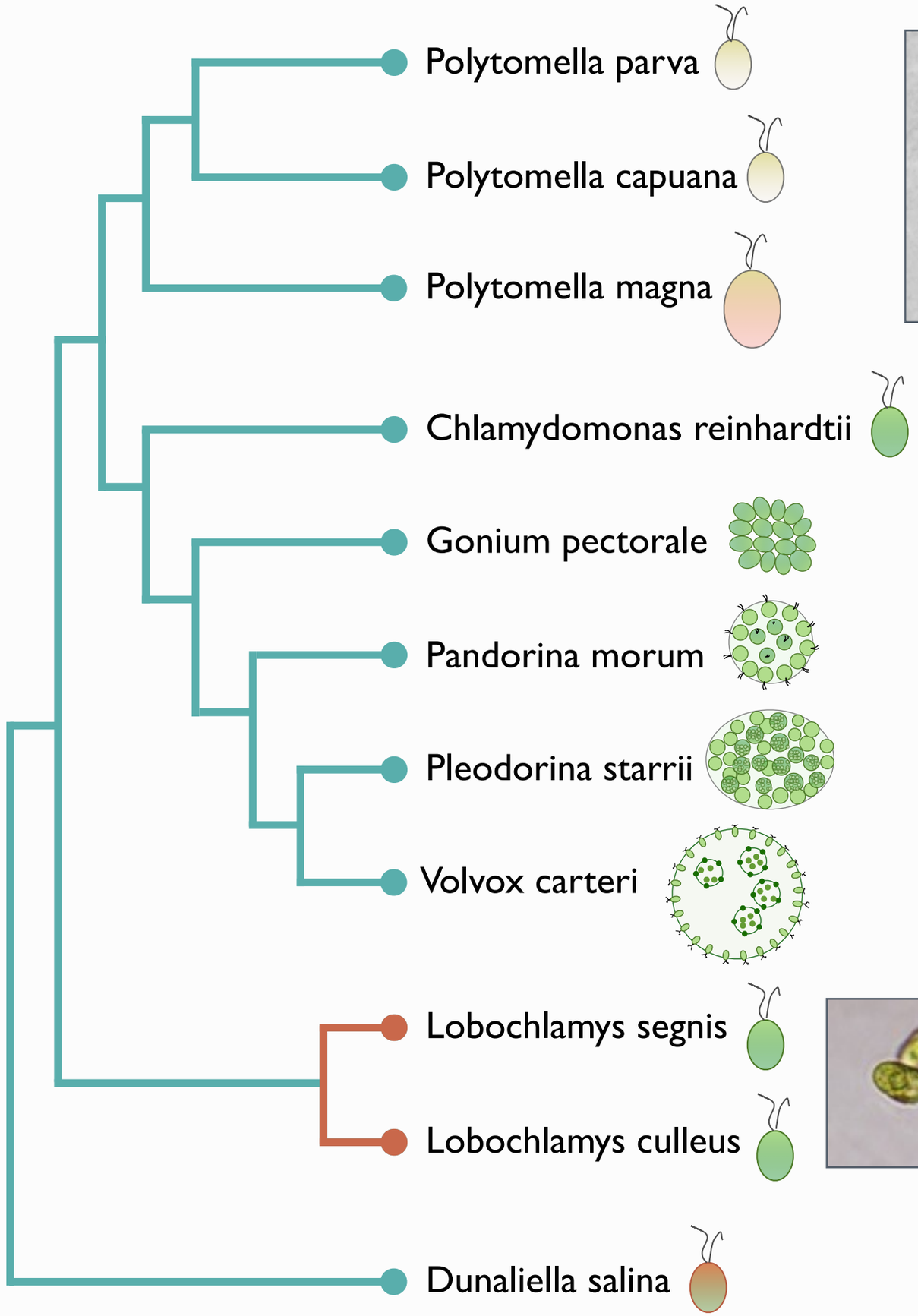
THE VOLVOCALES

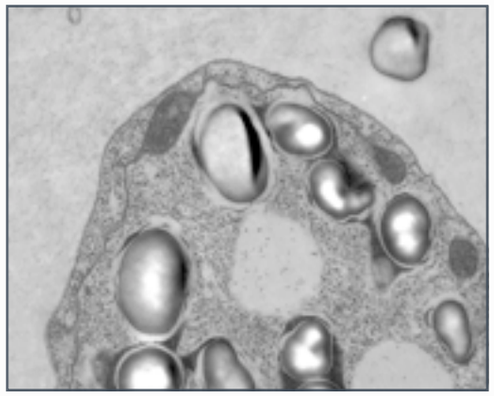




Volvocine lineage

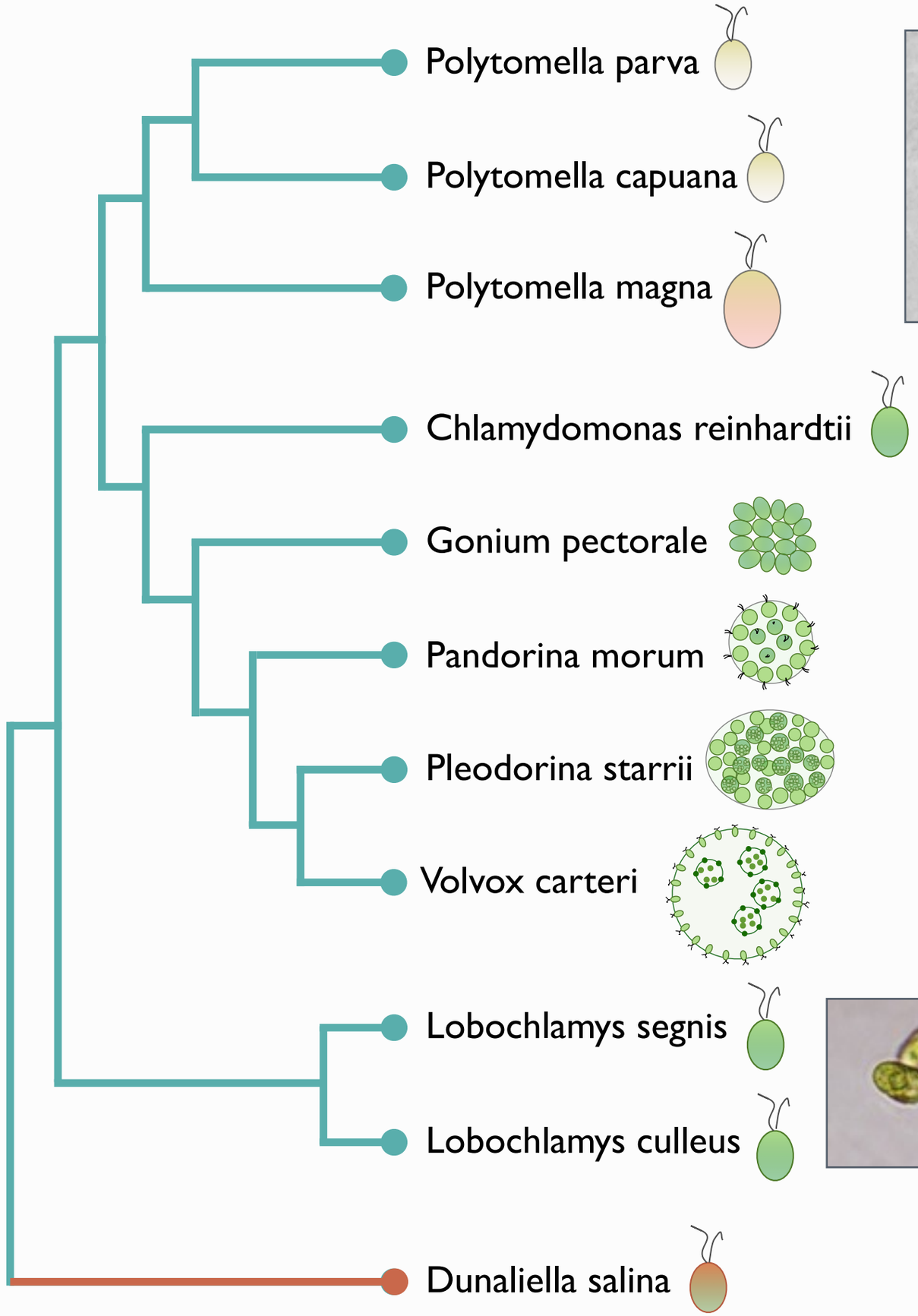
THE VOLVOCALES

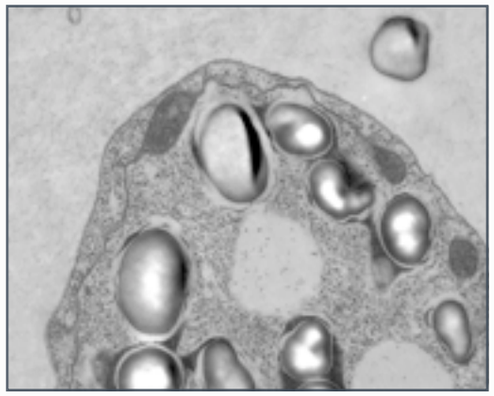




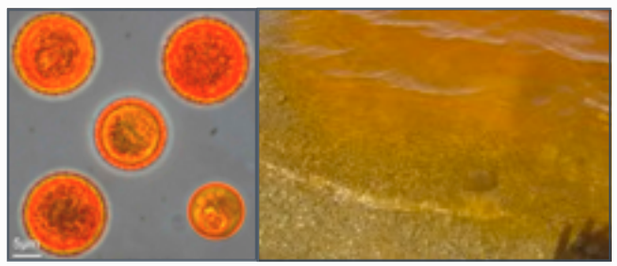
Volvocine lineage

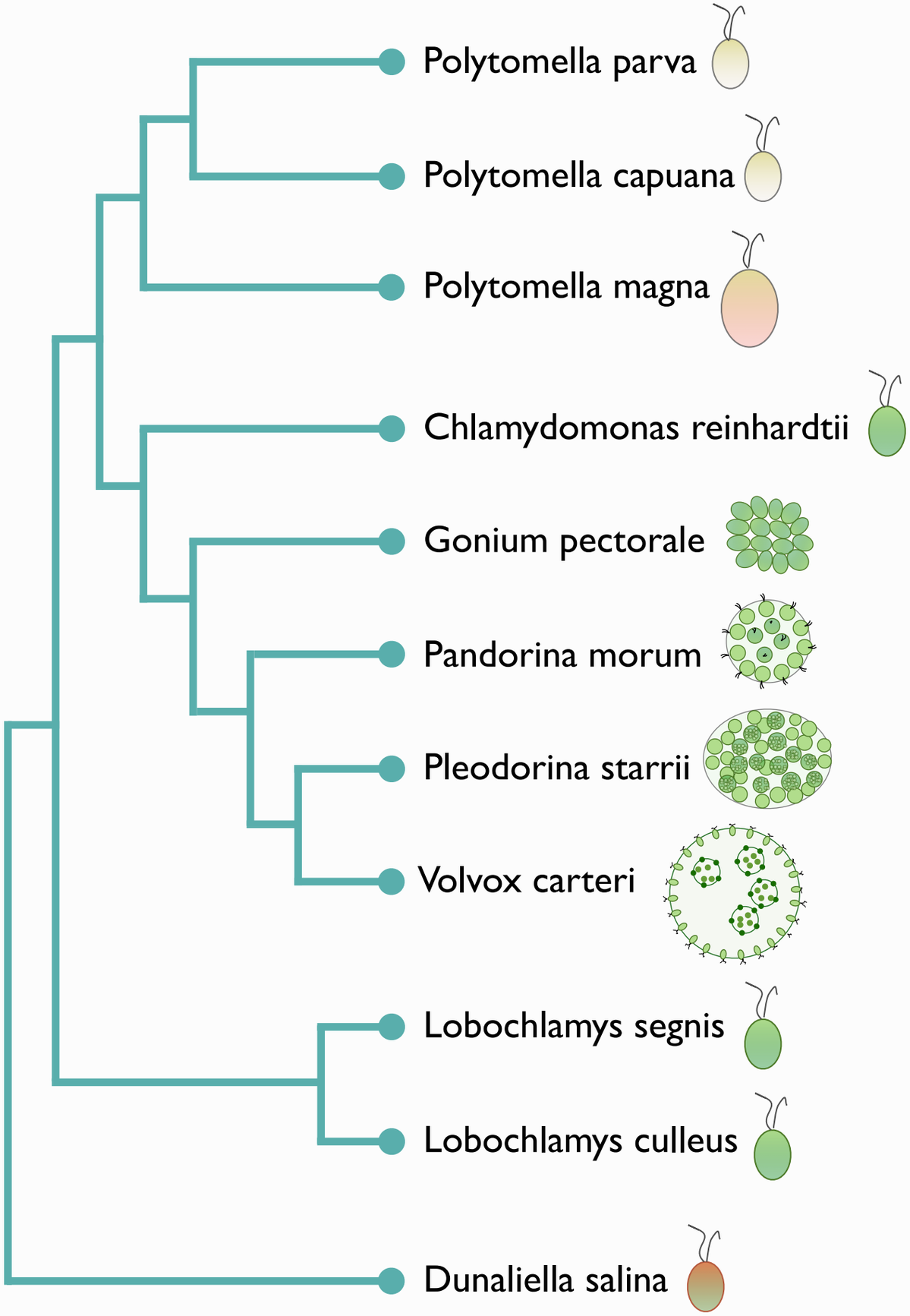
THE VOLVOCALES



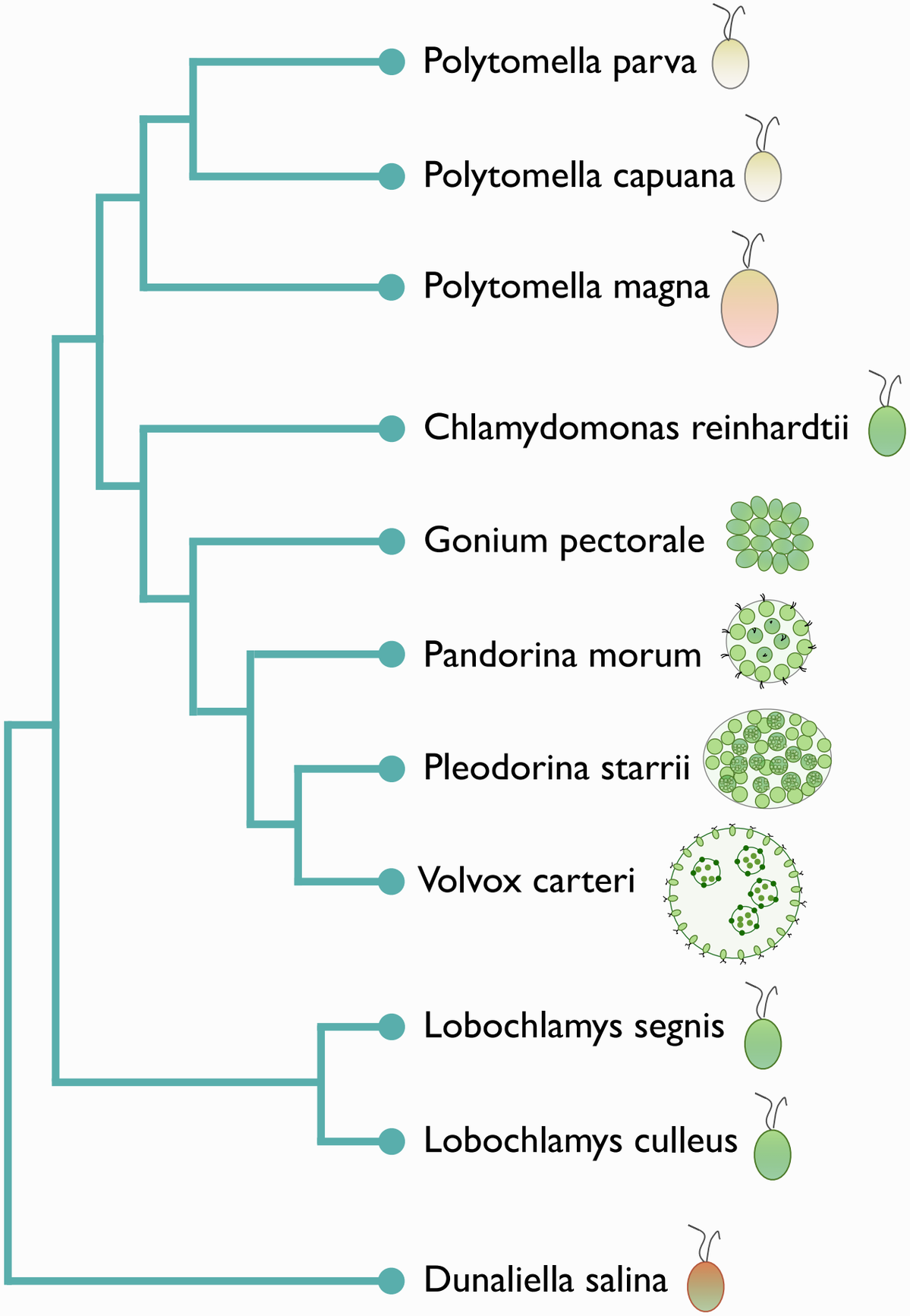


Volvocine lineage

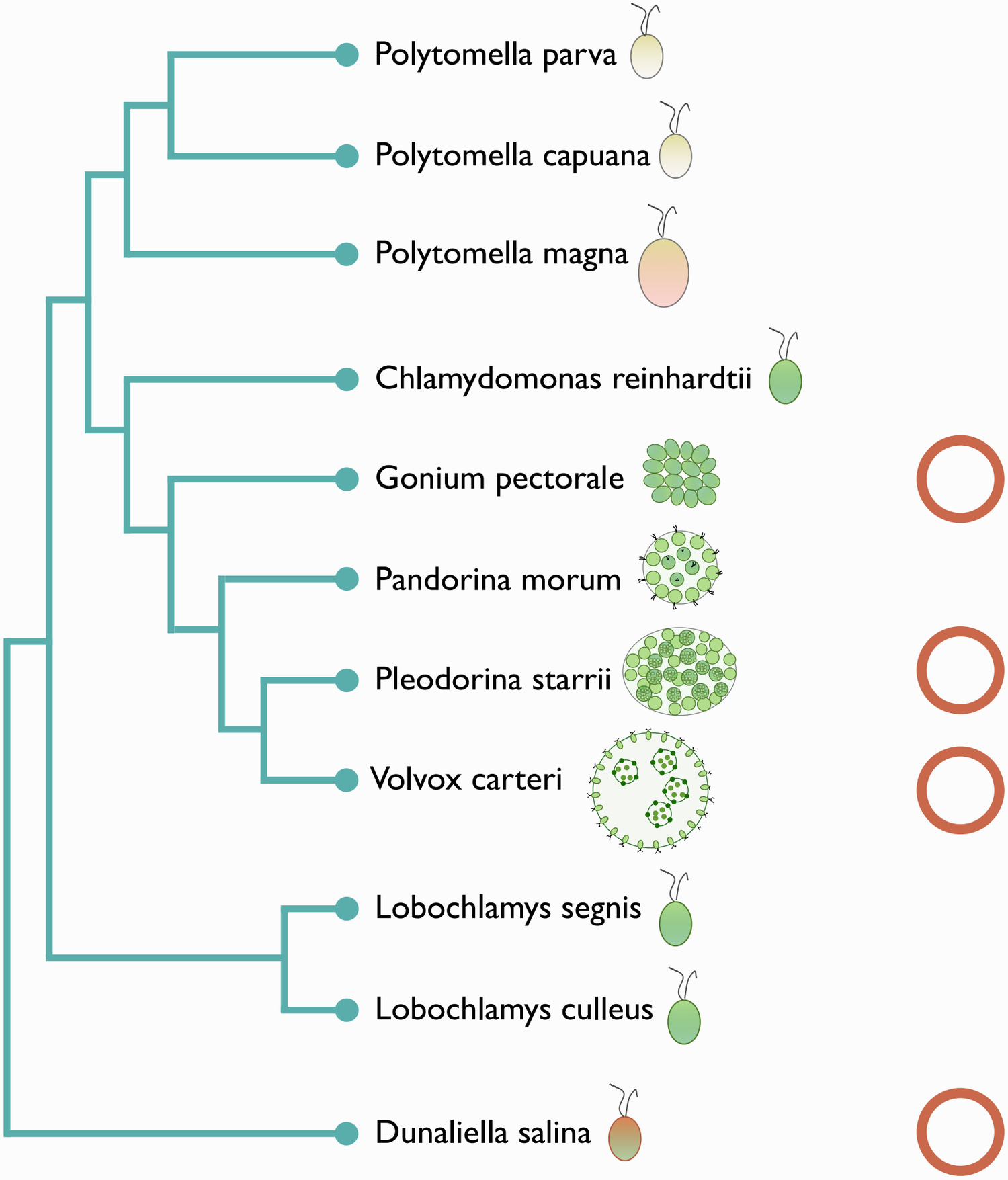



Polytomella parva
Polytomella capuana
Polytomella magna
Chlamydomonas reinhardtii
Gonium pectorale
Pandorina morum
Pleodorina starrii
Volvox carteri
Lobochlamys segnis
Lobochlamys culleus
Dunaliella salina

MITOCHONDRIAL DNA CONFORMATION



MITOCHONDRIAL DNA CONFORMATION



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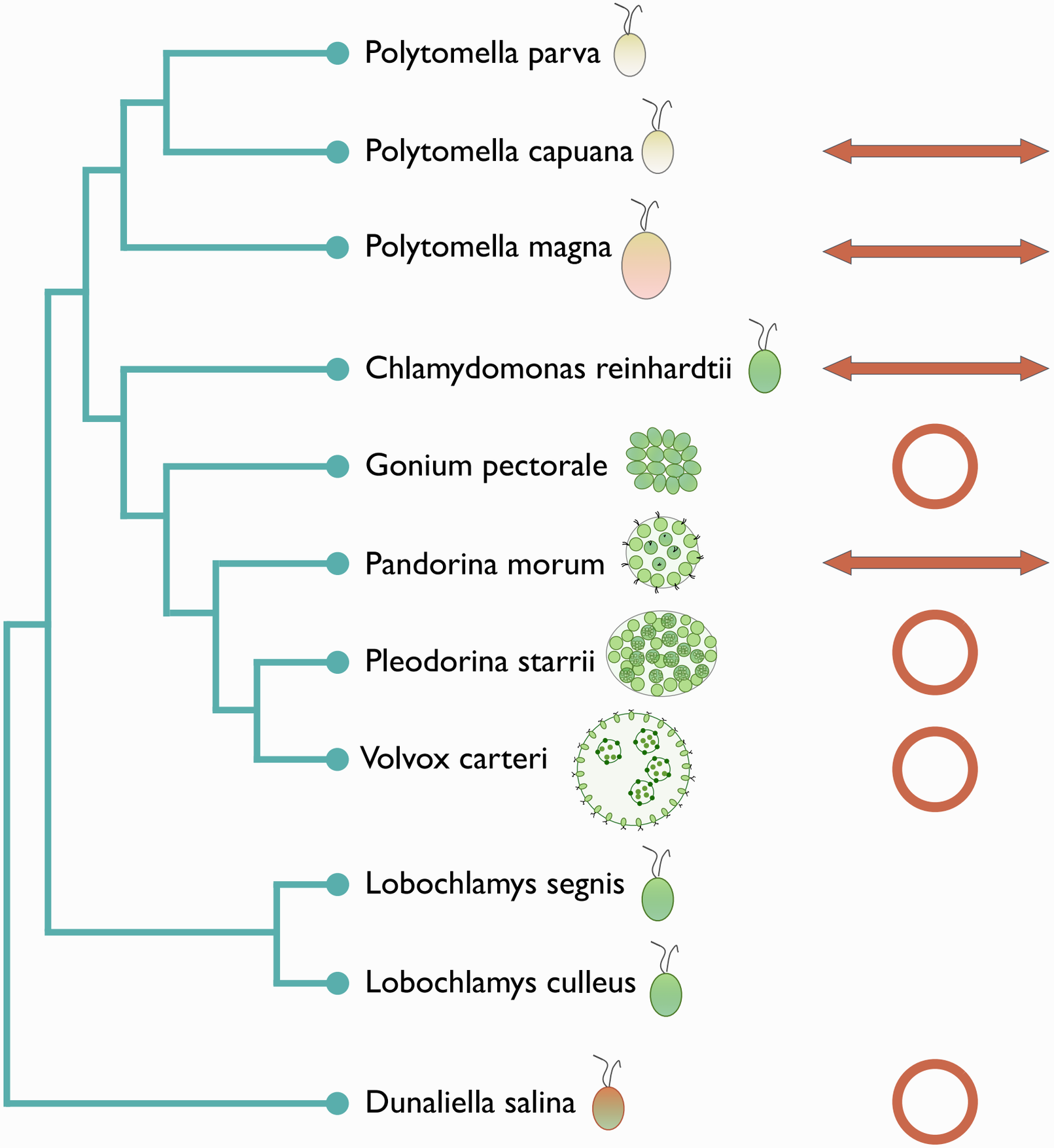
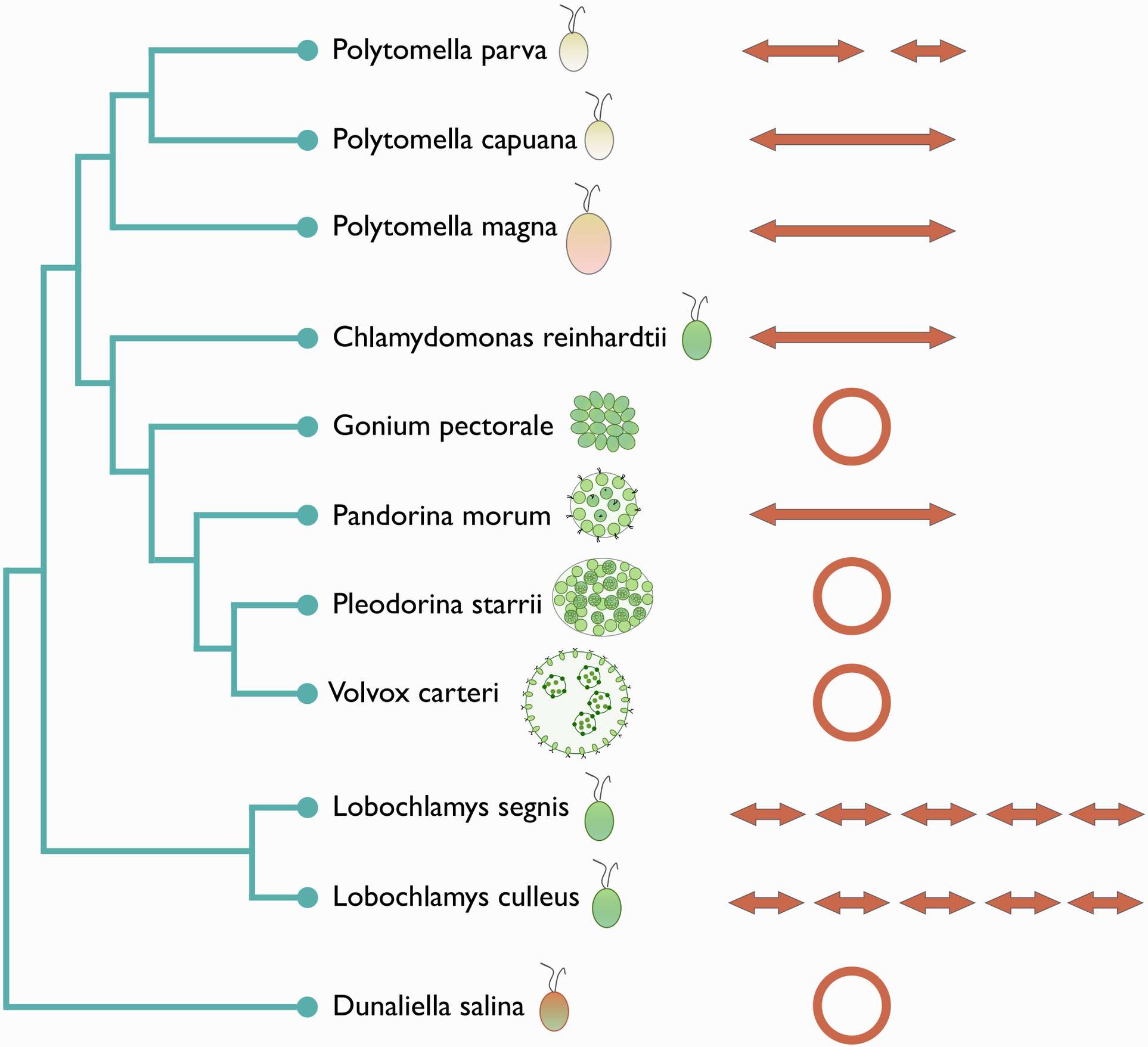
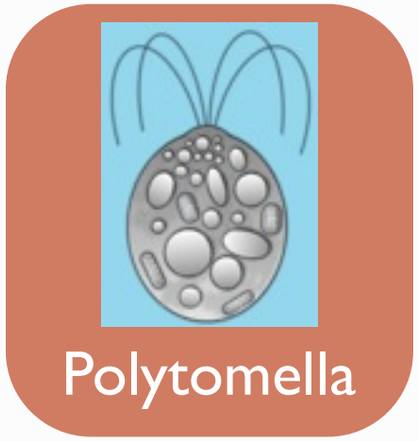
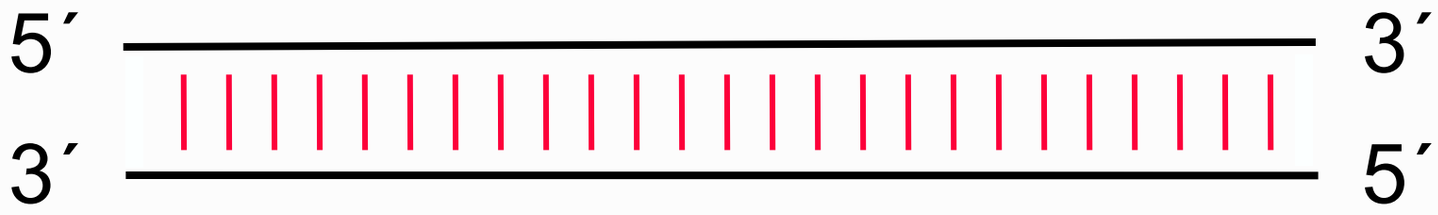
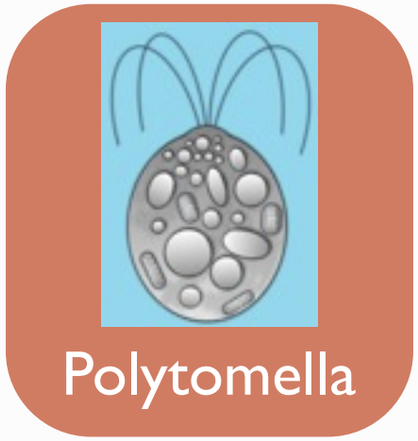


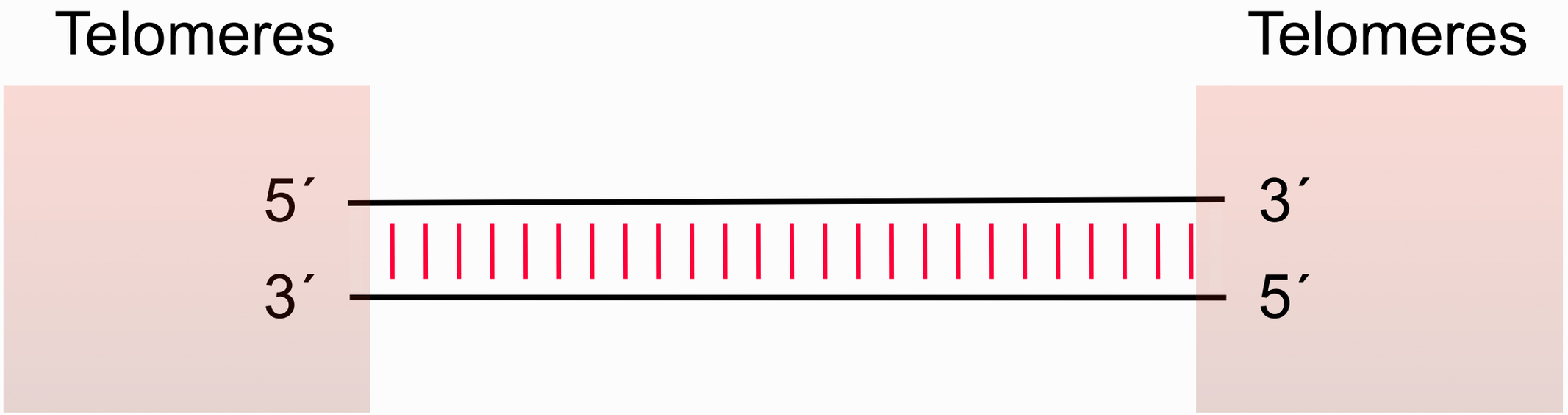
MITOCHONDRIAL DNA CONFORMATION

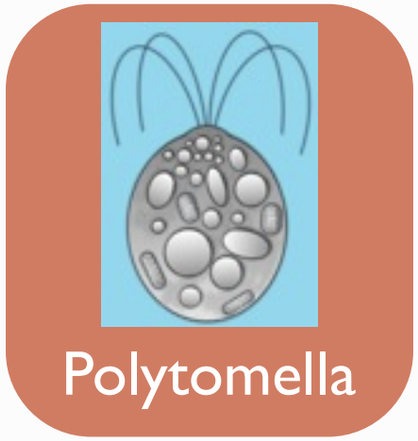


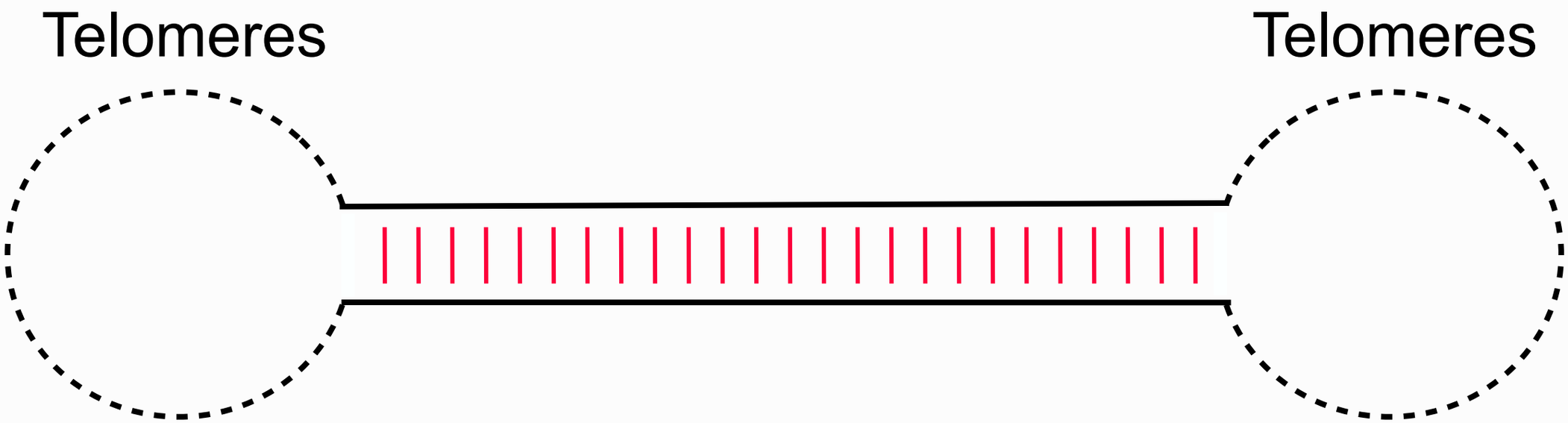

Polytomella

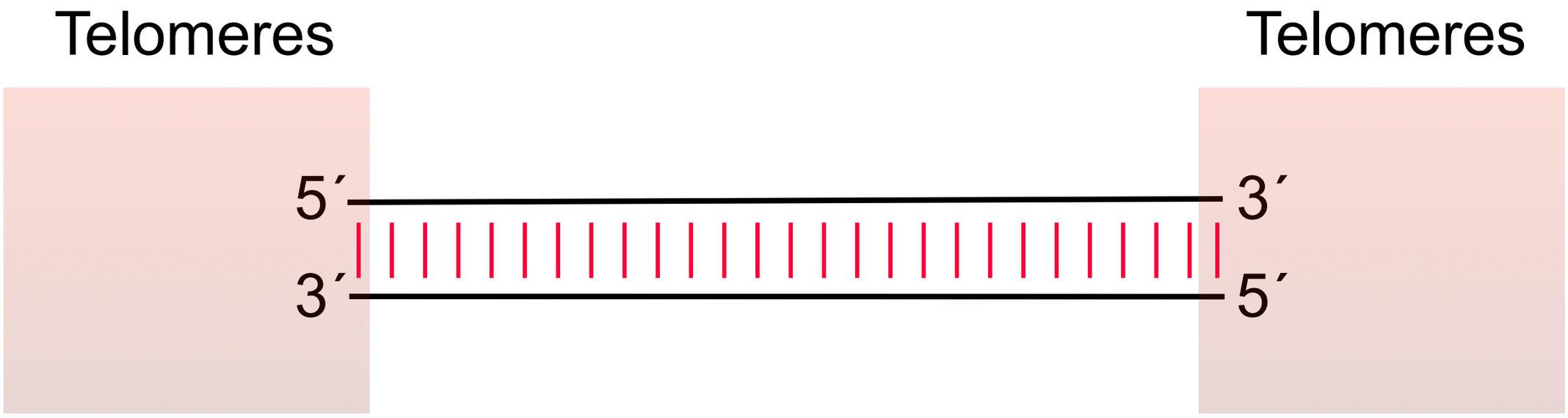

5´
3´
3´
5´


Polytomella

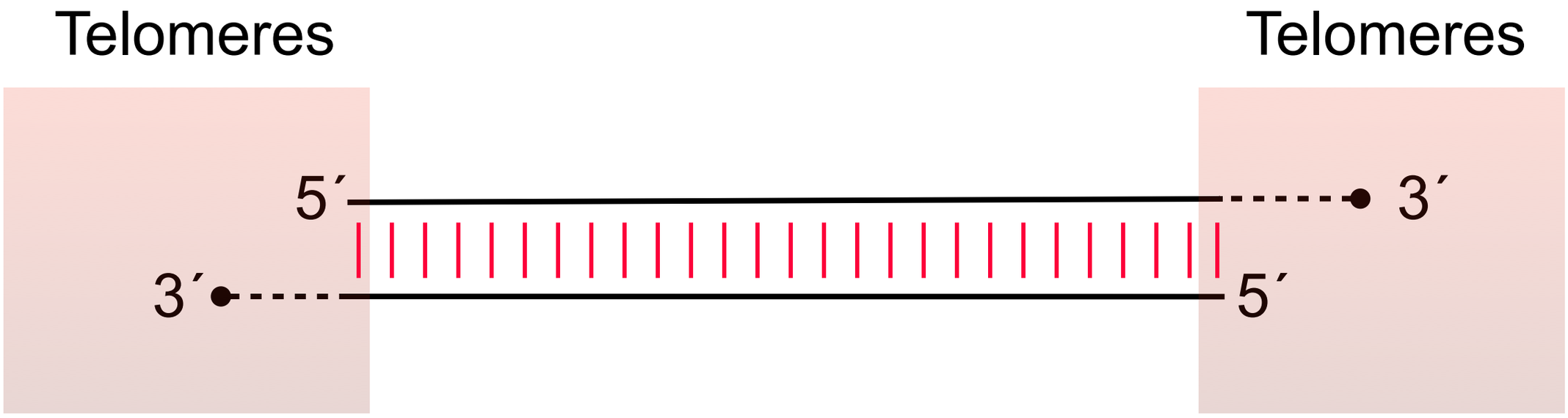

Telomeres
Telomeres
5´
3´
3´
5´


Polytomella

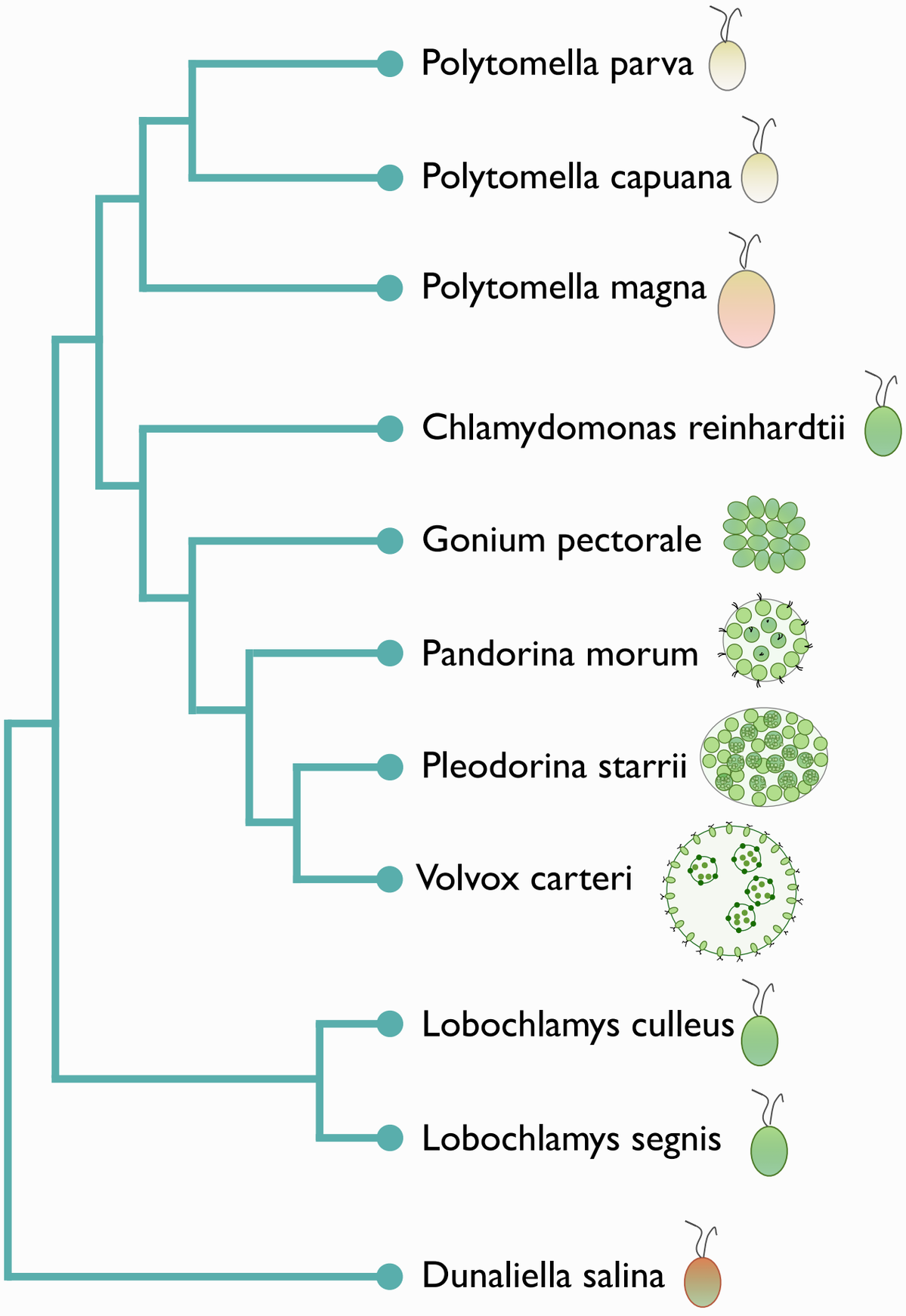

Telomeres
Telomeres


Telomeres
Telomeres
5´
3´
3´
5´

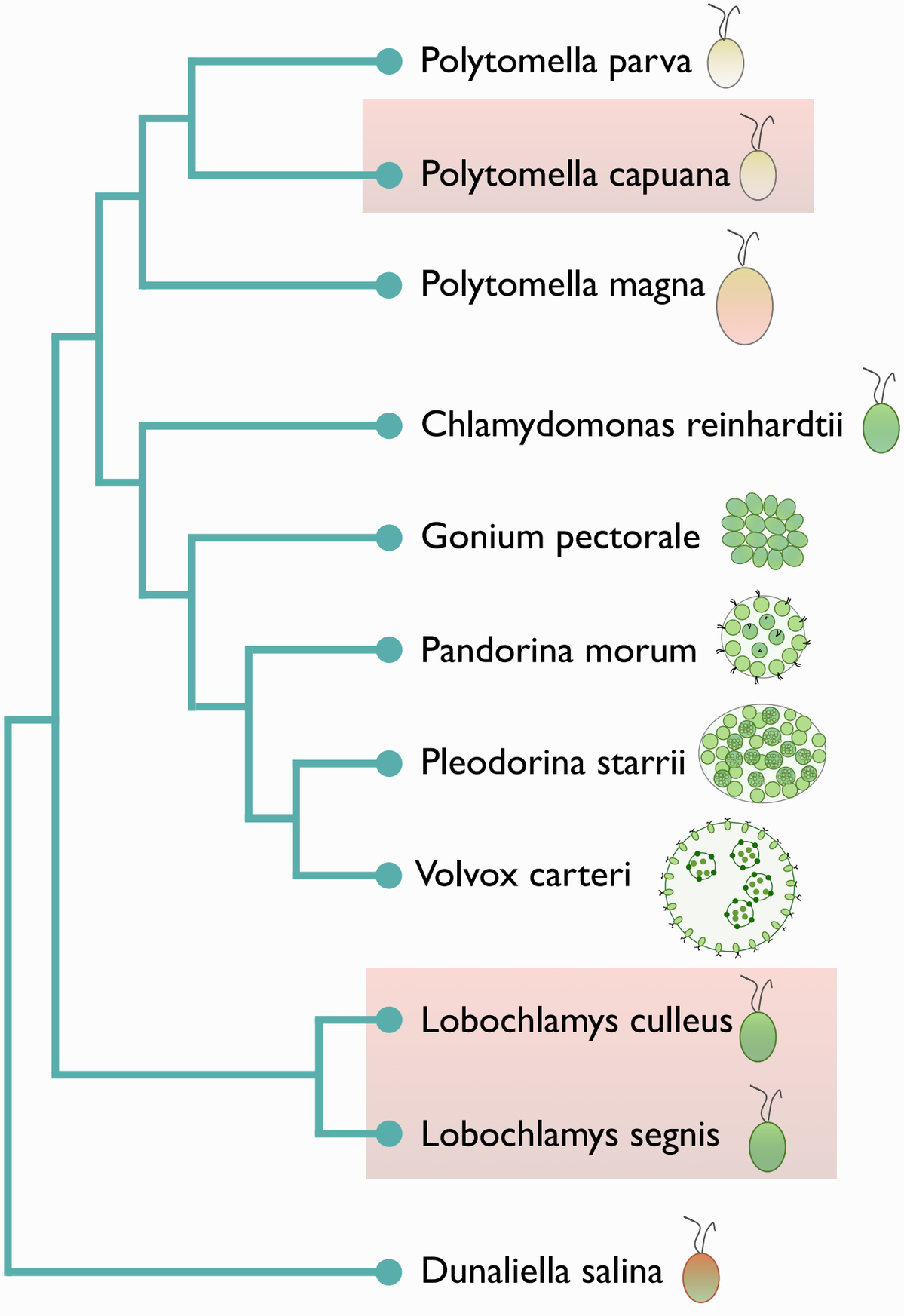

Chlamy


Telomeres
Telomeres
5´
3´
3´
5´

MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE



MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE



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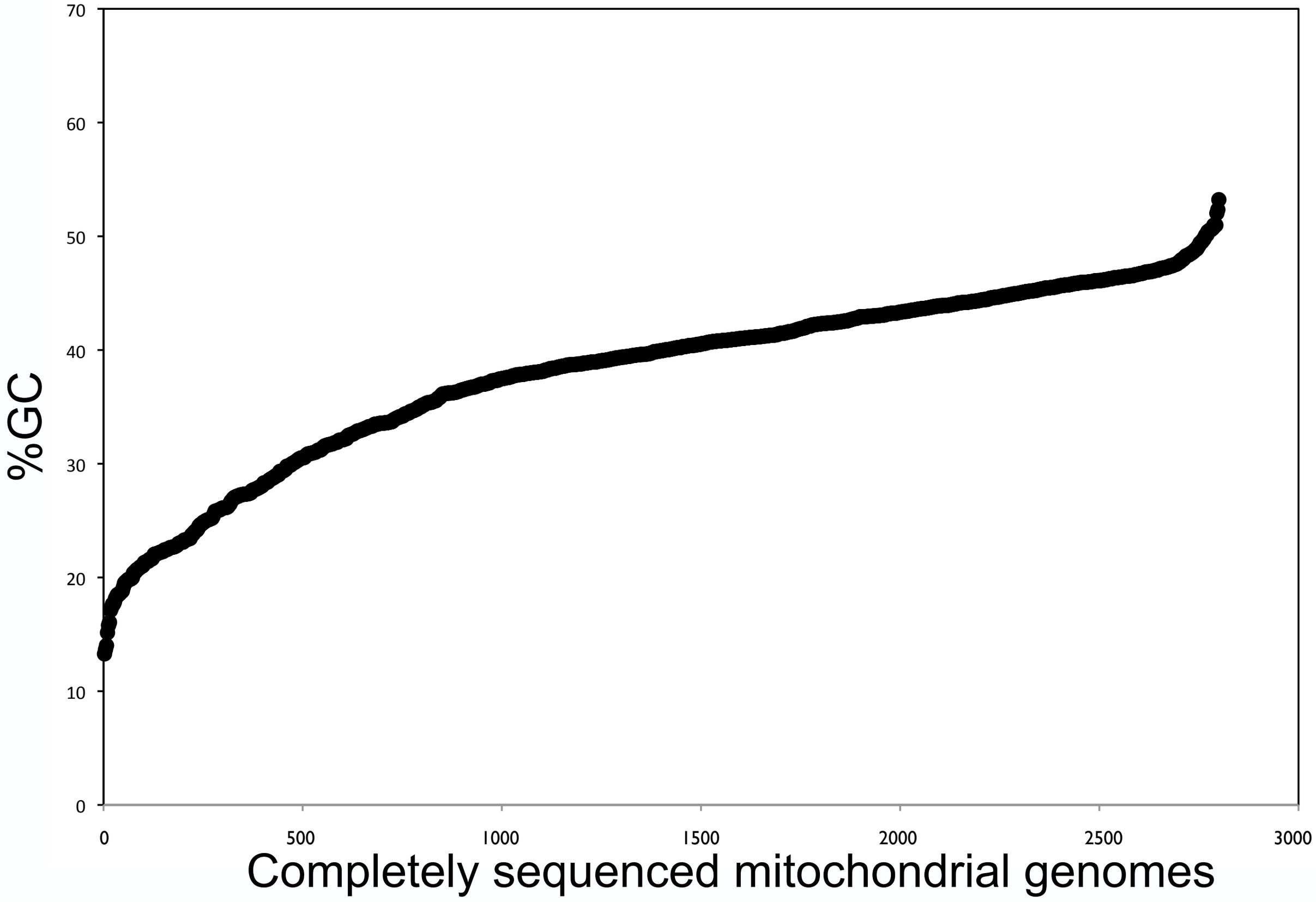
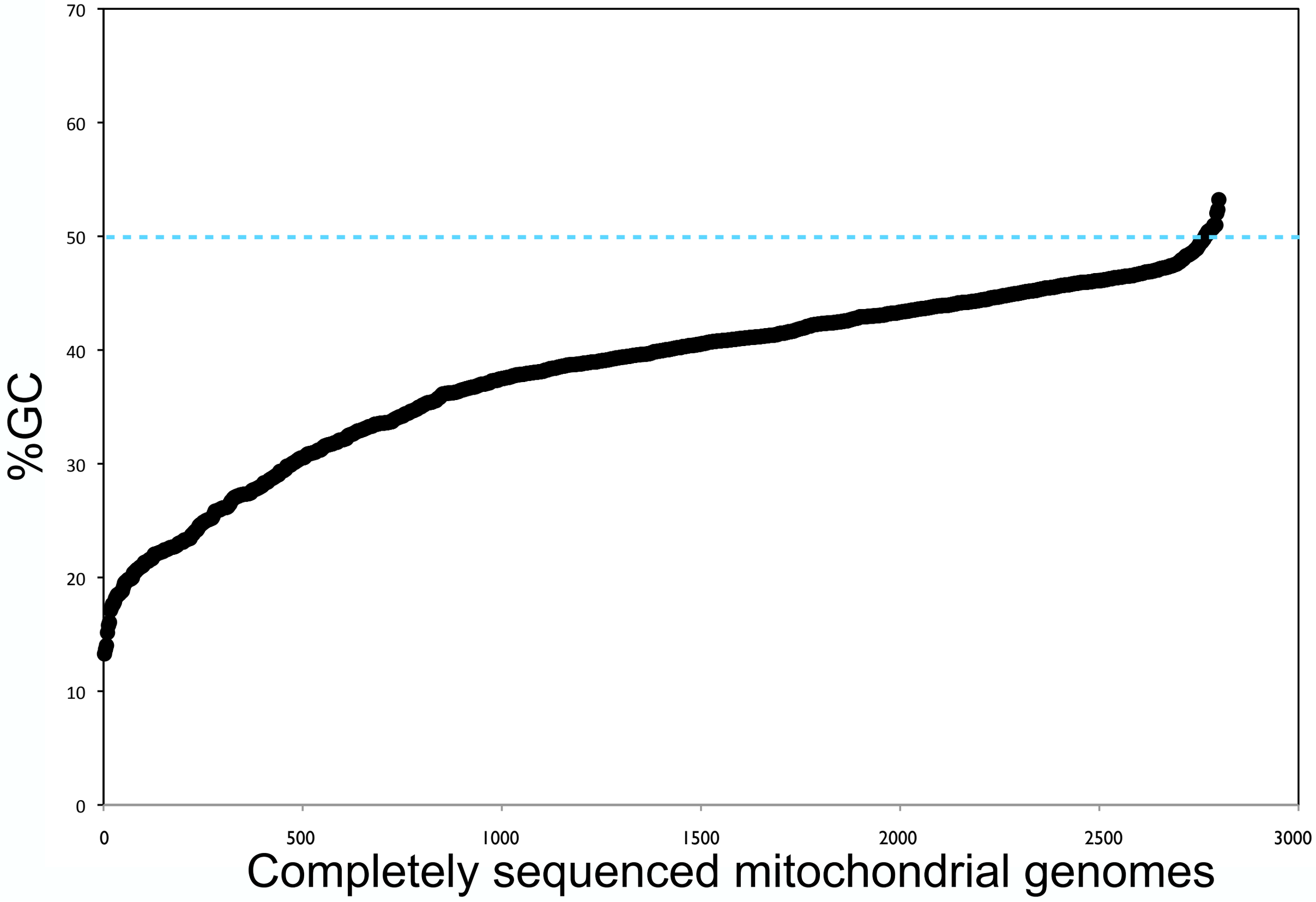
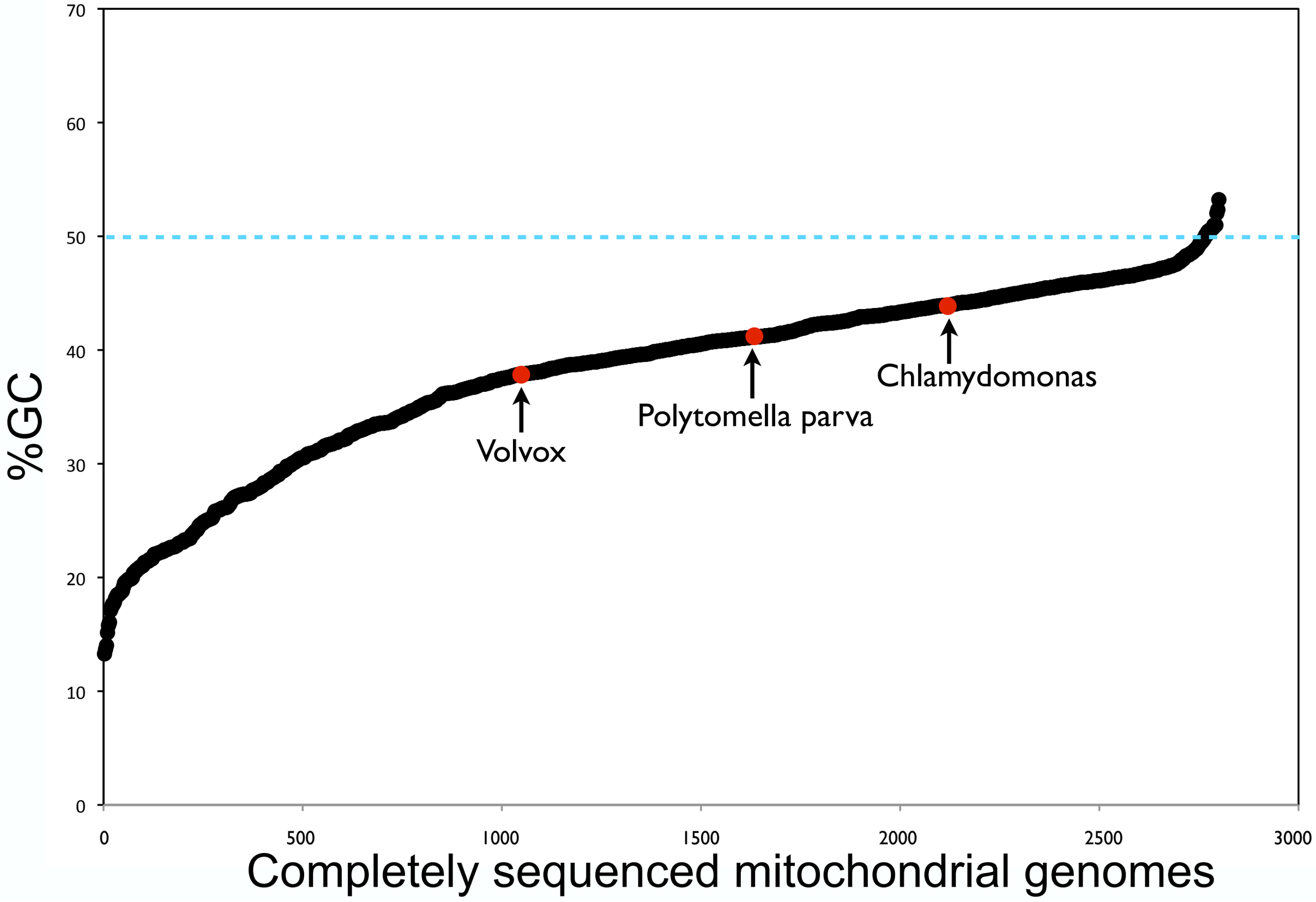


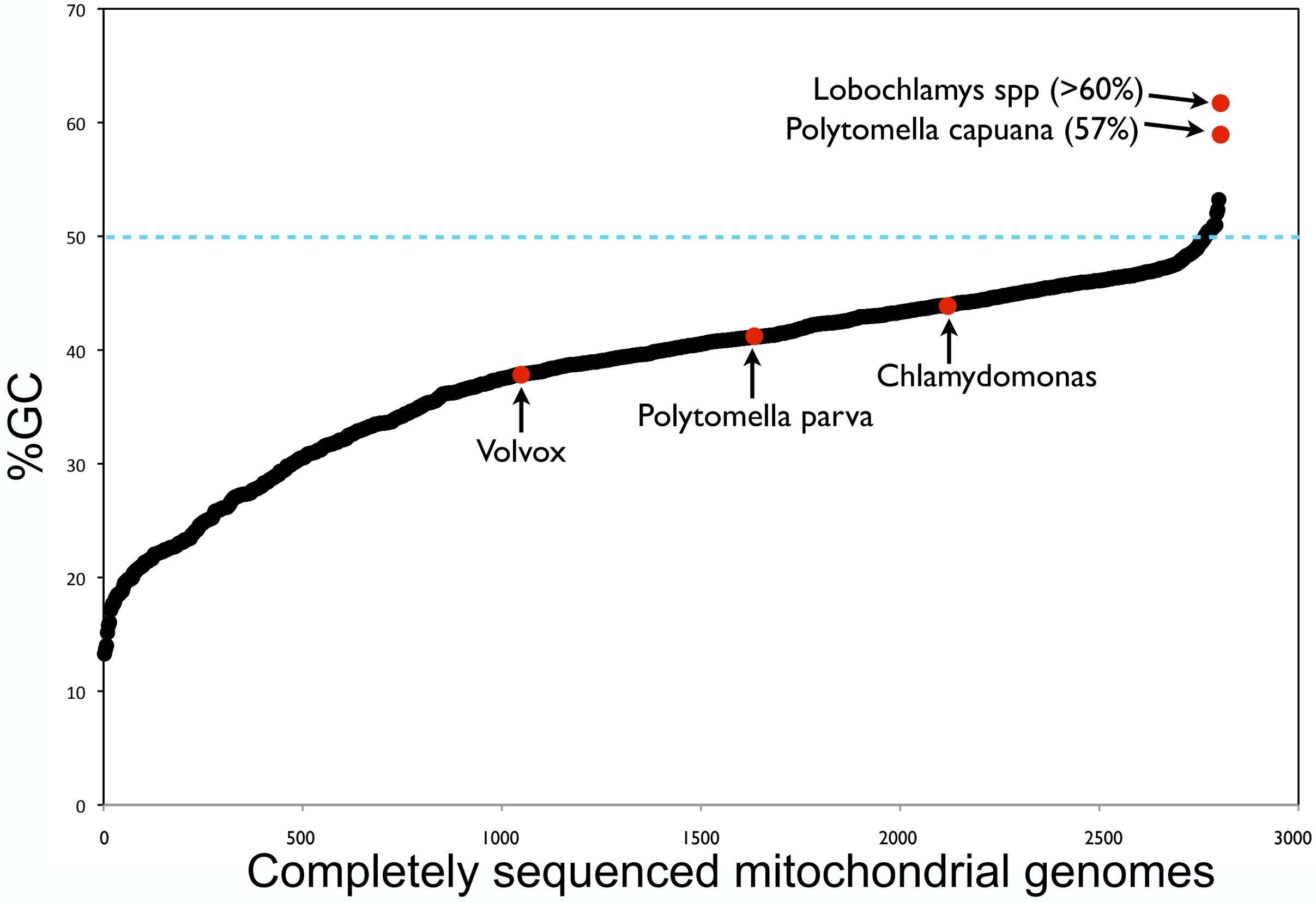
MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE



MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE



MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE



MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE

Selaginella moellendorffii (~70%)

Lobochlamys spp (>60%)

Polytomella capuana (57%)

Volvox

Polytomella parva

Chlamydomonas

%GC

70
60
50
40
30
20
10
0

0
500
1000
1500
2000
2500
3000

Completely sequenced mitochondrial genomes

MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE

DNA 5´-ACG,CCA,CGT,GCA,CAC-3´

Selaginella moellendorffii (~70%)

Lobochlamys spp (>60%)

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Volvox

Polytomella parva

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10
0

0
500
1000
1500
2000
2500
3000

Completely sequenced mitochondrial genomes

MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE

DNA 5´-ACG,CCA,CGT,GCA,CAC-3´
RNA 5´-ACG,CCA,CGU,GCA,CAC-3´

Selaginella moellendorffii (~70%)

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50
40
30
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10
0

0
500
1000
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2000
2500
3000

Completely sequenced mitochondrial genomes

MITOCHONDRIAL DNA NUCLEOTIDE LANDSCAPE

DNA 5´-ACG,CCA,CGT,GCA,CAC-3´
RNA 5´-AUG,UCA,UGU,GUA,UAC-3´

Selaginella moellendorffii (~70%)

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70
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1000
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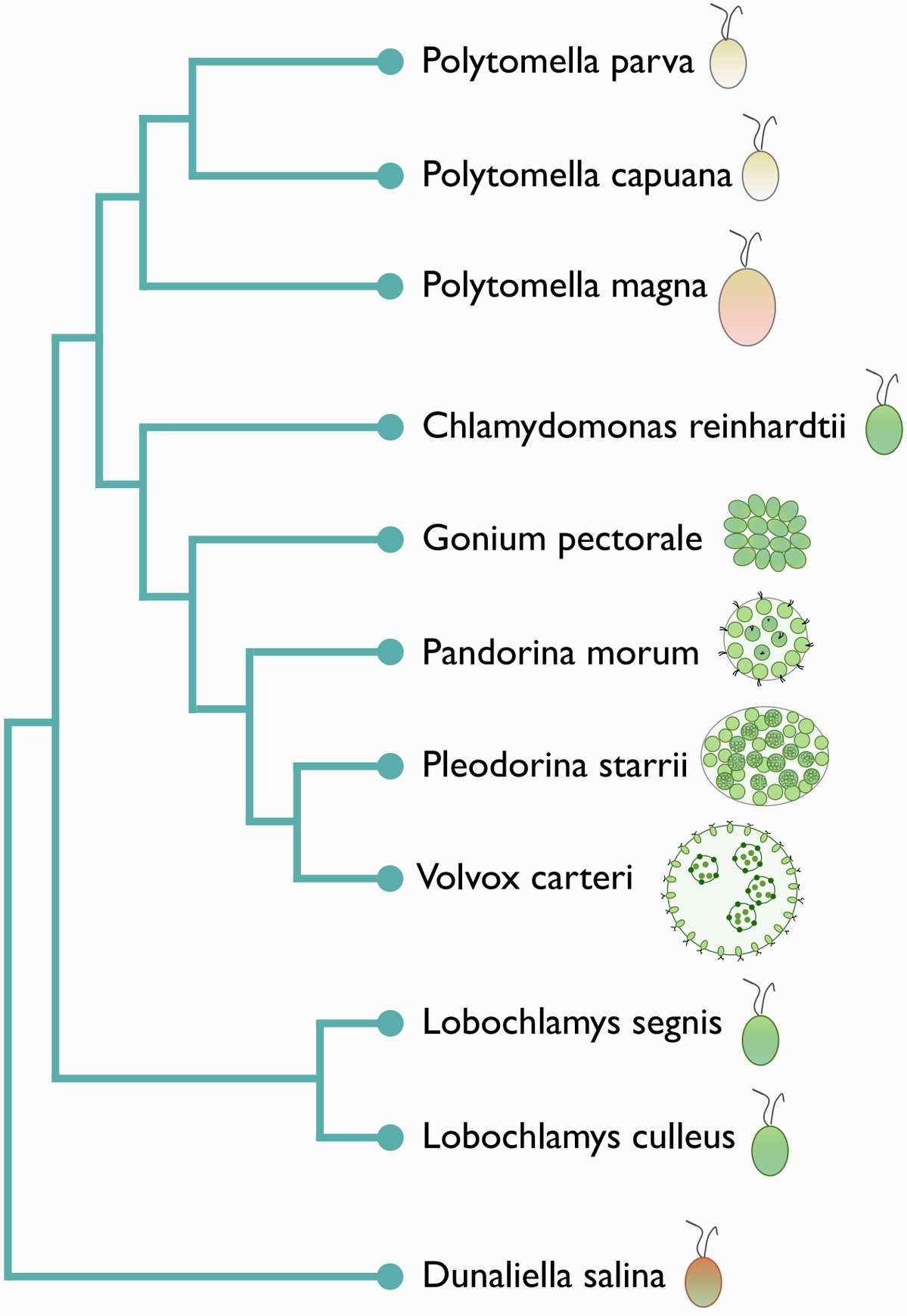
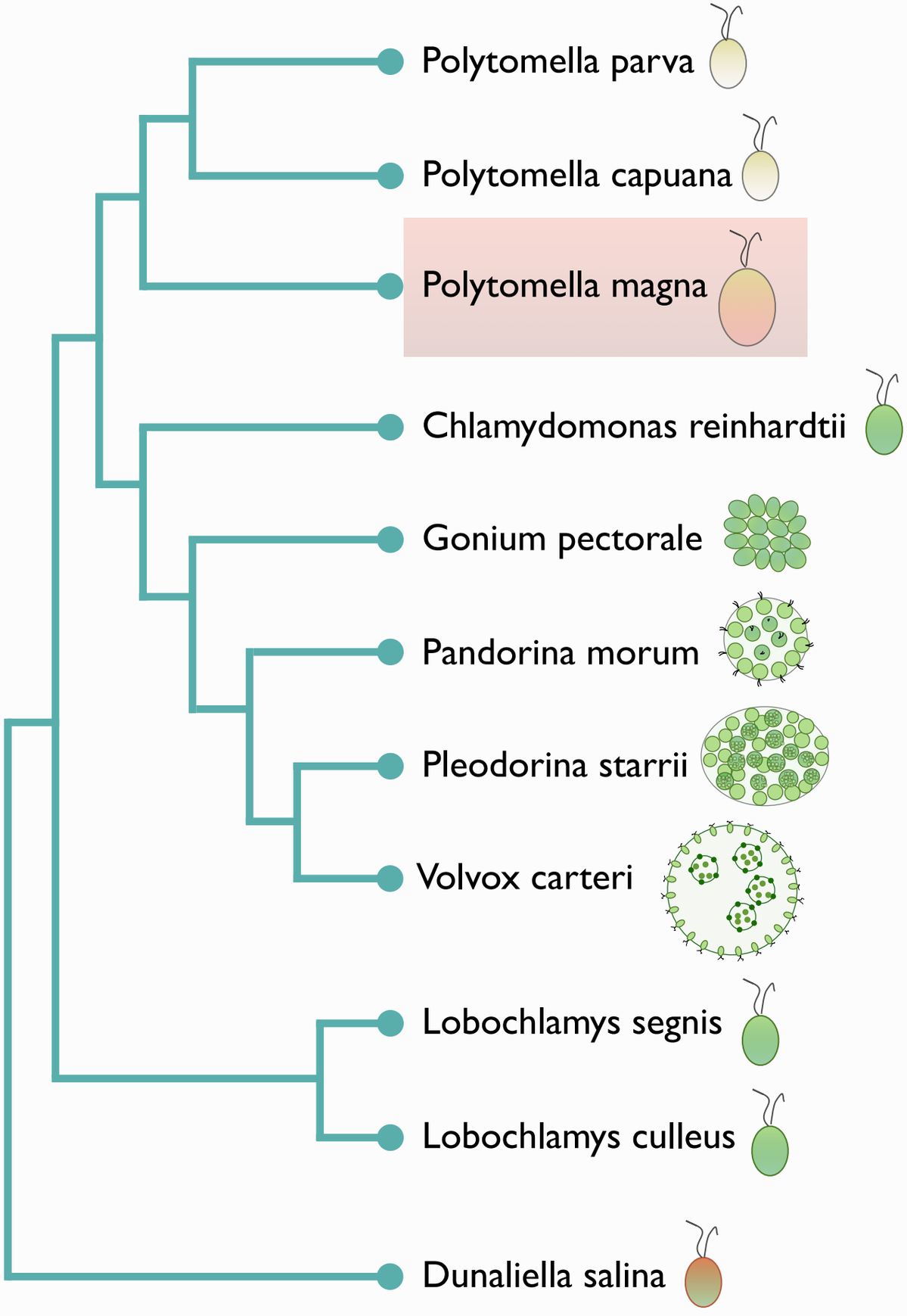
Completely sequenced mitochondrial genomes

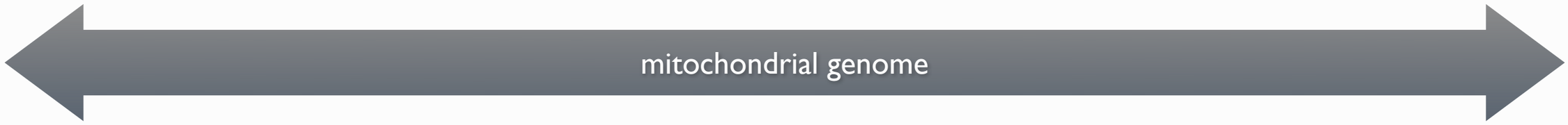
MITOCHONDRIAL DNA GENE CONTENT



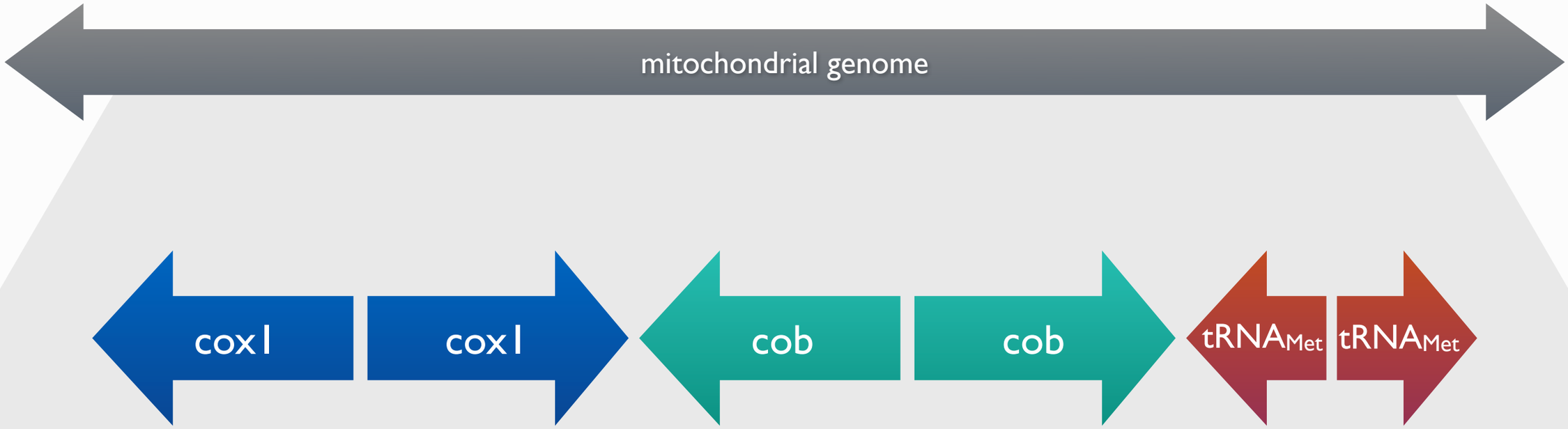
MITOCHONDRIAL DNA GENE CONTENT



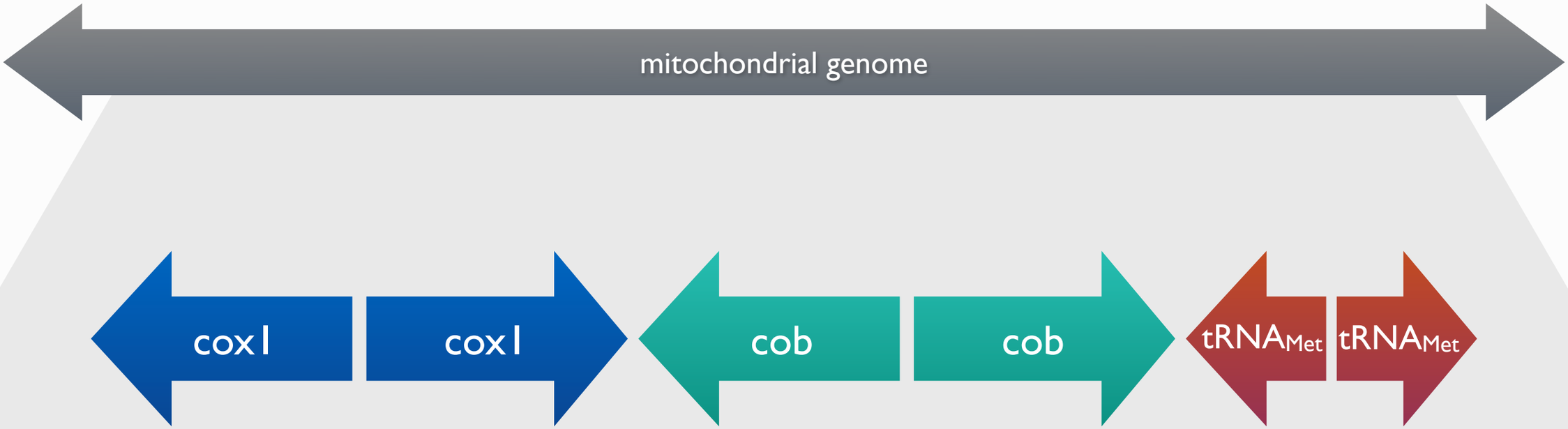
PALINDROMIC GENES IN POLYTOMELLA MAGNA

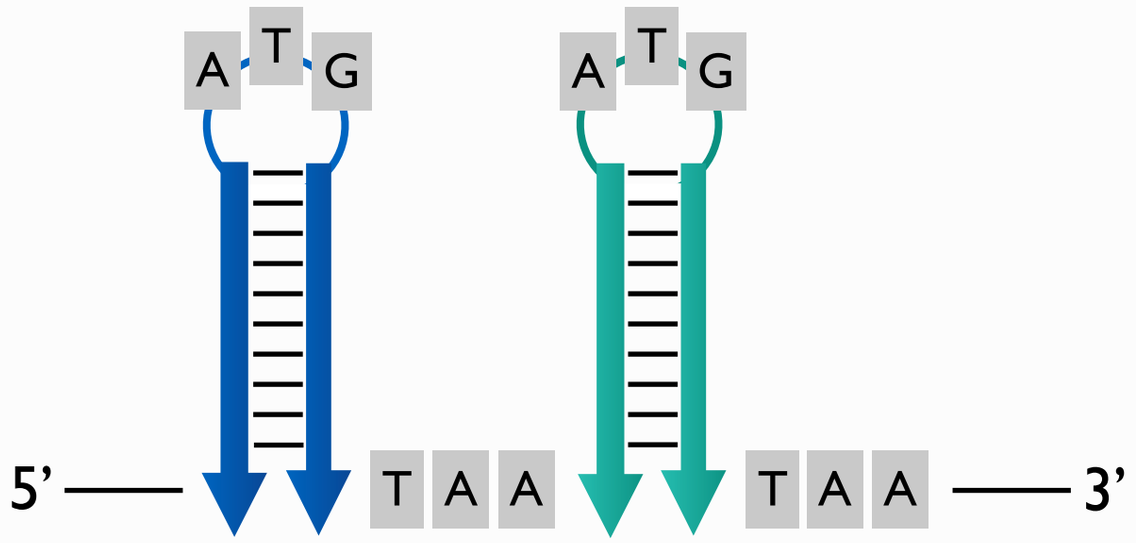


PALINDROMIC GENES IN POLYTOMELLA MAGNA

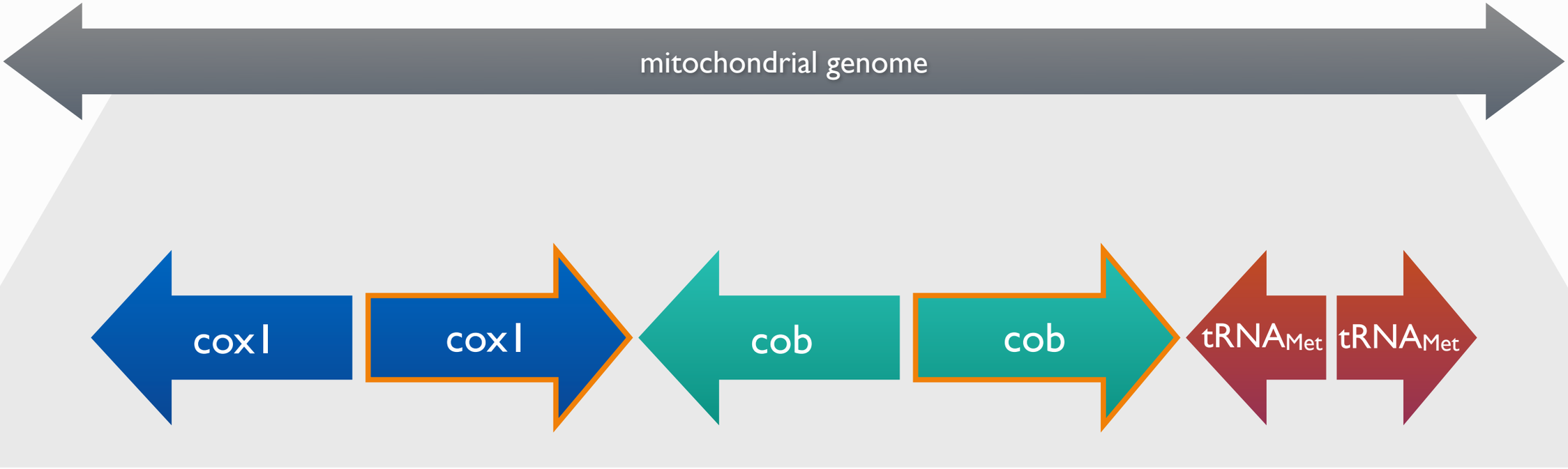


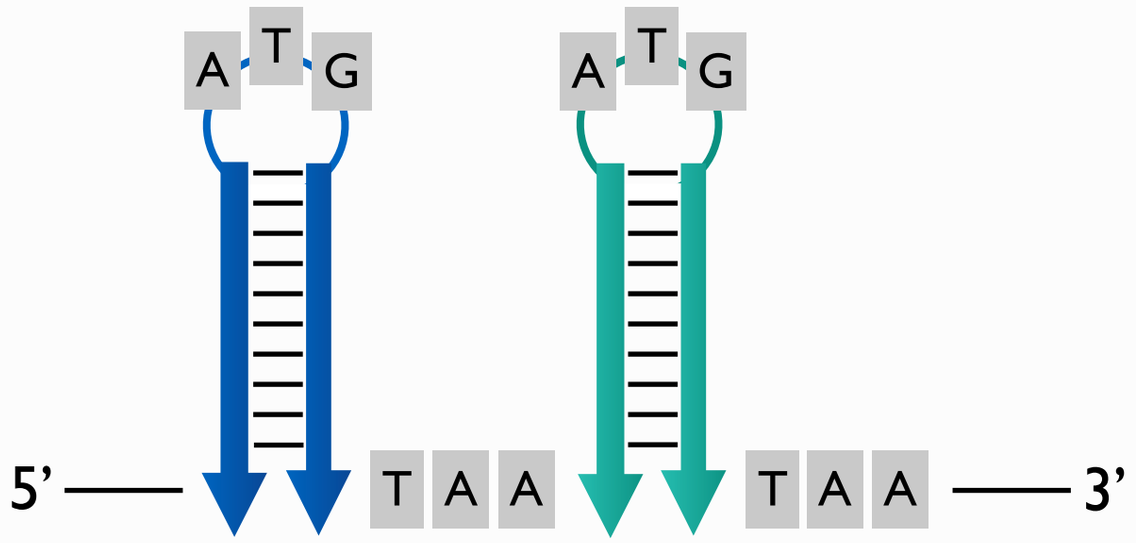
PALINDROMIC GENES IN POLYTOMELLA MAGNA



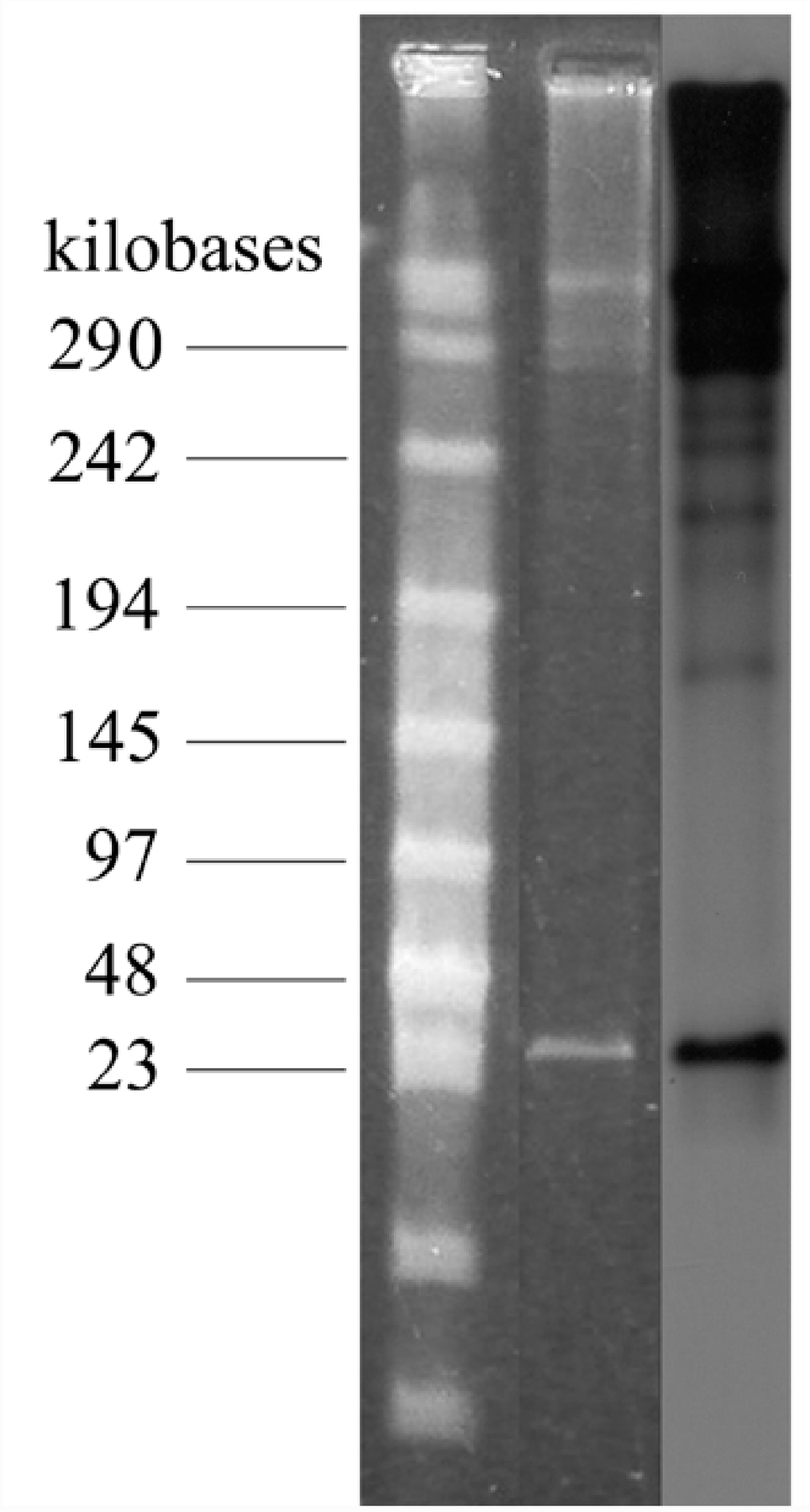


PALINDROMIC GENES IN POLYTOMELLA MAGNA

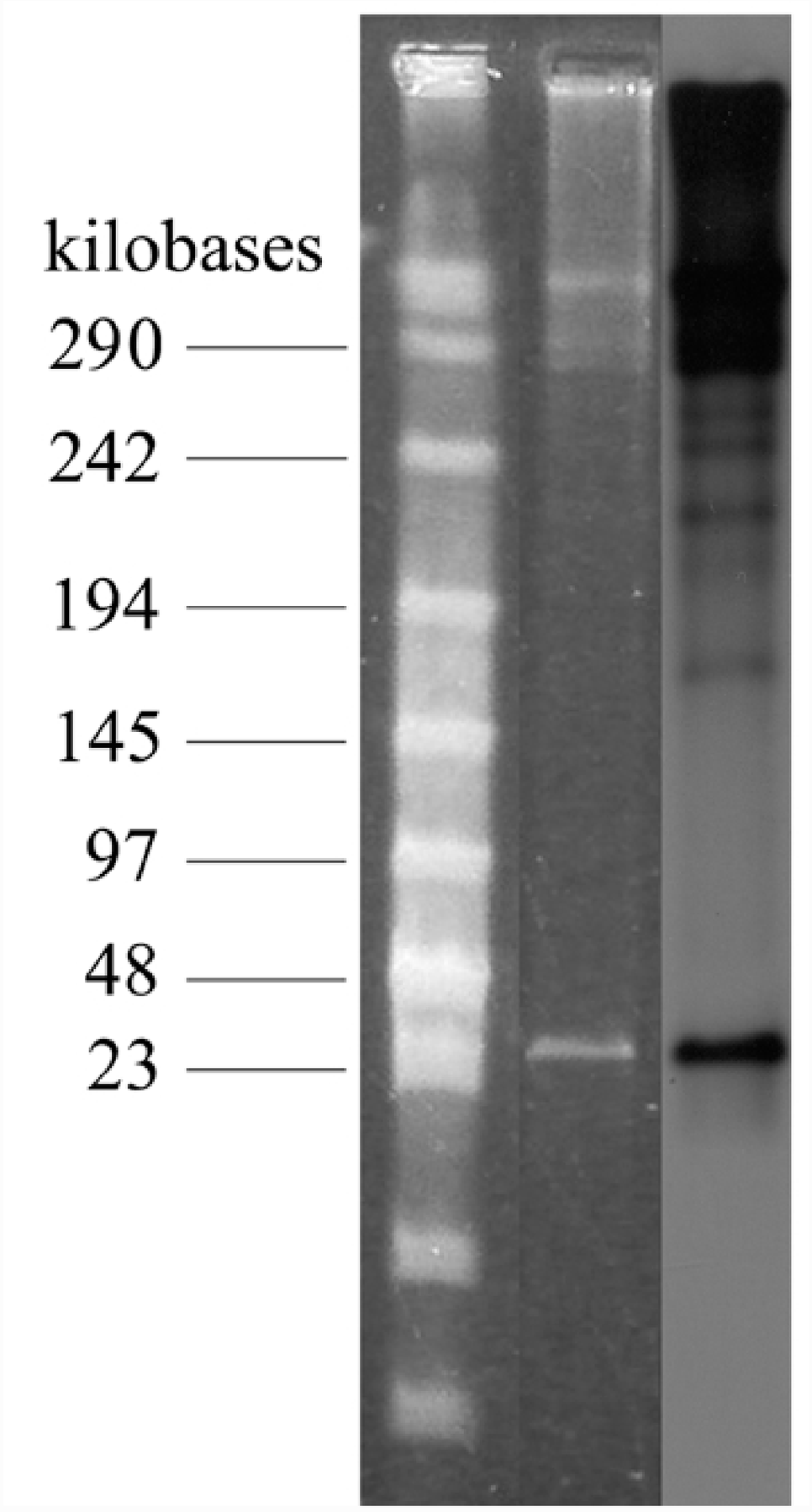




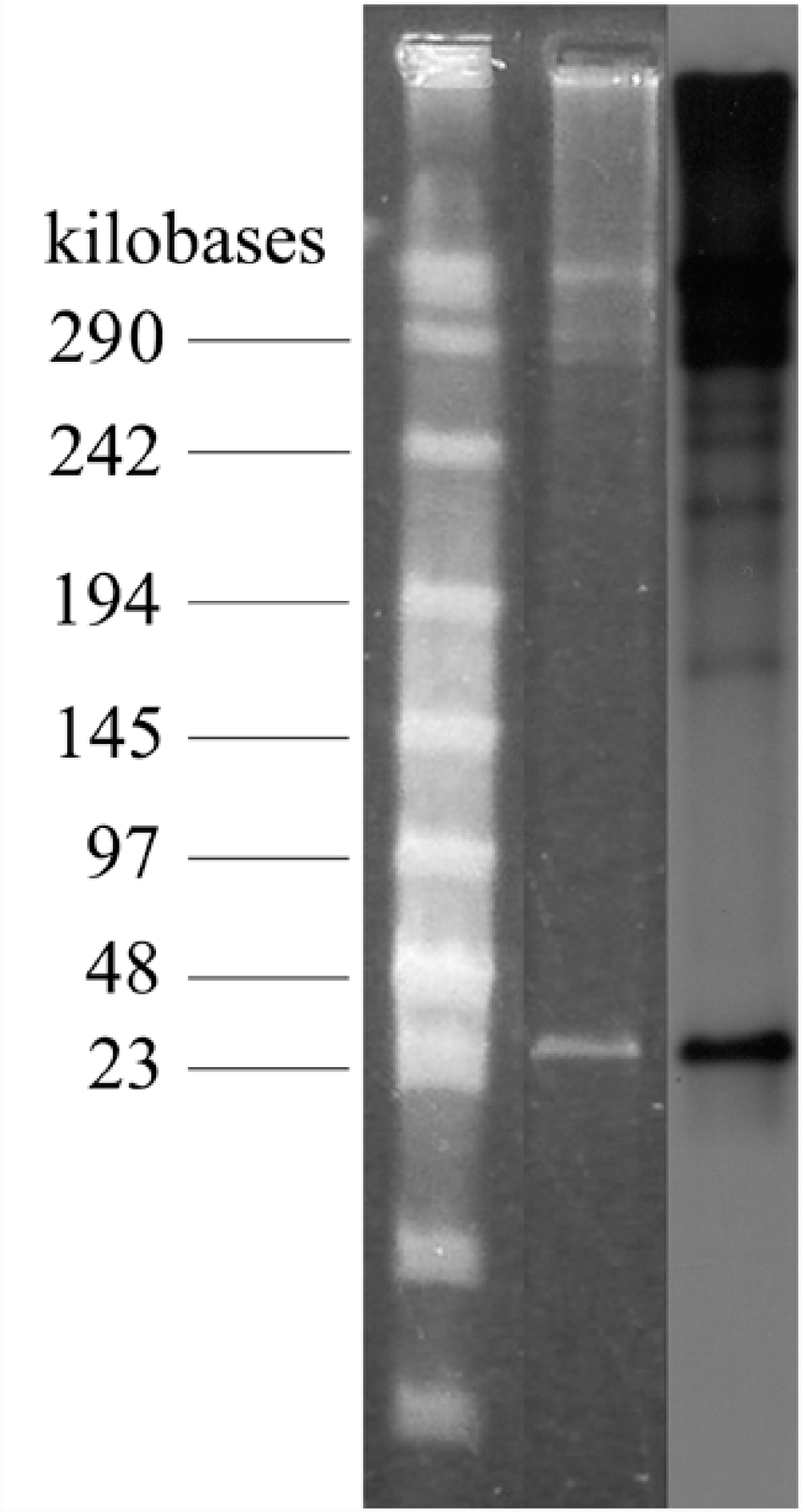
PALINDROMIC GENES IN POLYTOMELLA MAGNA

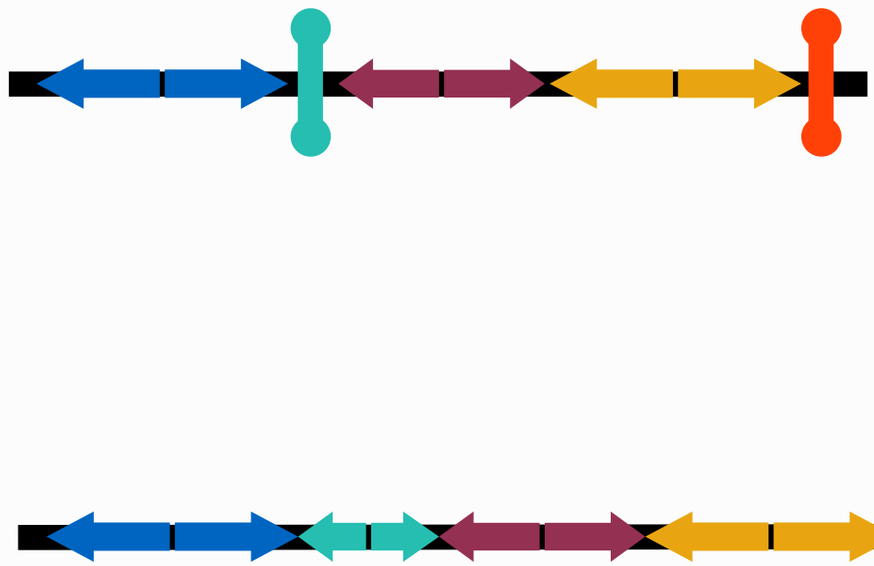


PALINDROMIC GENES IN POLYTOMELLA MAGNA

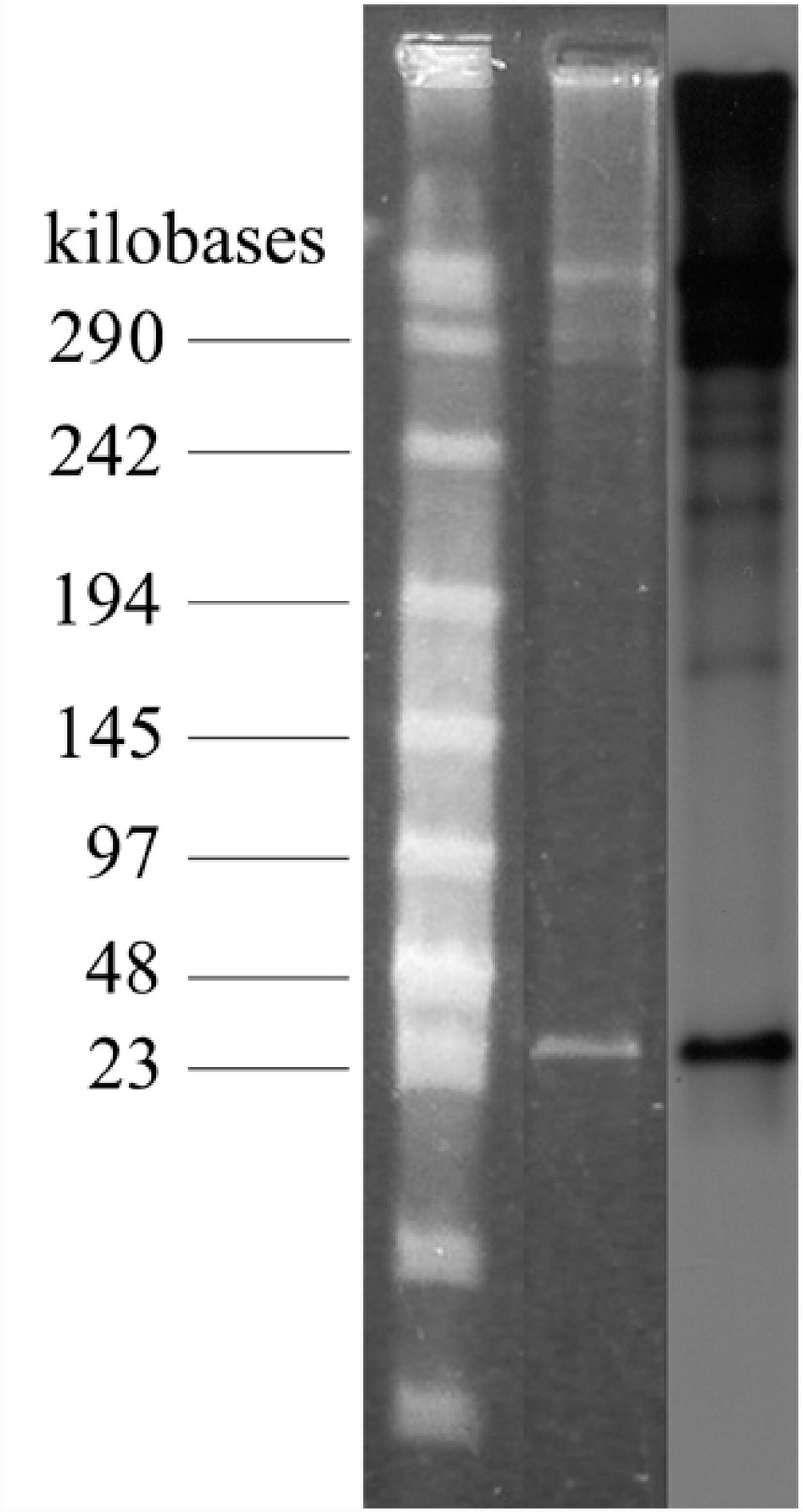


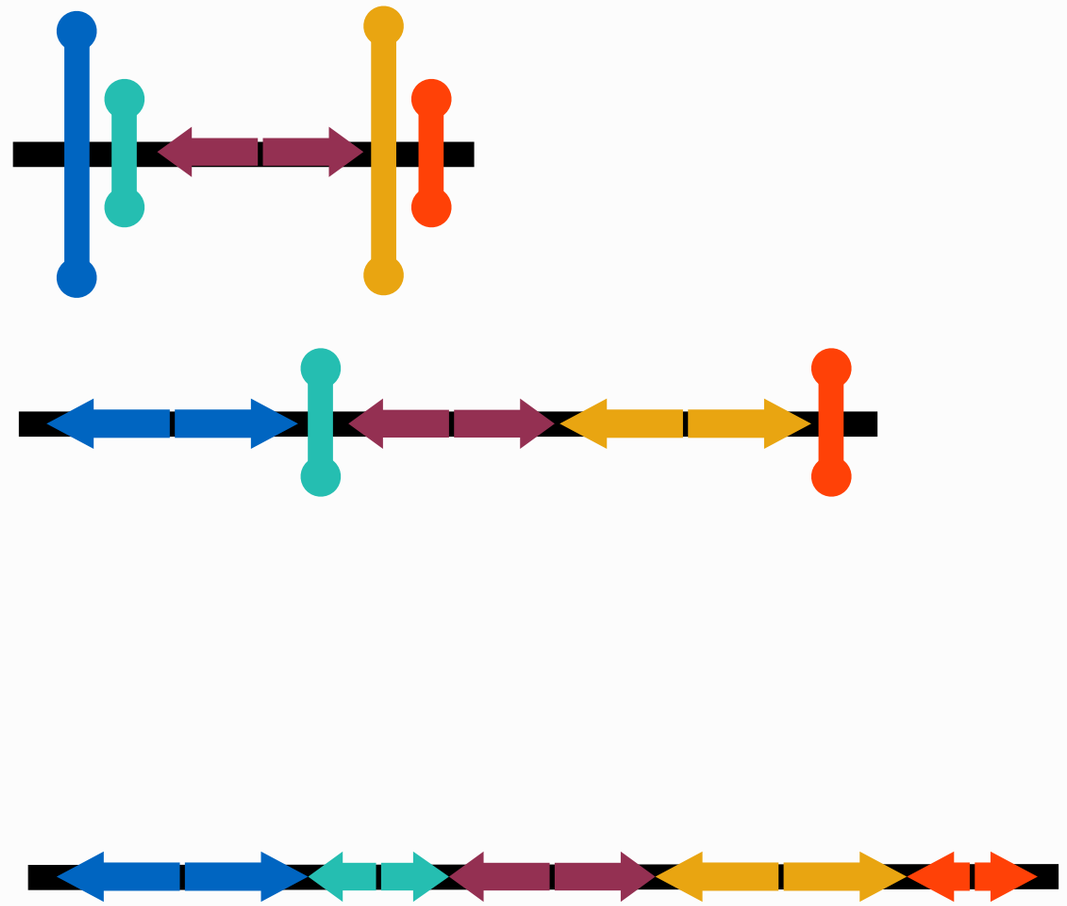
PALINDROMIC GENES IN POLYTOMELLA MAGNA



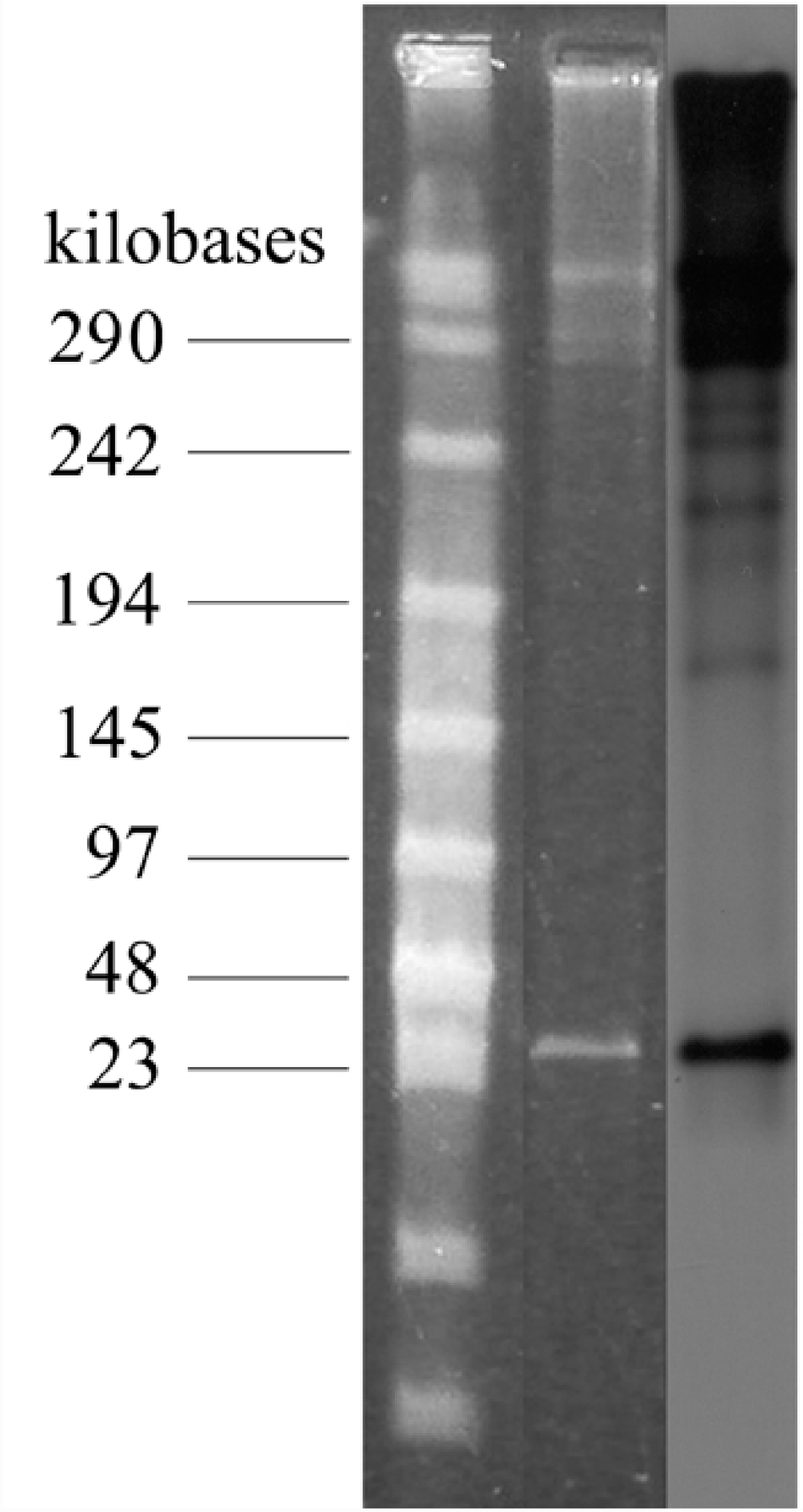


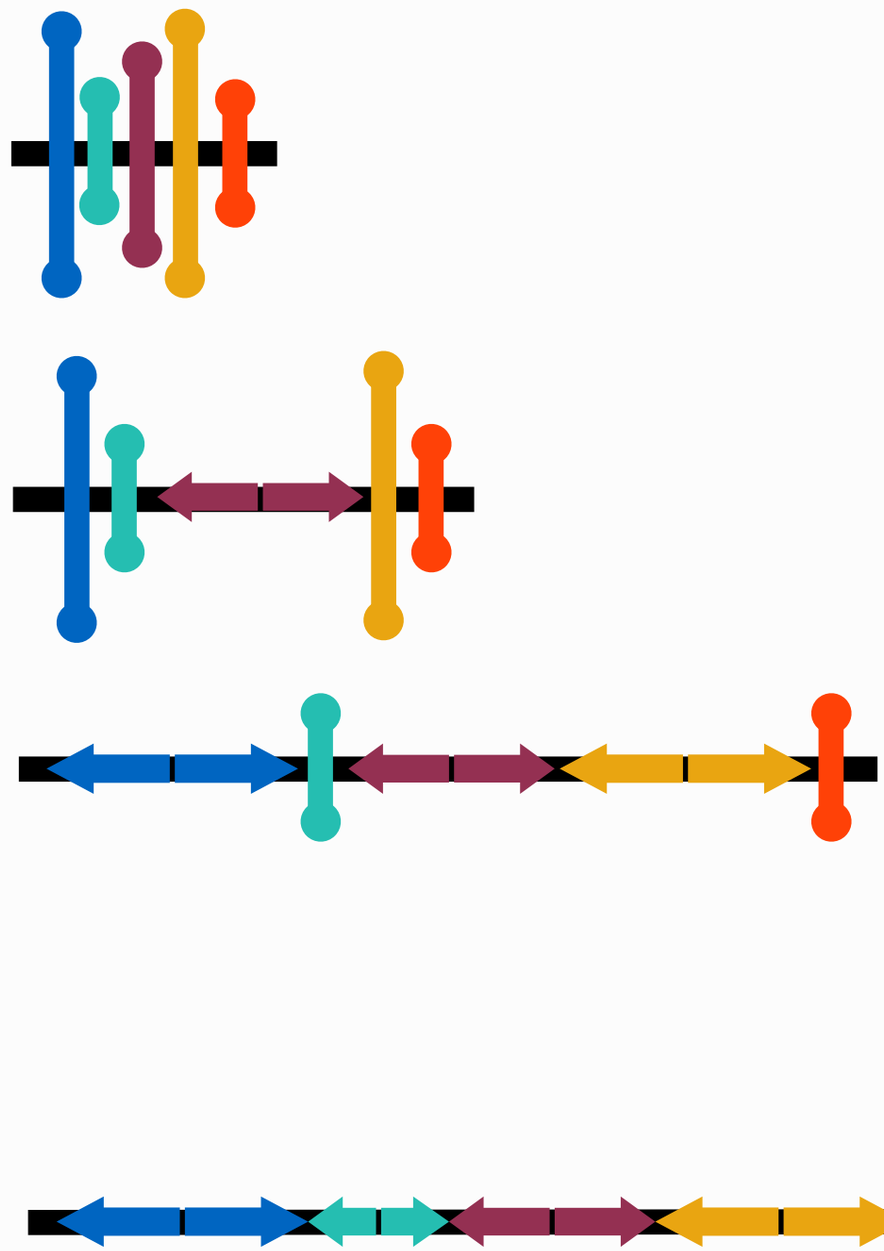
PALINDROMIC GENES IN POLYTOMELLA MAGNA



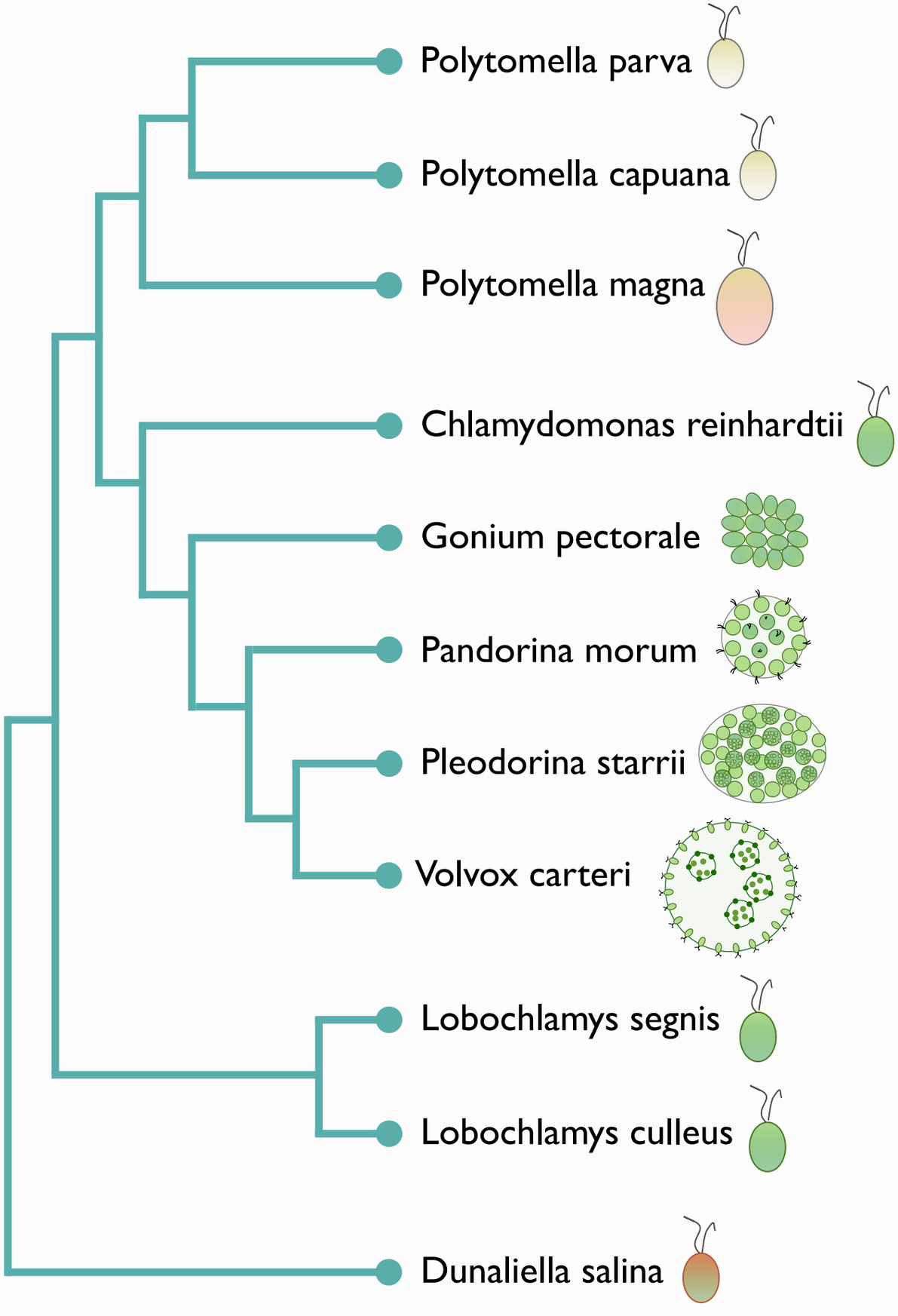


PALINDROMIC GENES IN POLYTOMELLA MAGNA

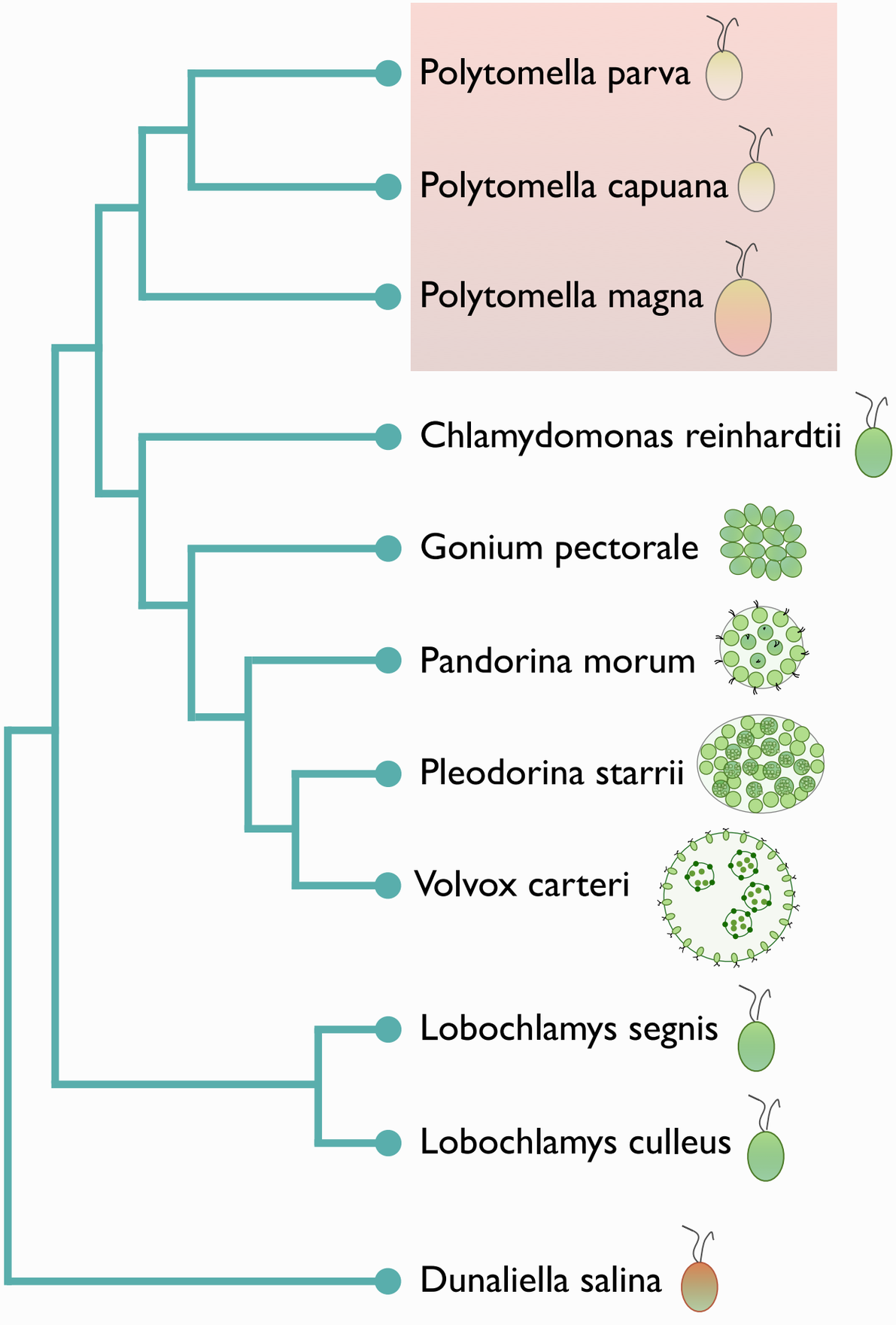




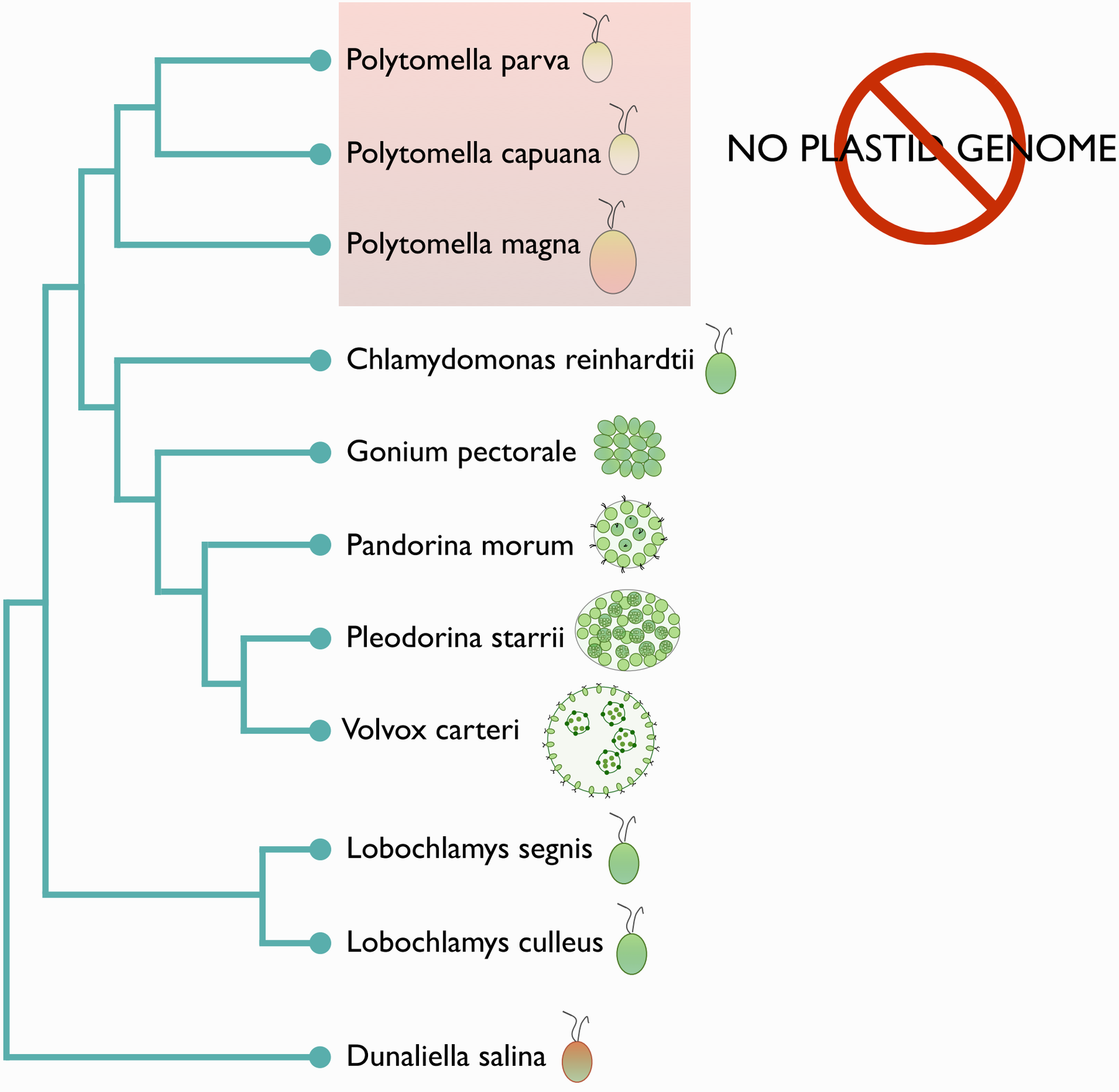
CHLOROPLAST GENOMES



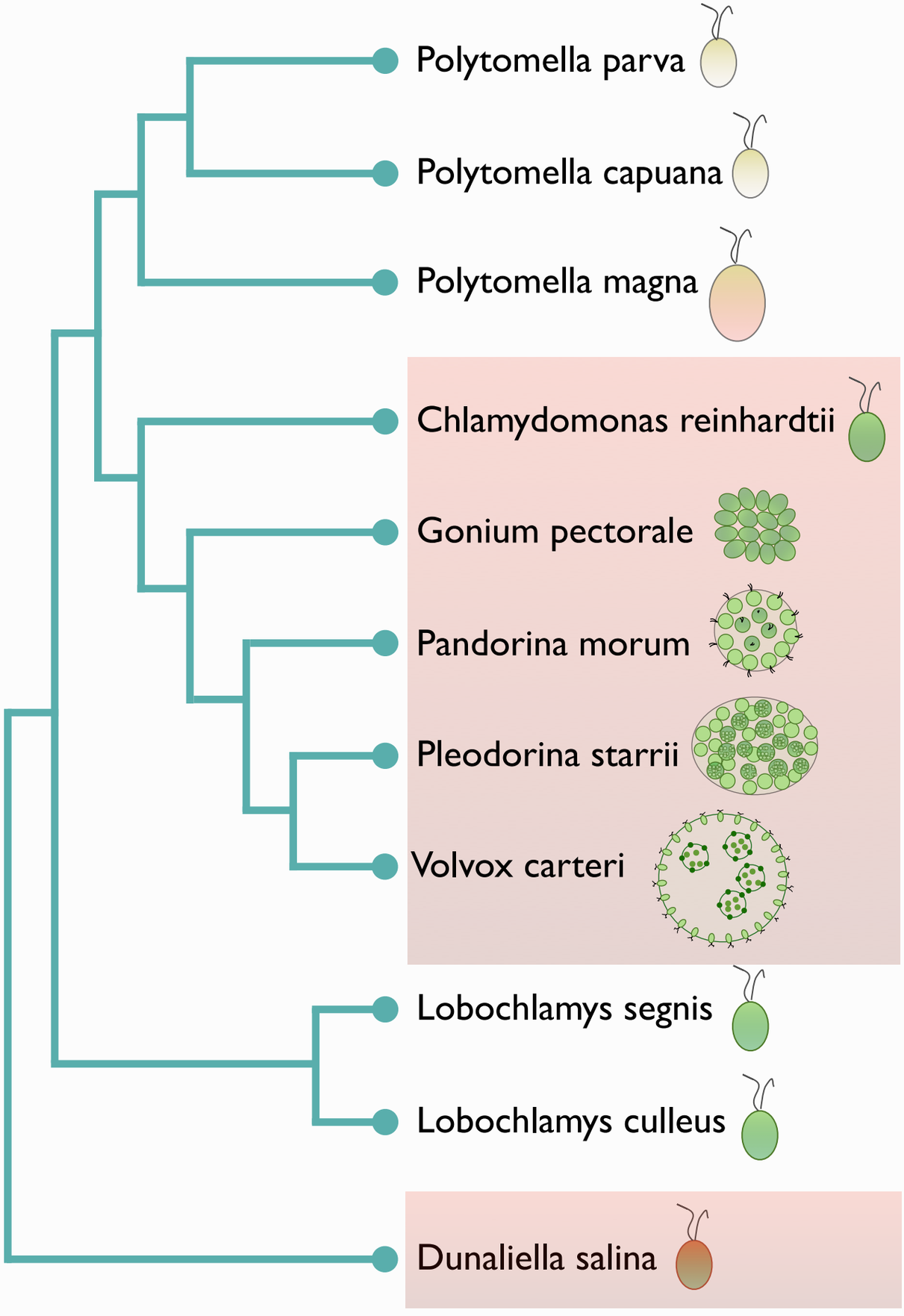
CHLOROPLAST GENOMES



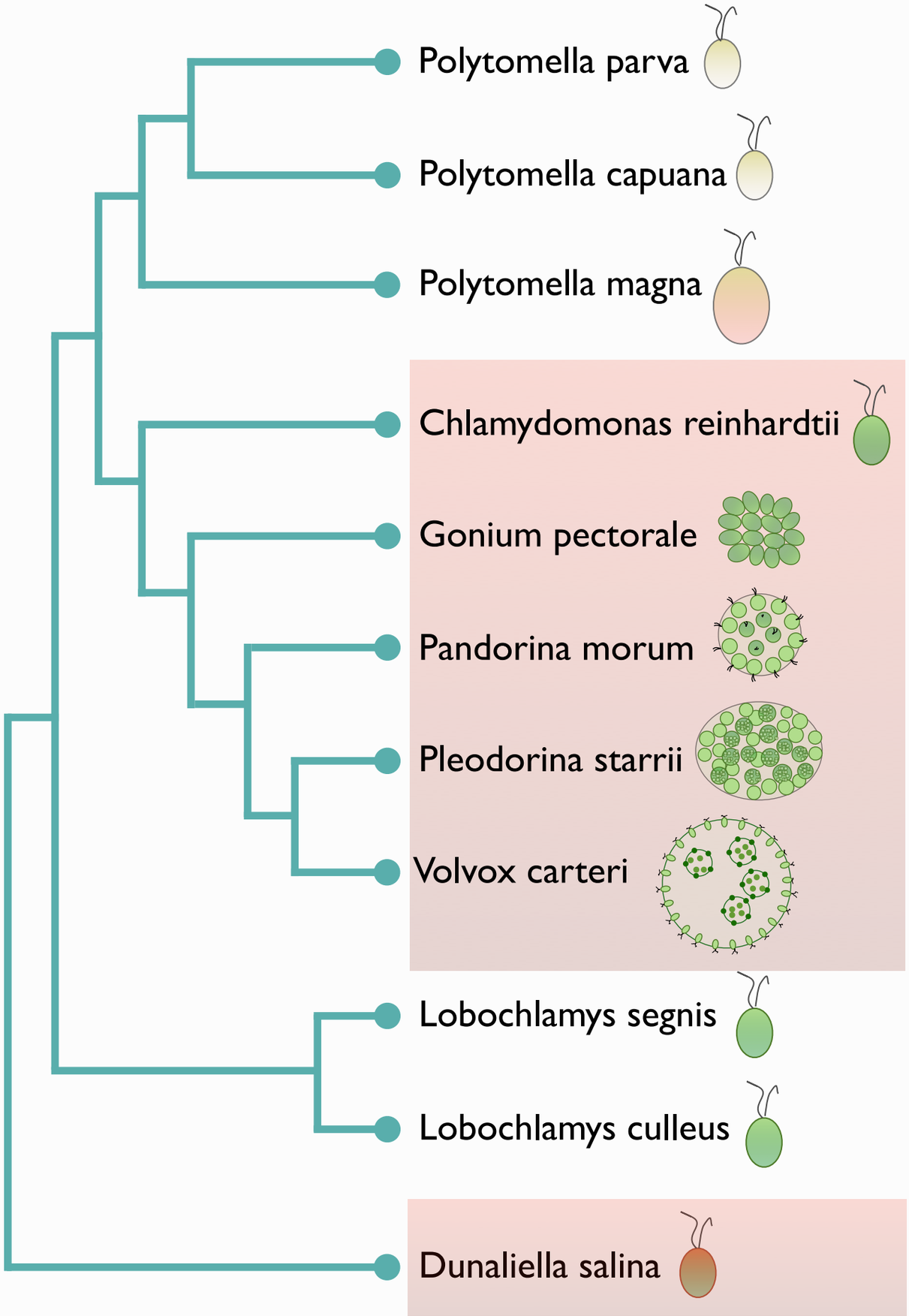
CHLOROPLAST GENOMES

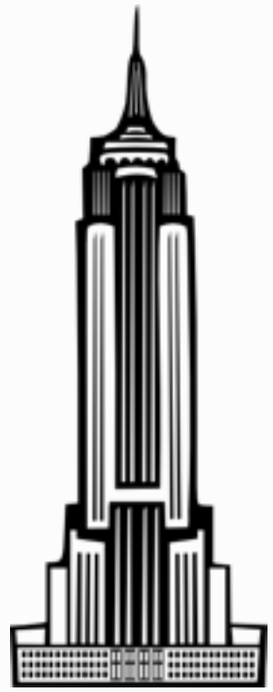


CHLOROPLAST GENOMES



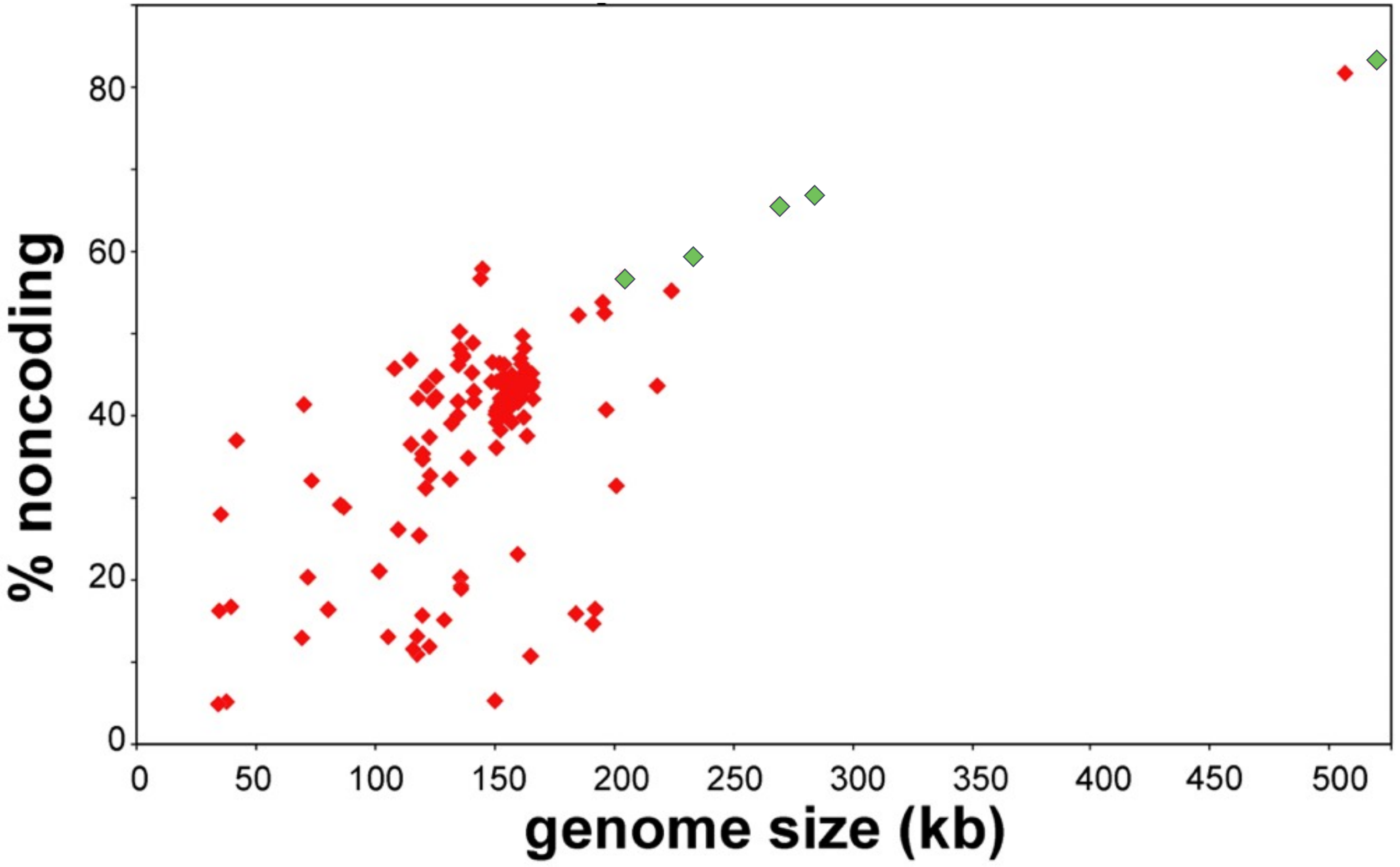
CHLOROPLAST GENOMES





GIANT PLASTID GENOMES

GIANT PLASTID GENOMES



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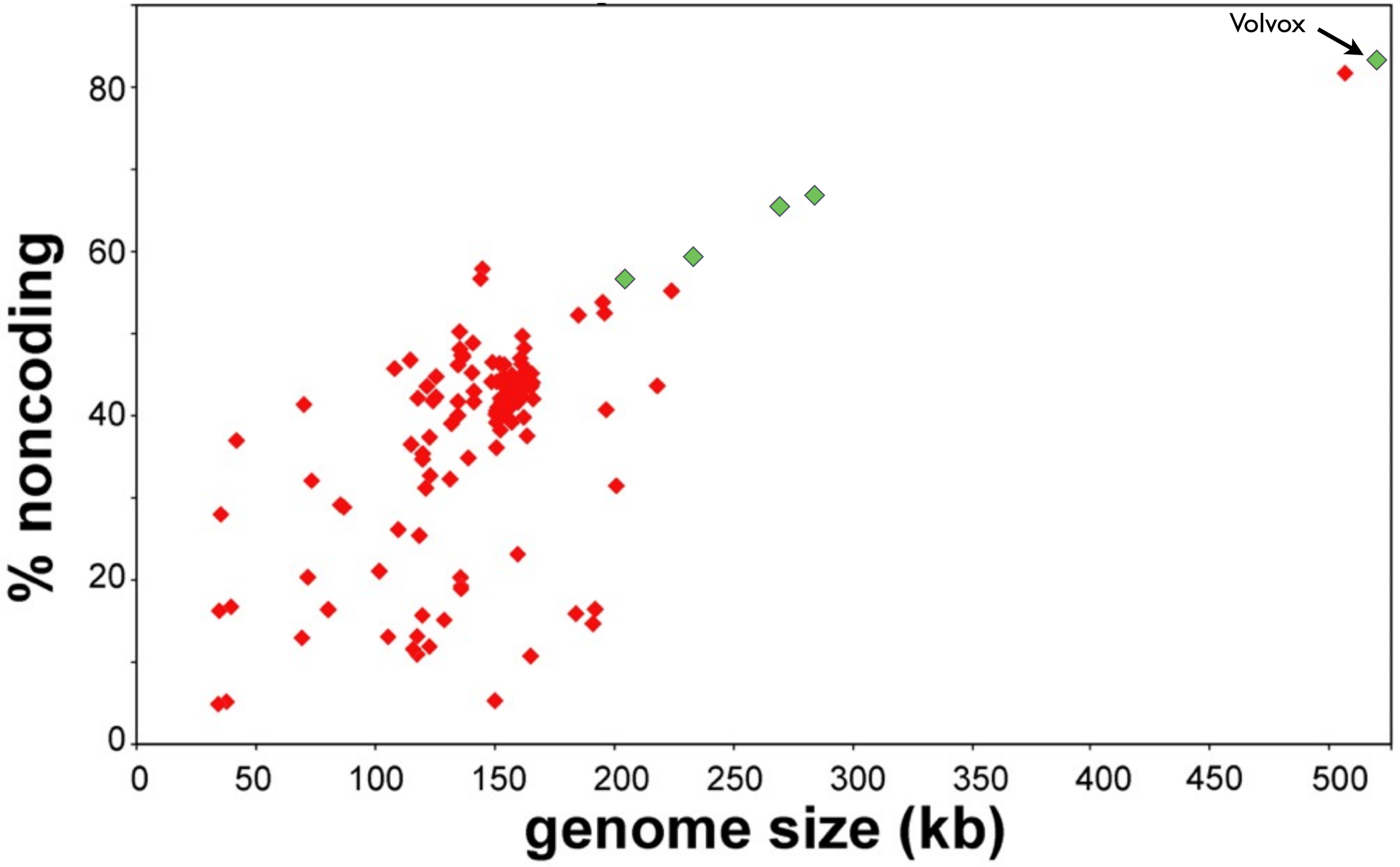

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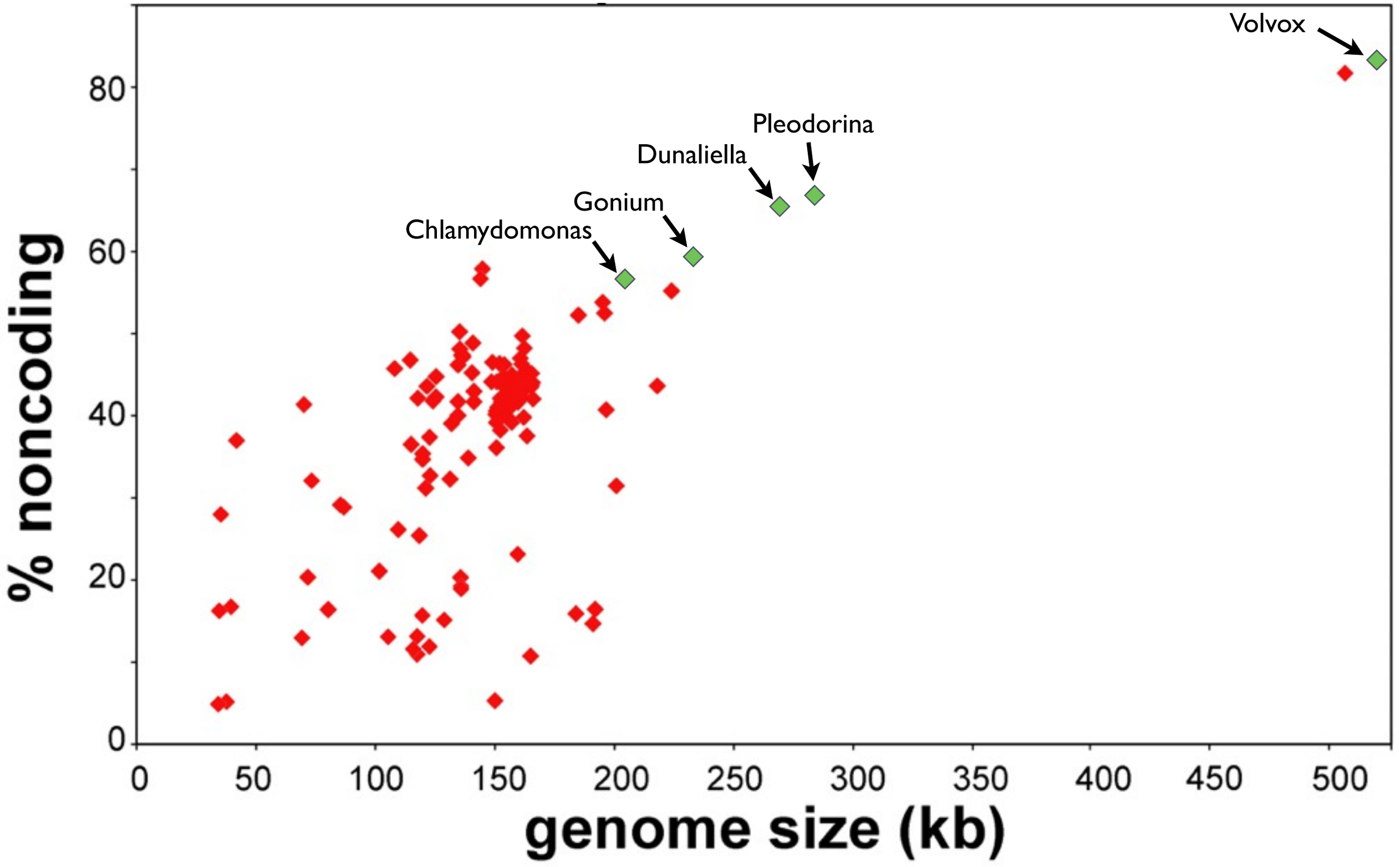

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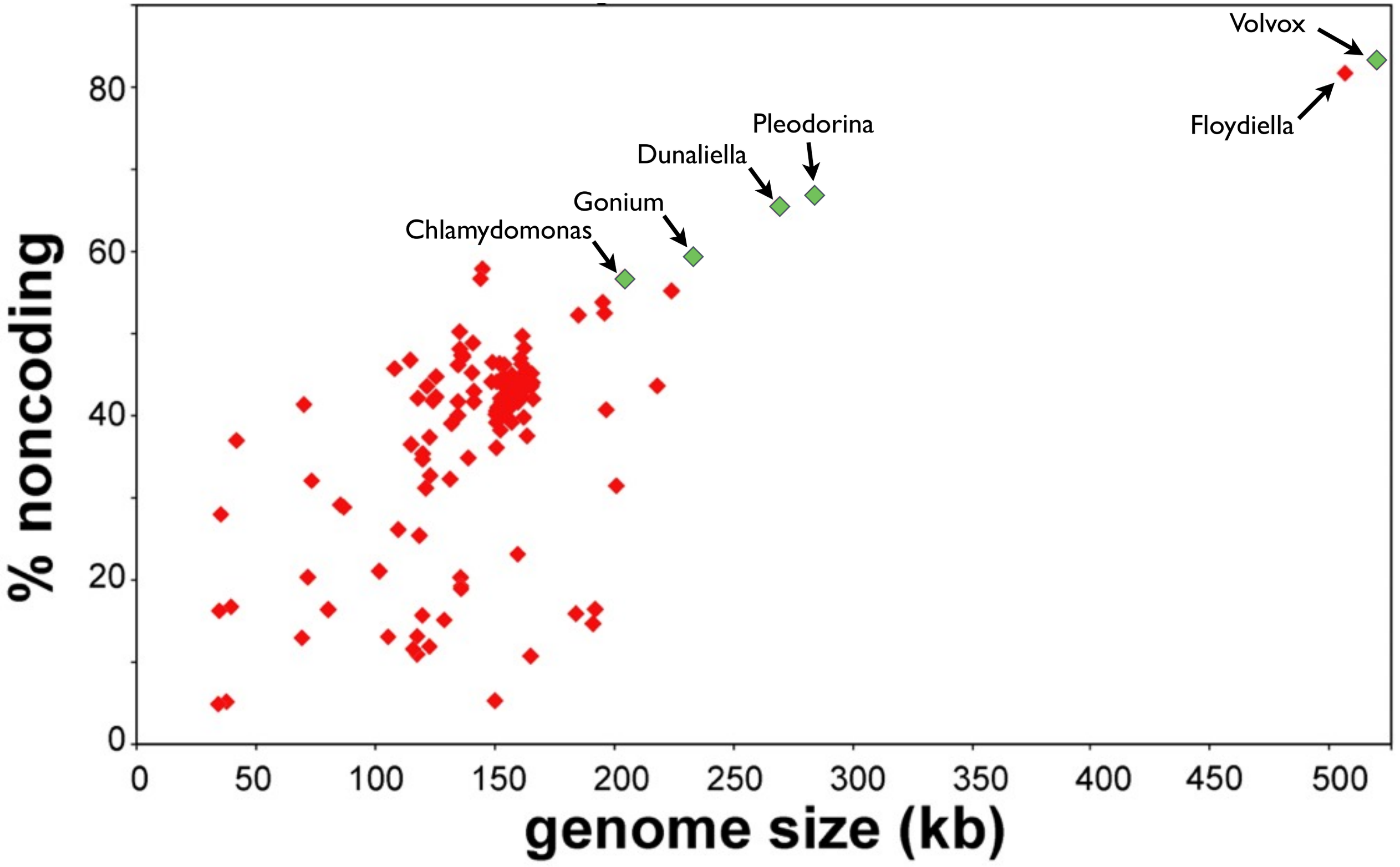

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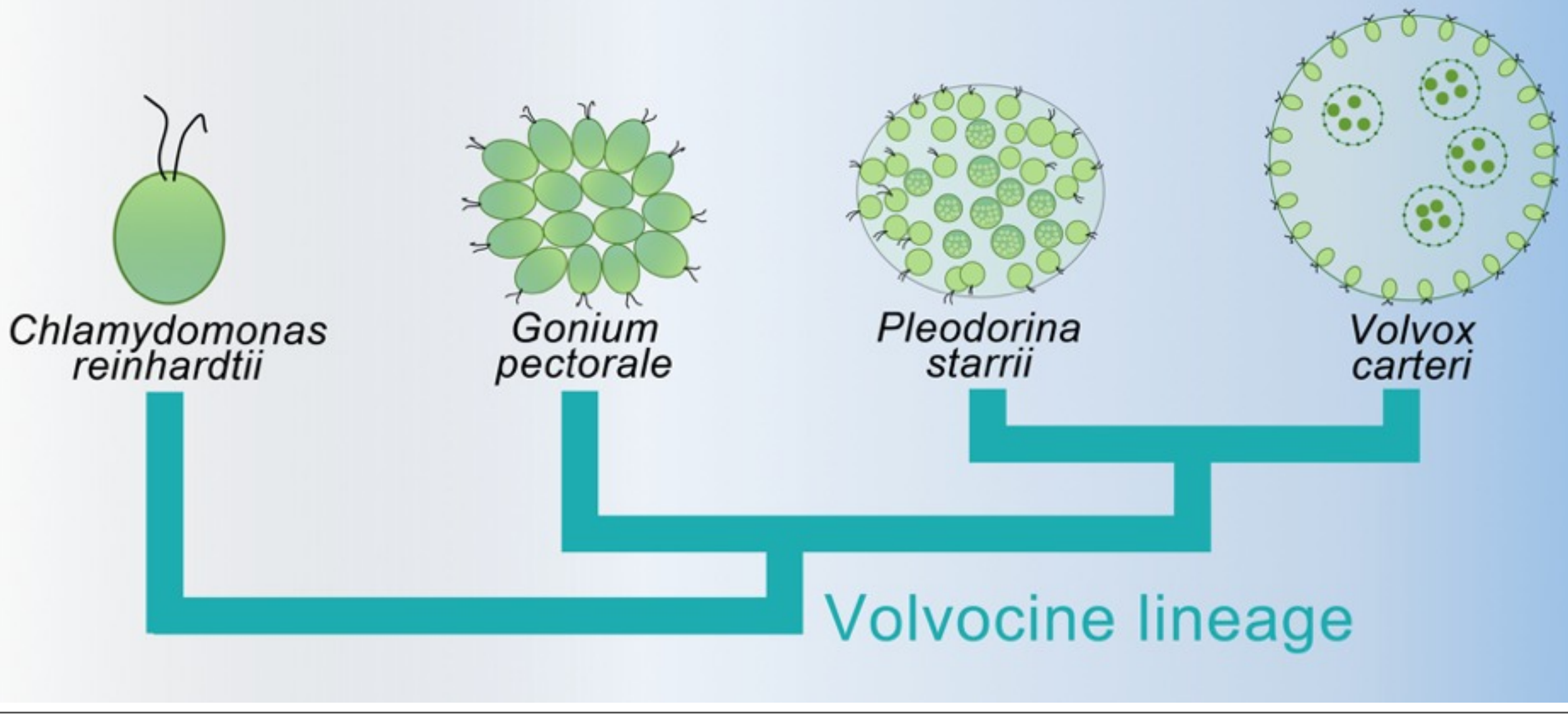

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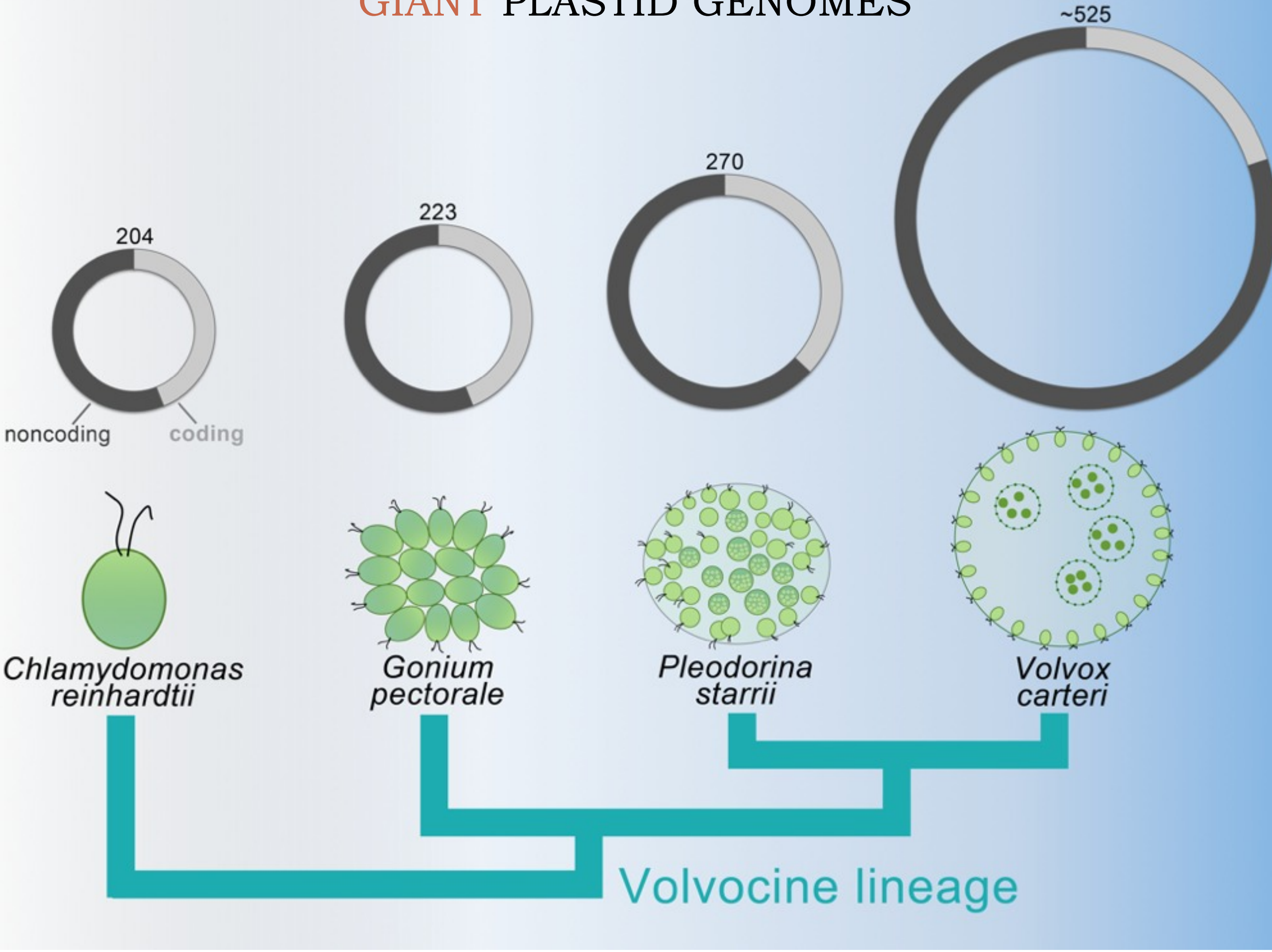
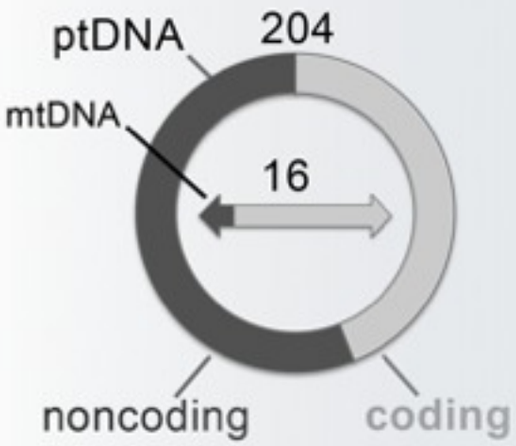
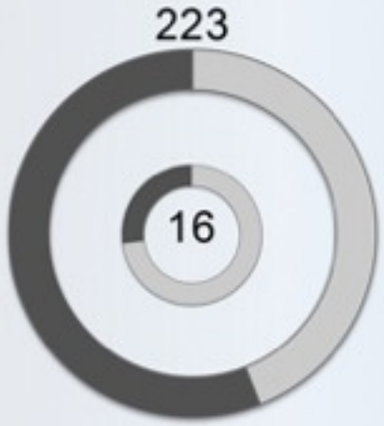
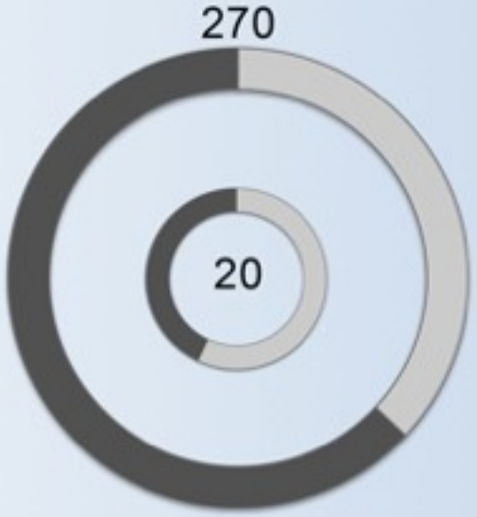
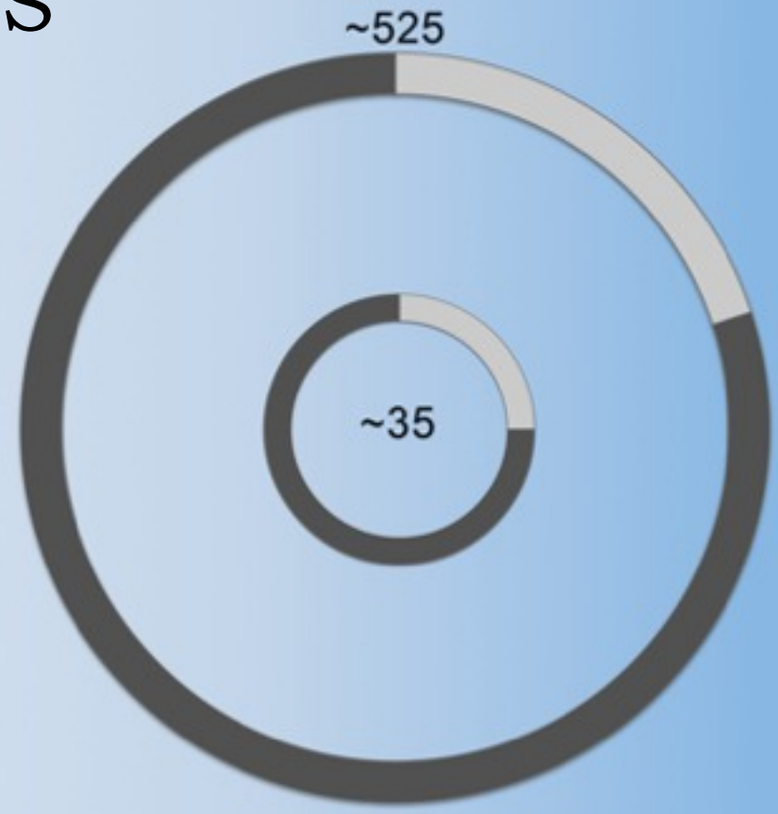


GIANT PLASTID GENOMES

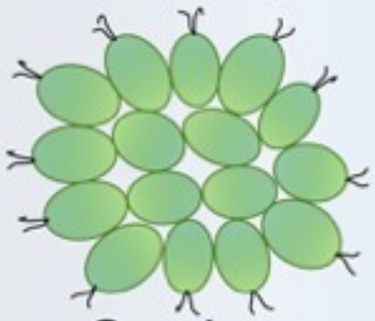




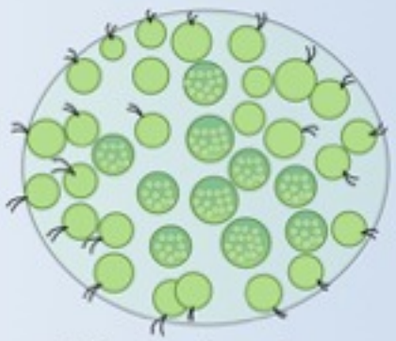




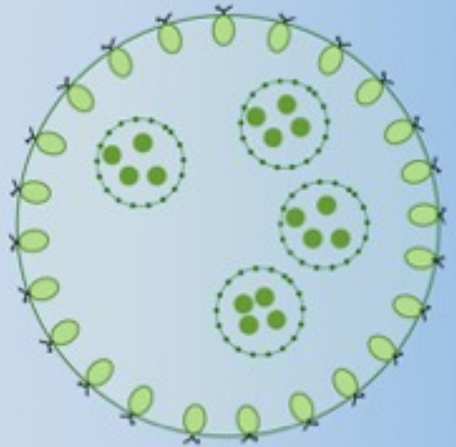
Chlamydomonas reinhardtii



Gonium pectorale



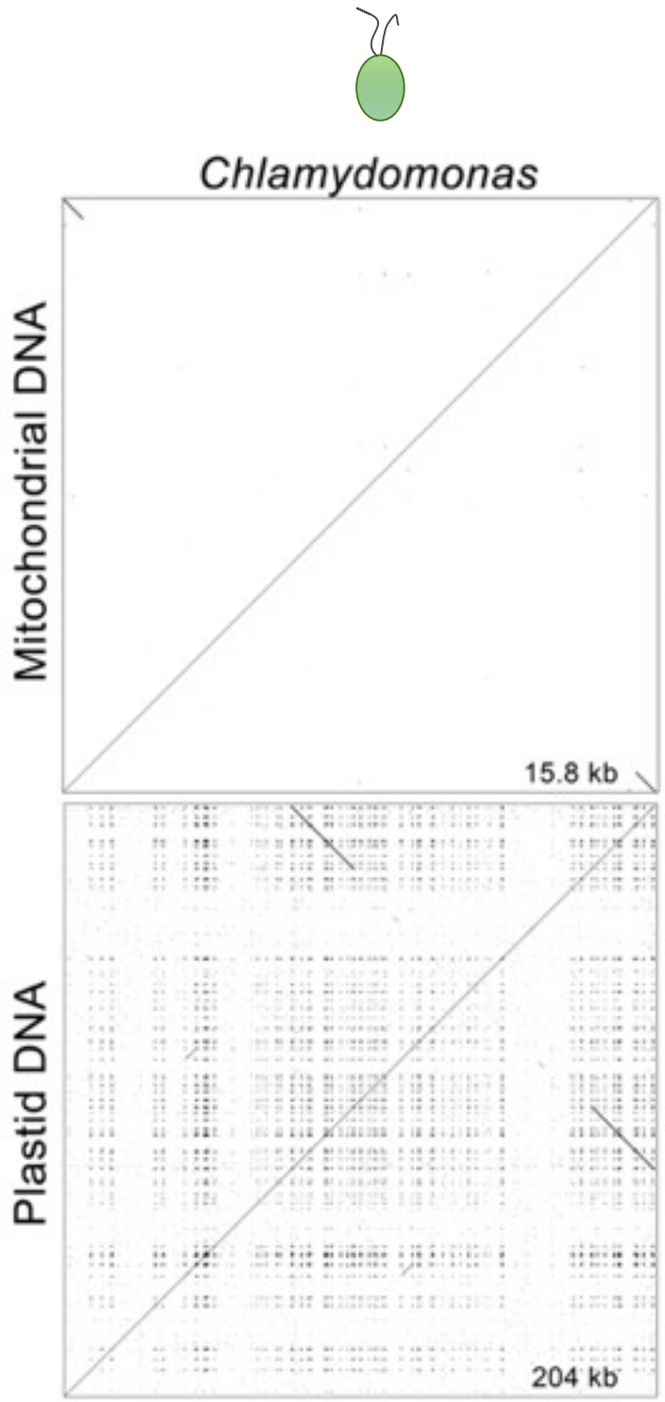
Pleodorina starrii



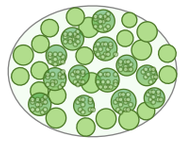
Volvox carteri

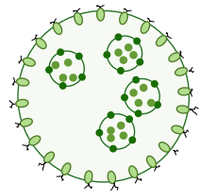
Volvocine lineage

ORGANELLE GENOME DOT PLOTS



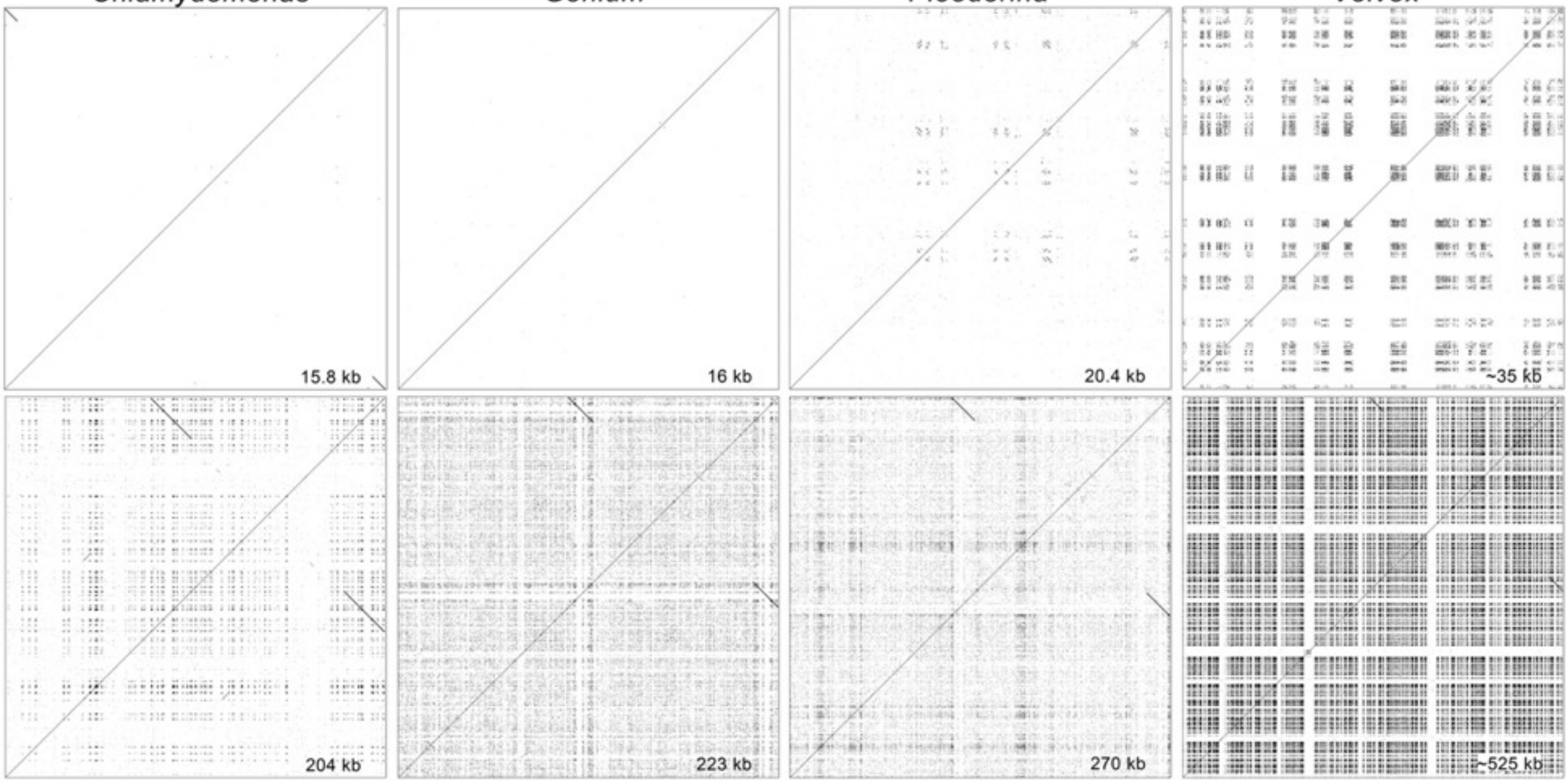
ORGANELLE GENOME DOT PLOTS





Chlamydomonas | *Gonium* | *Pleodorina* | *Volvox*

Mitochondrial DNA



Plastid DNA

ORGANELLE GENOME DOT PLOTS

Chlamydomonas

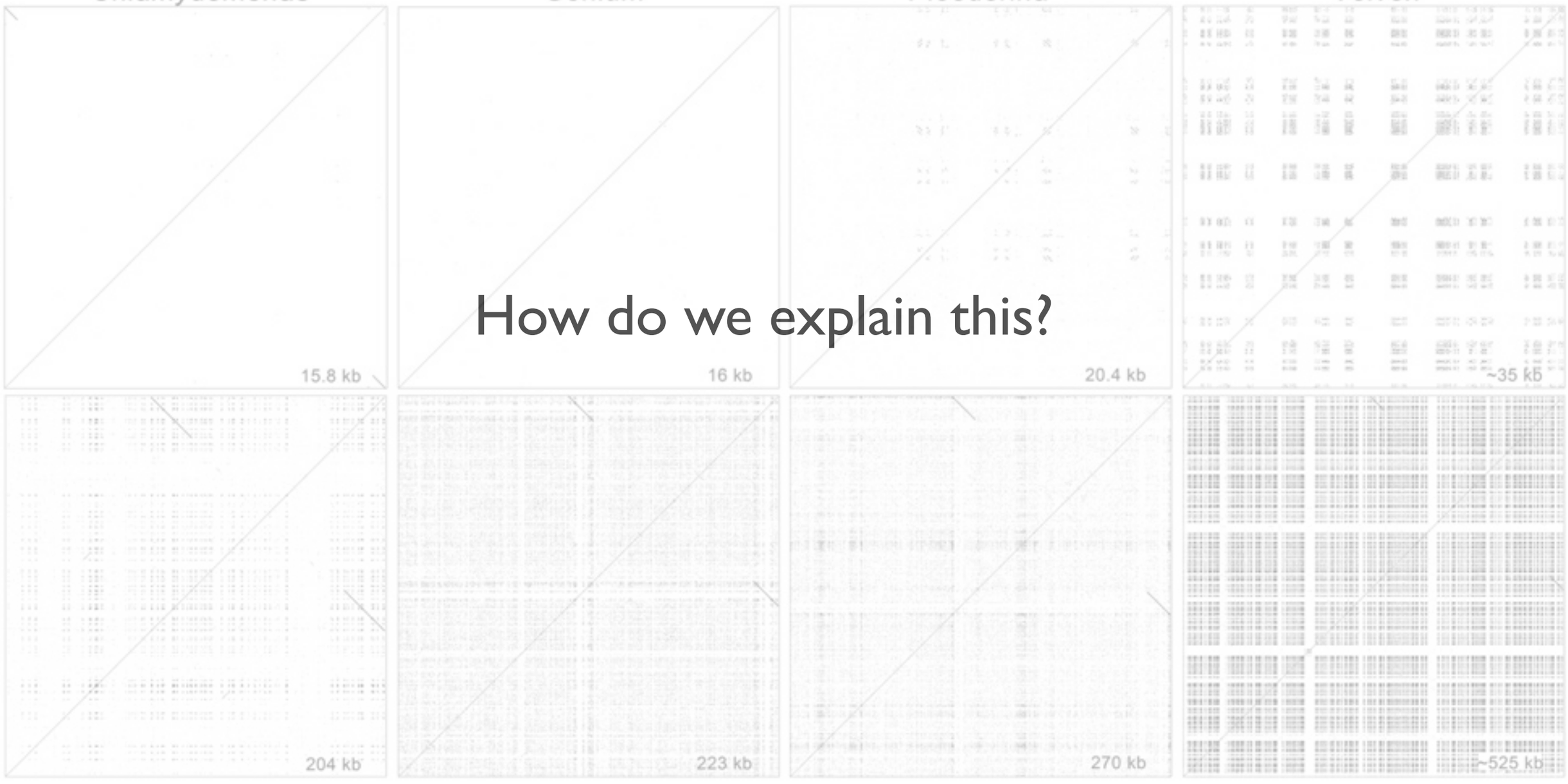
Gonium

Pleodorina

Volvox

Mitochondrial DNA

Plastid DNA



How do we explain this?

EVOLUTION OF GENOME SIZE

EVOLUTION OF GENOME SIZE

N_e μ

(effective population size) (mutation rate)

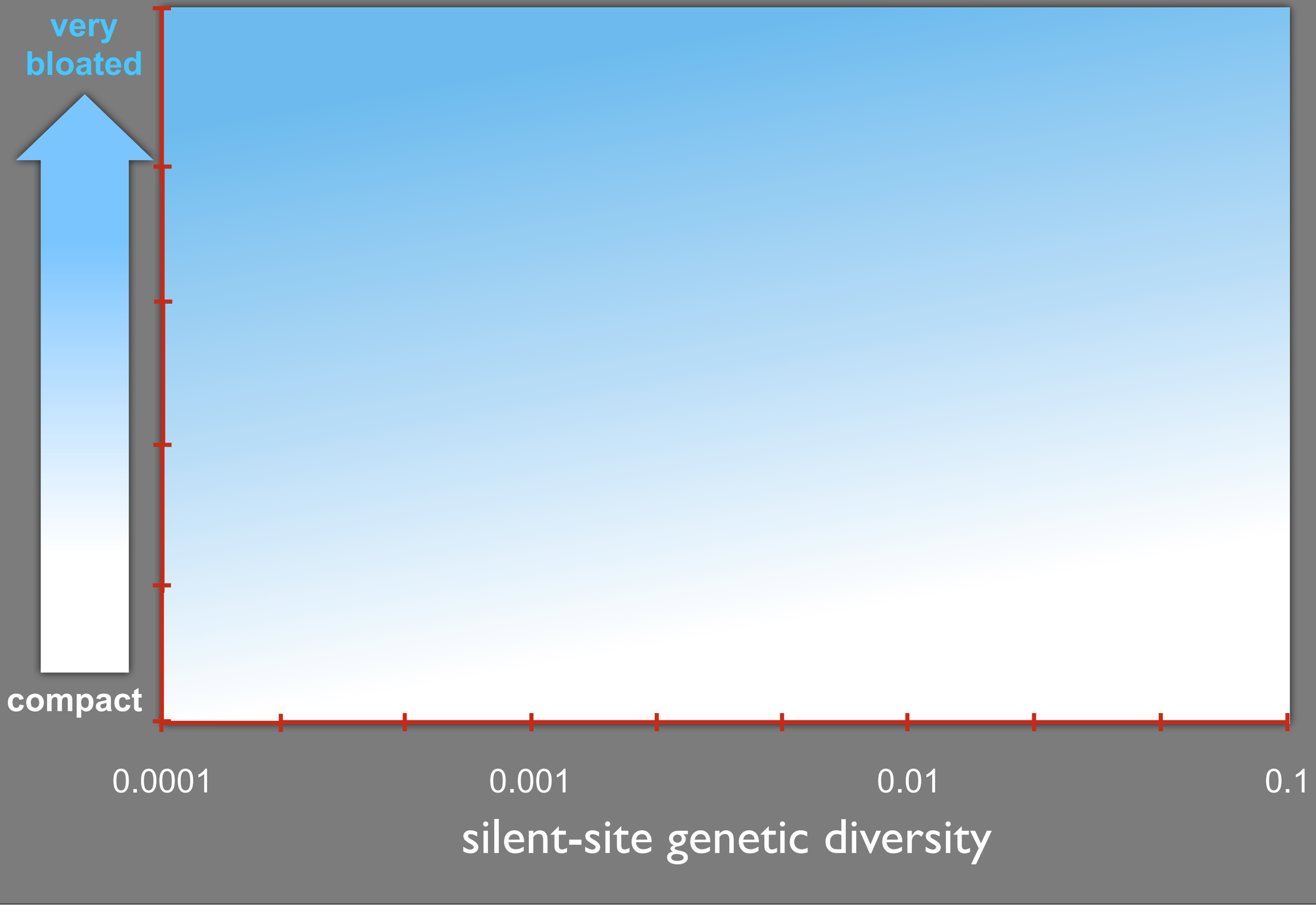
GENOME SIZE

nucleotide diversity
at silent sites

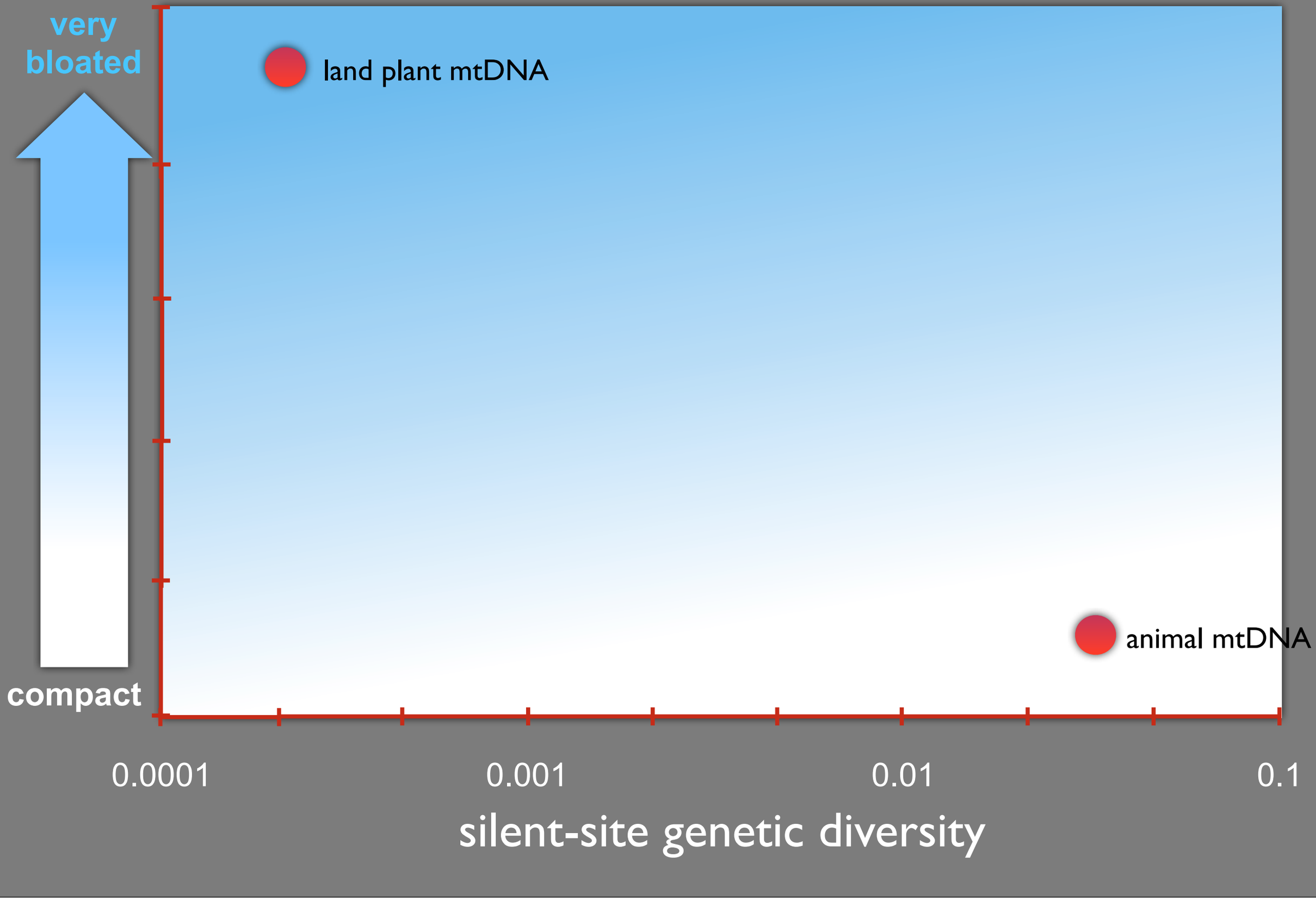
$$\pi_{silent} \approx N_e \mu$$

SILENT-SITE DIVERSITY & GENOME ARCHITECTURE

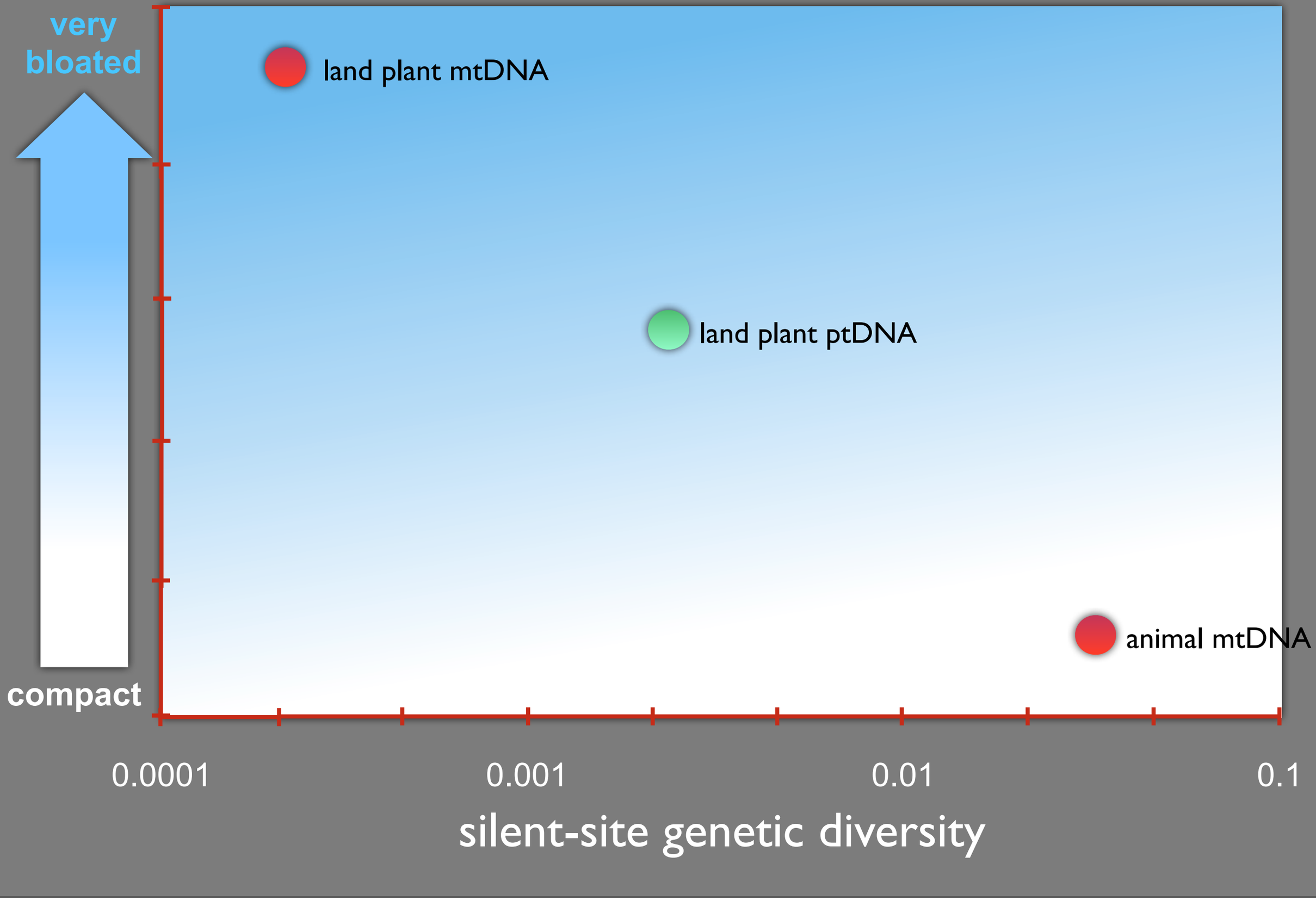
SILENT-SITE DIVERSITY & GENOME ARCHITECTURE



SILENT-SITE DIVERSITY & GENOME ARCHITECTURE



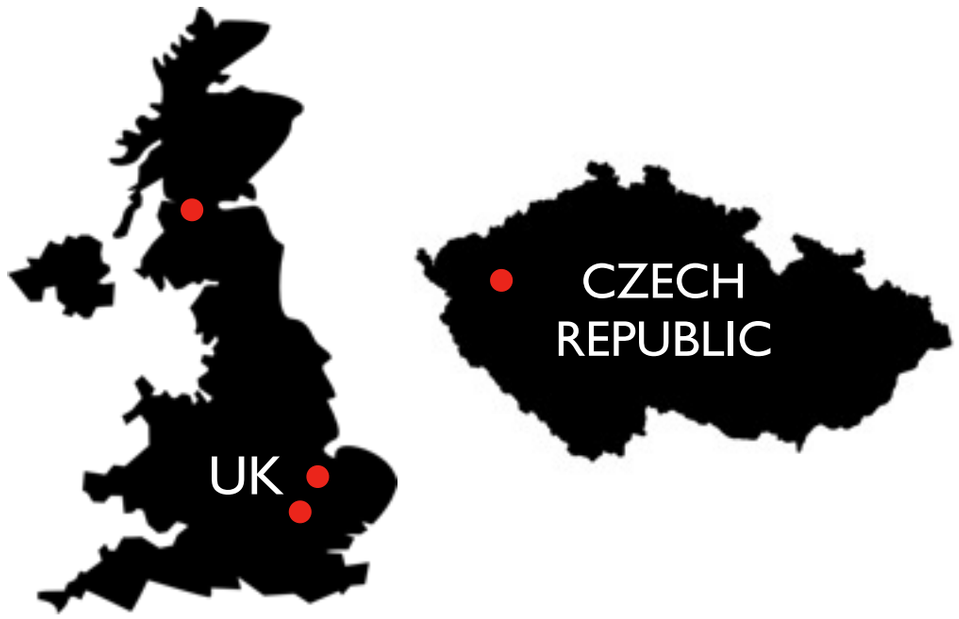
SILENT-SITE DIVERSITY & GENOME ARCHITECTURE



NUCLEOTIDE DIVERSITY

NUCLEOTIDE DIVERSITY

Polytomella



Volvox

Chlamydomonas

Dunaliella

NUCLEOTIDE DIVERSITY

LOW

Polytomella

UK

CZECH REPUBLIC

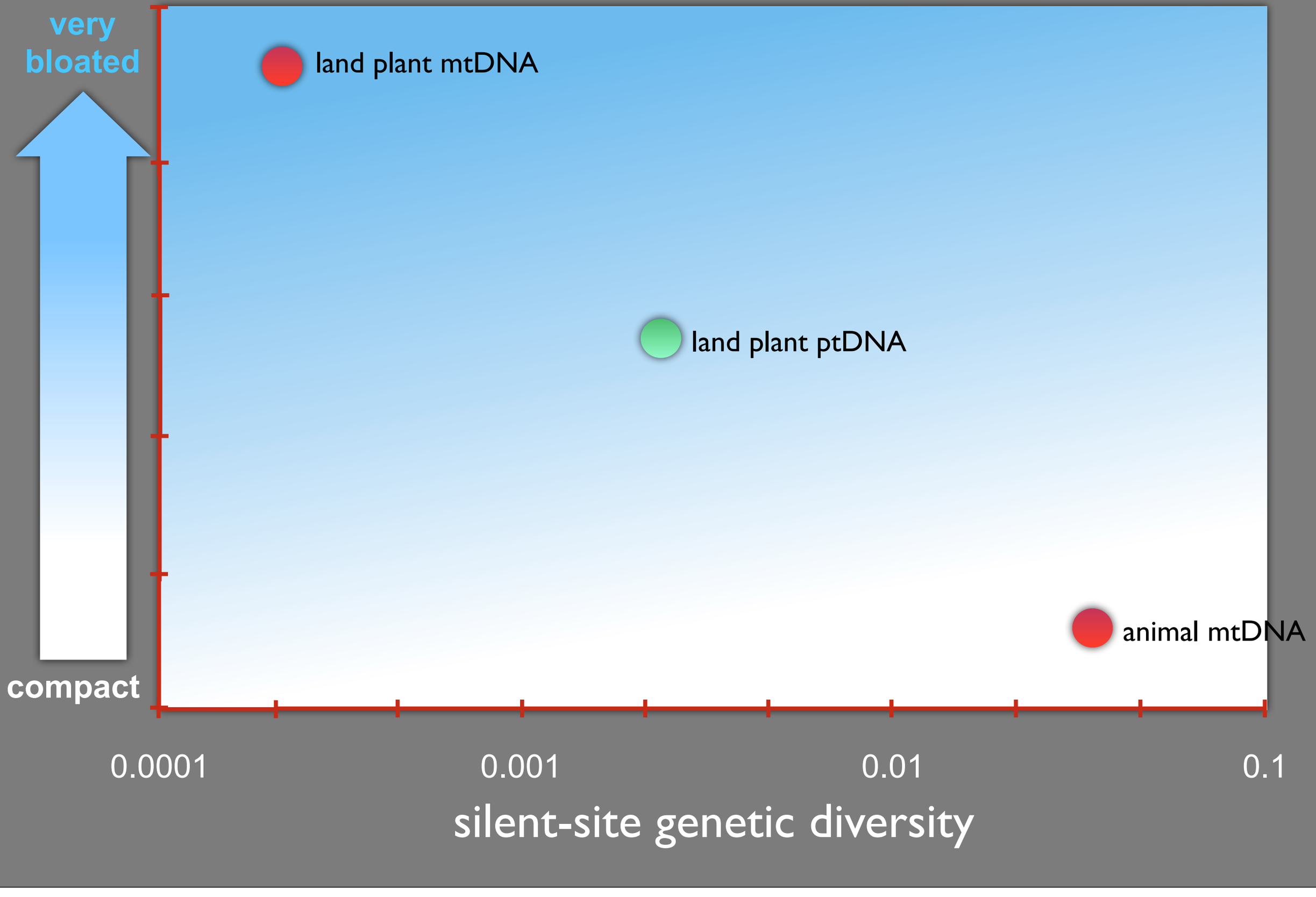
Volvox

Chlamydomonas

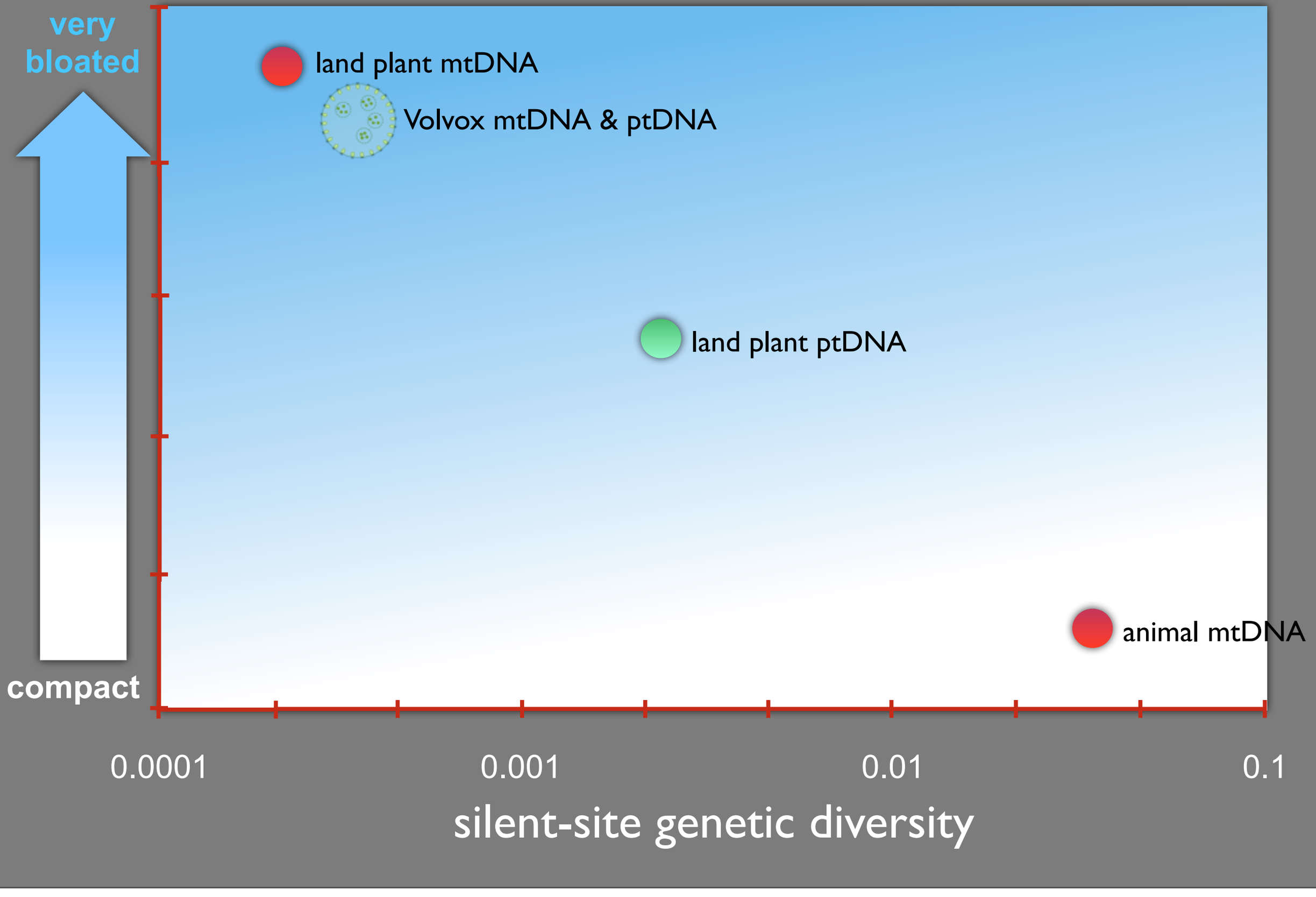
eastern USA

Dunaliella

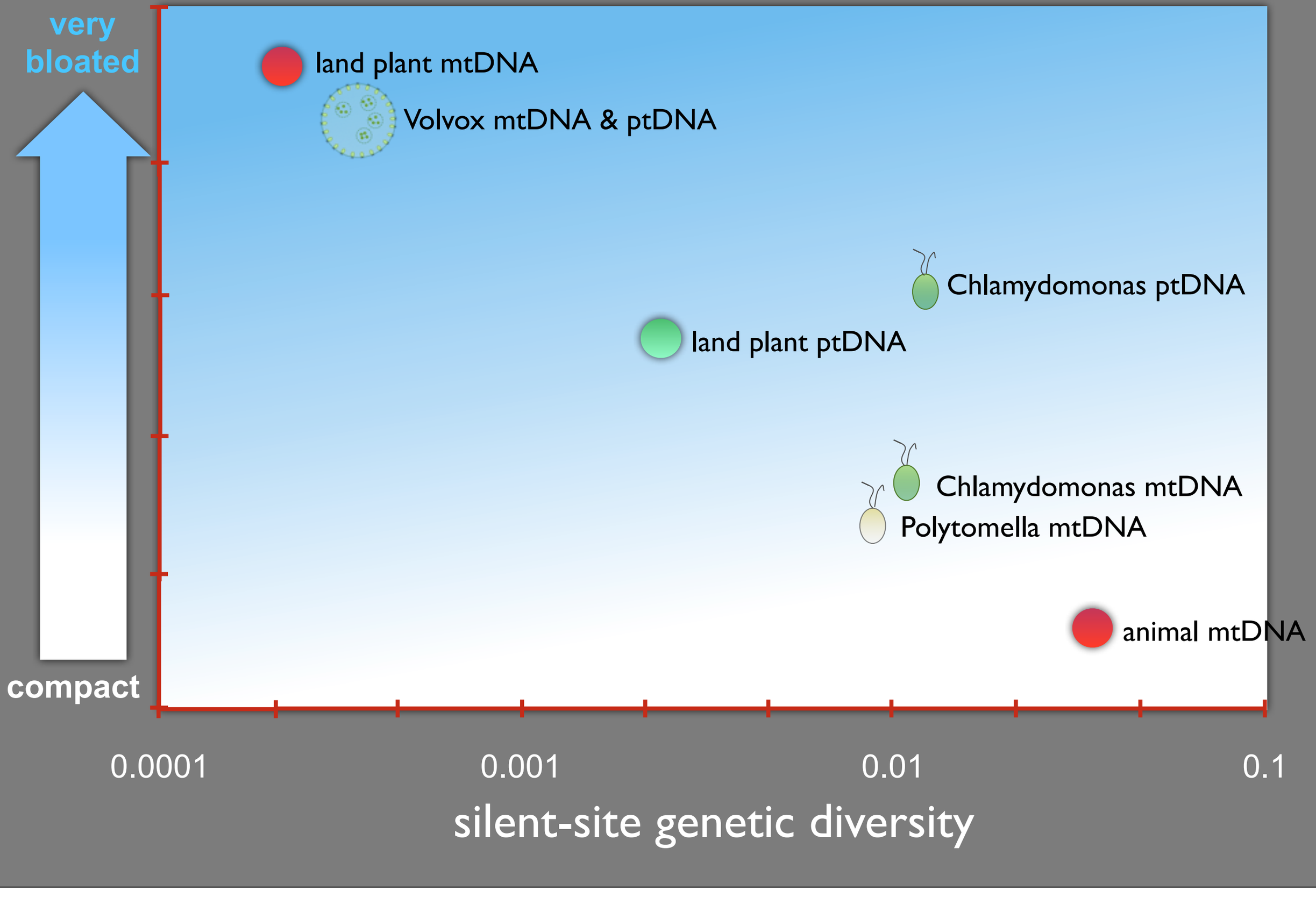
SILENT-SITE DIVERSITY & GENOME ARCHITECTURE



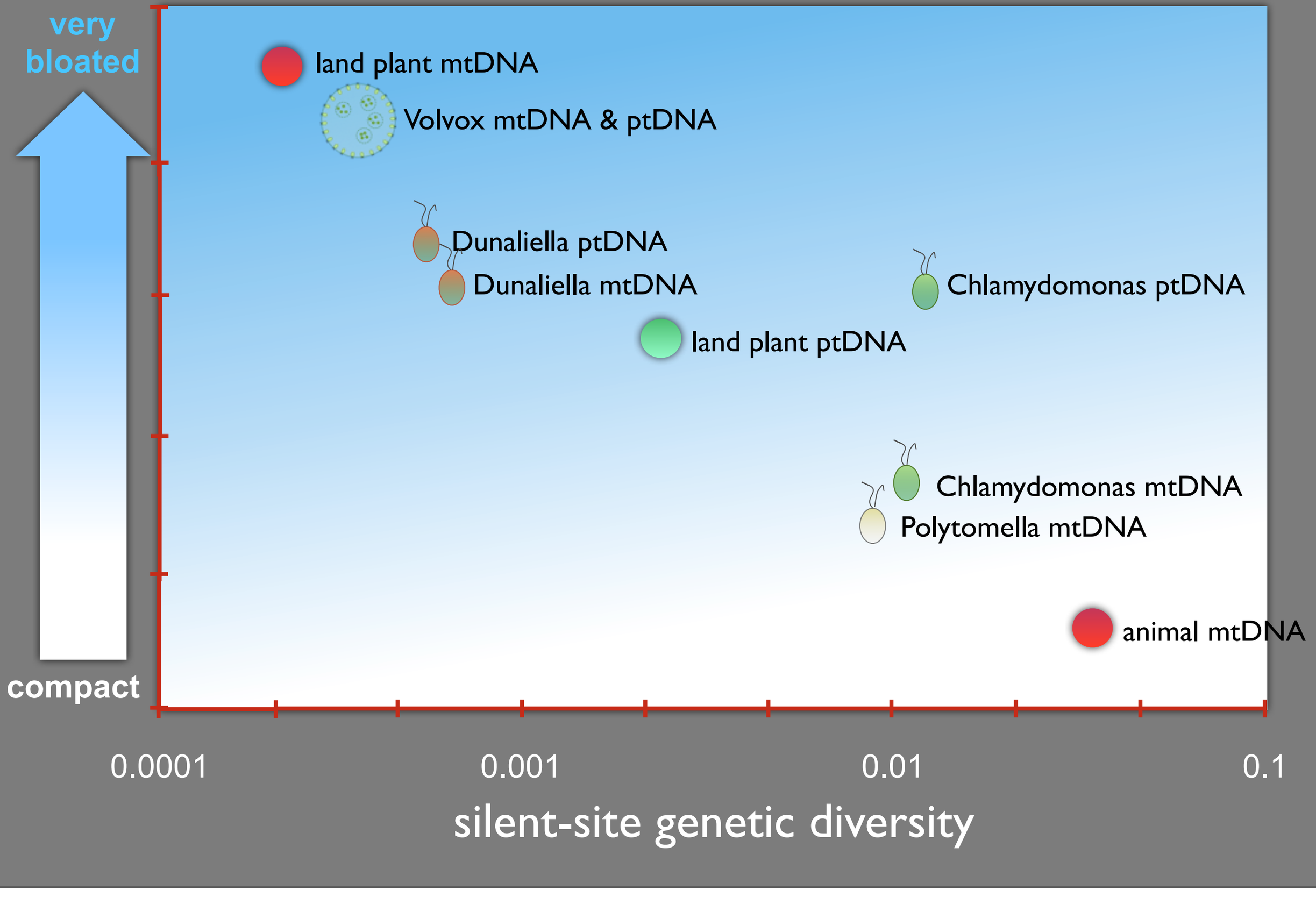
SILENT-SITE DIVERSITY & GENOME ARCHITECTURE



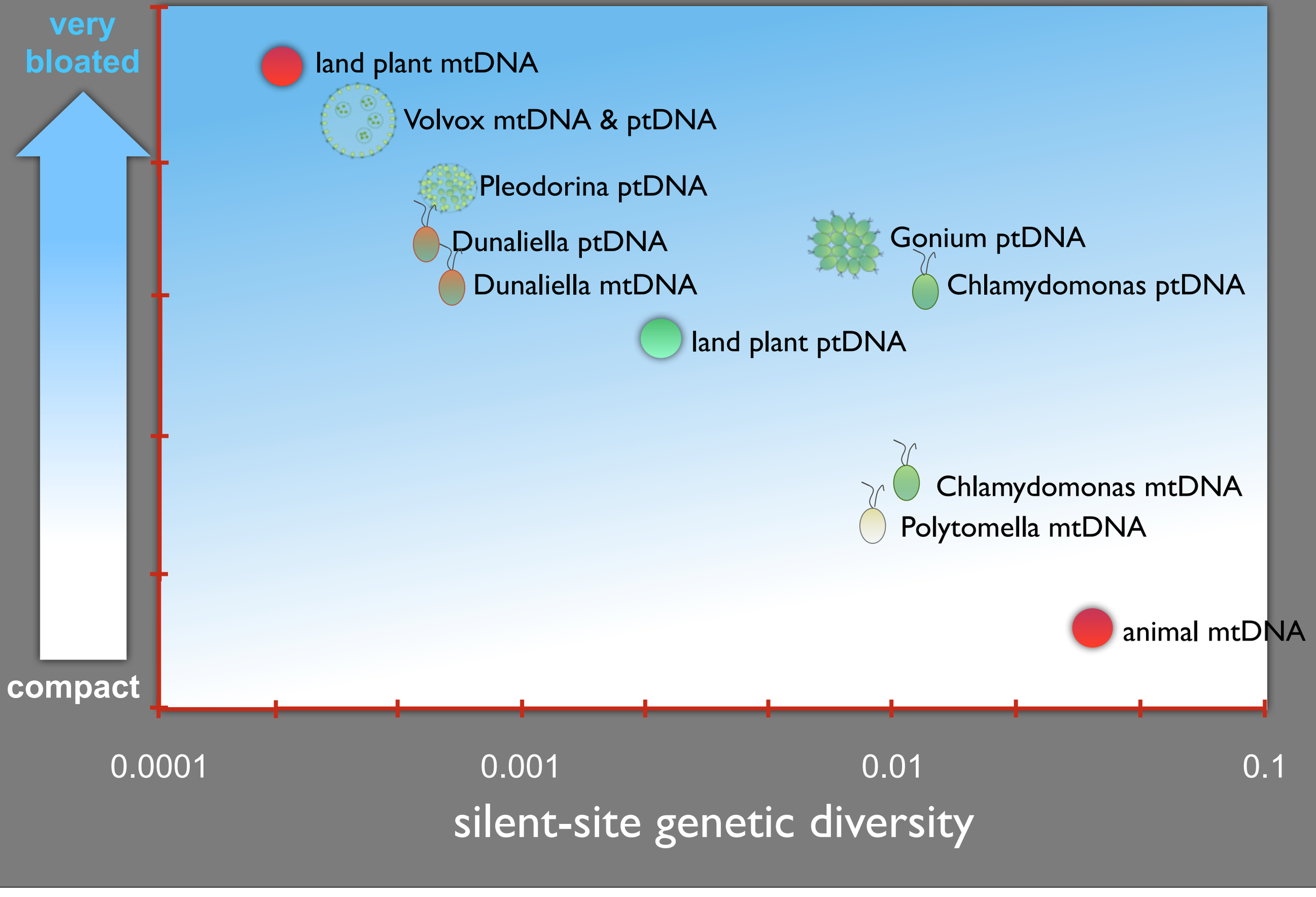
SILENT-SITE DIVERSITY & GENOME ARCHITECTURE



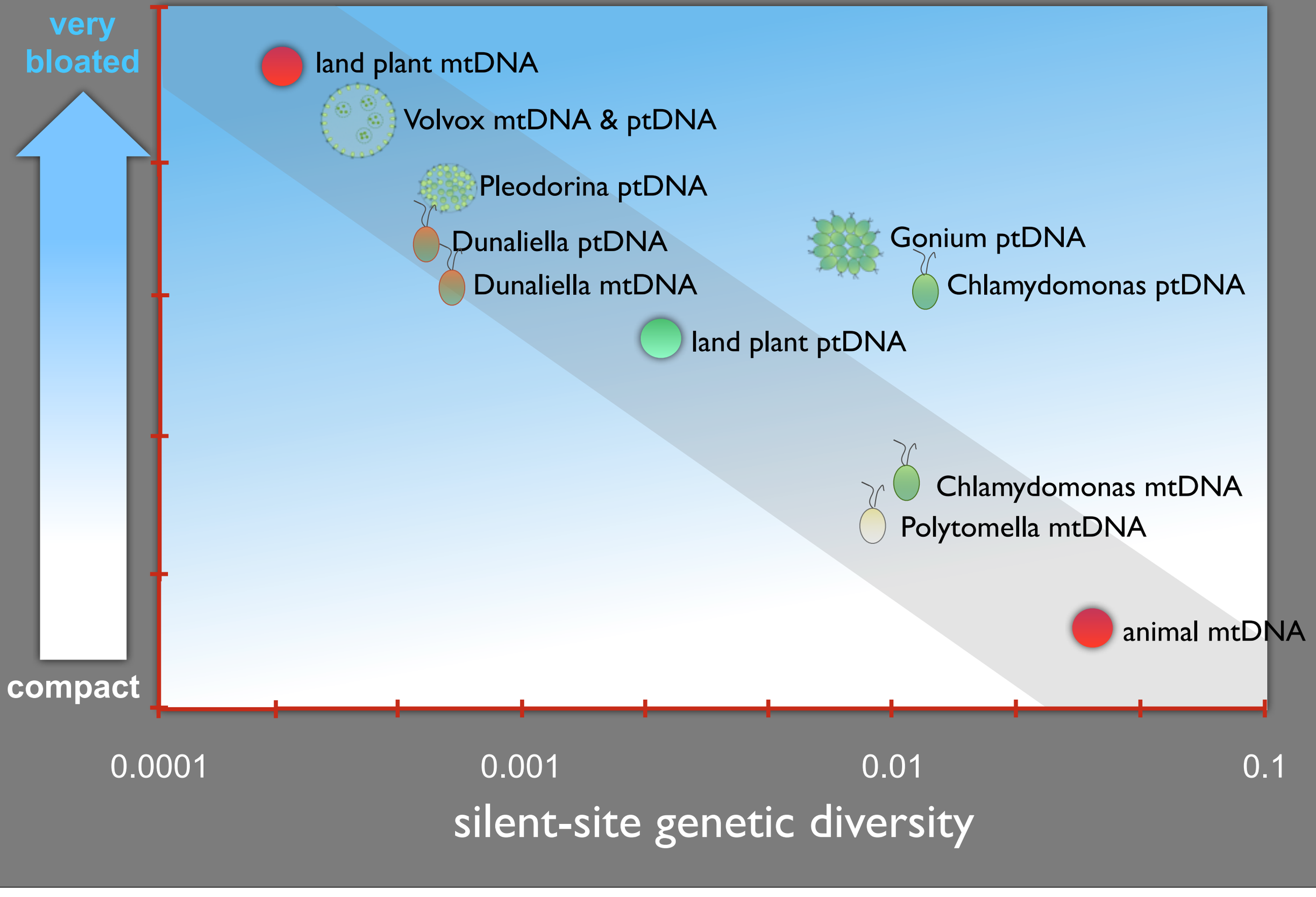
SILENT-SITE DIVERSITY & GENOME ARCHITECTURE

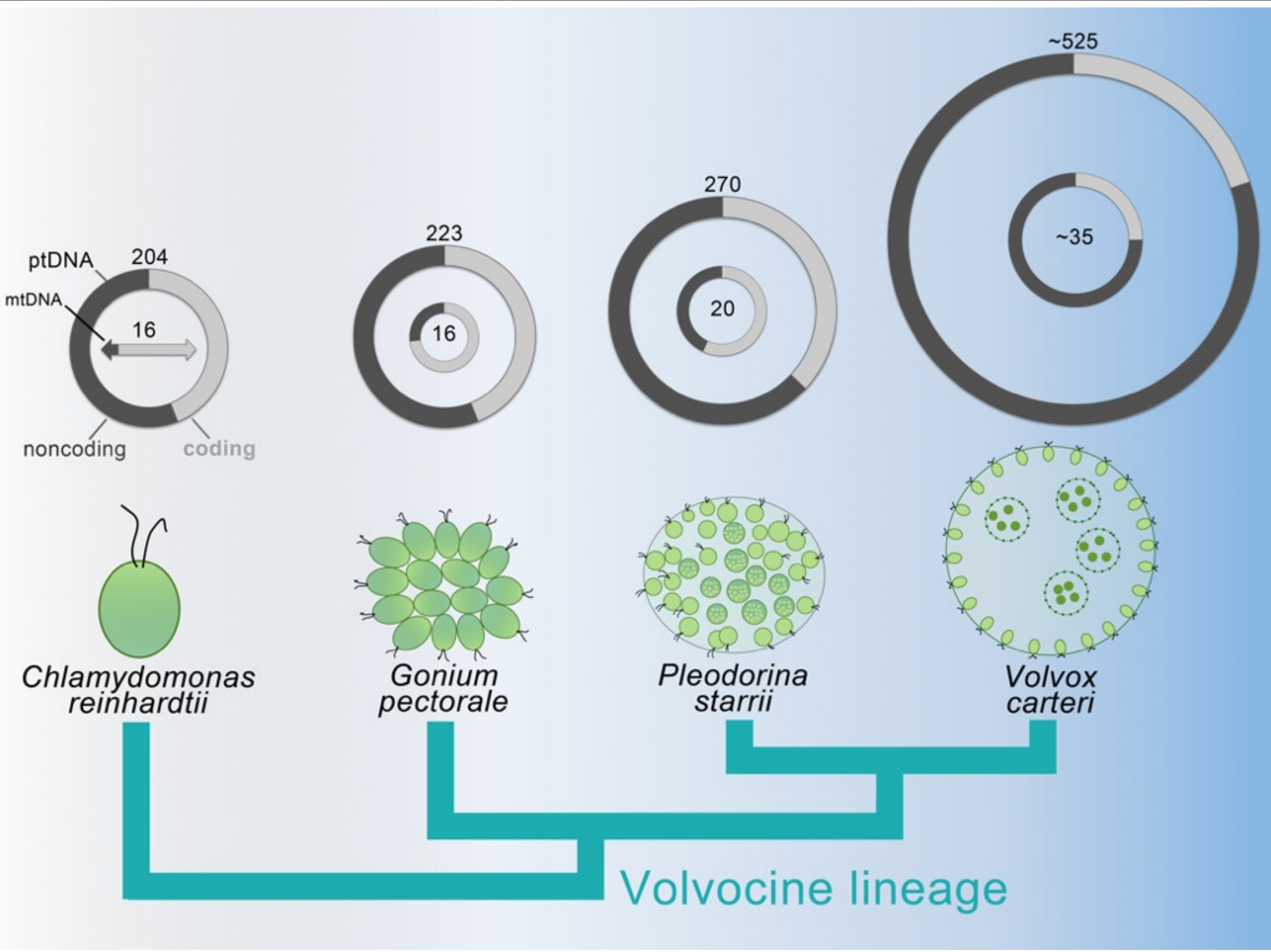


SILENT-SITE DIVERSITY & GENOME ARCHITECTURE

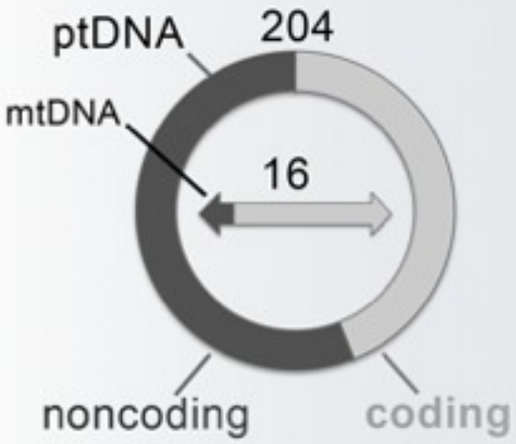


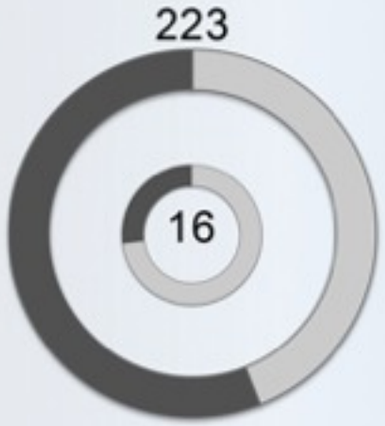
SILENT-SITE DIVERSITY & GENOME ARCHITECTURE

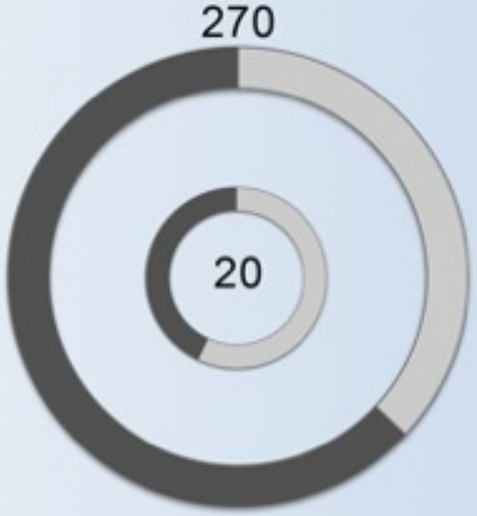


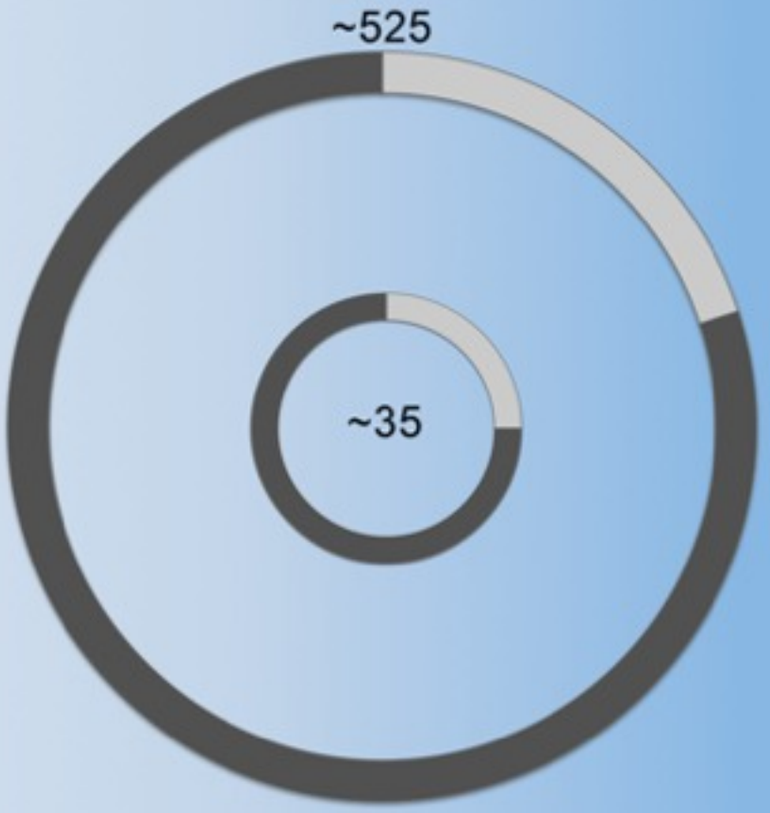

ptDNA
204
mtDNA
16
noncoding
coding
223
16
270
20
~525
~35
Chlamydomonas reinhardtii
Gonium pectorale
Pleodorina starrii
Volvox carteri
Volvocine lineage

increase in organelle silent-site diversity

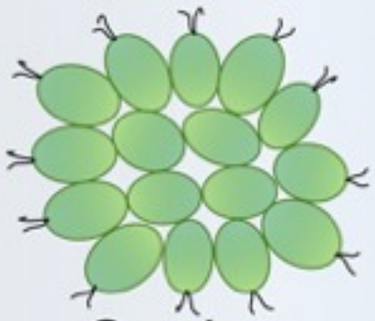




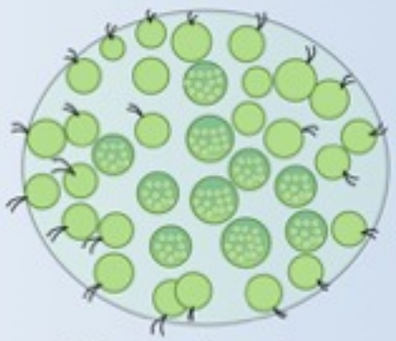




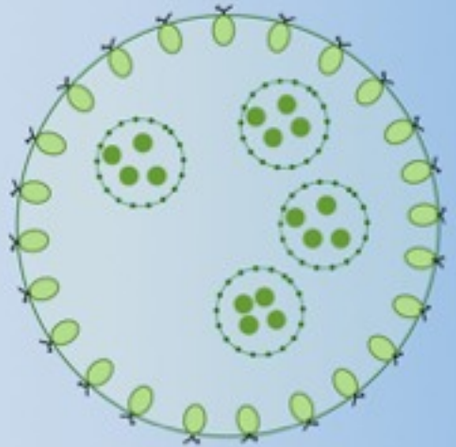
Chlamydomonas reinhardtii



Gonium pectorale



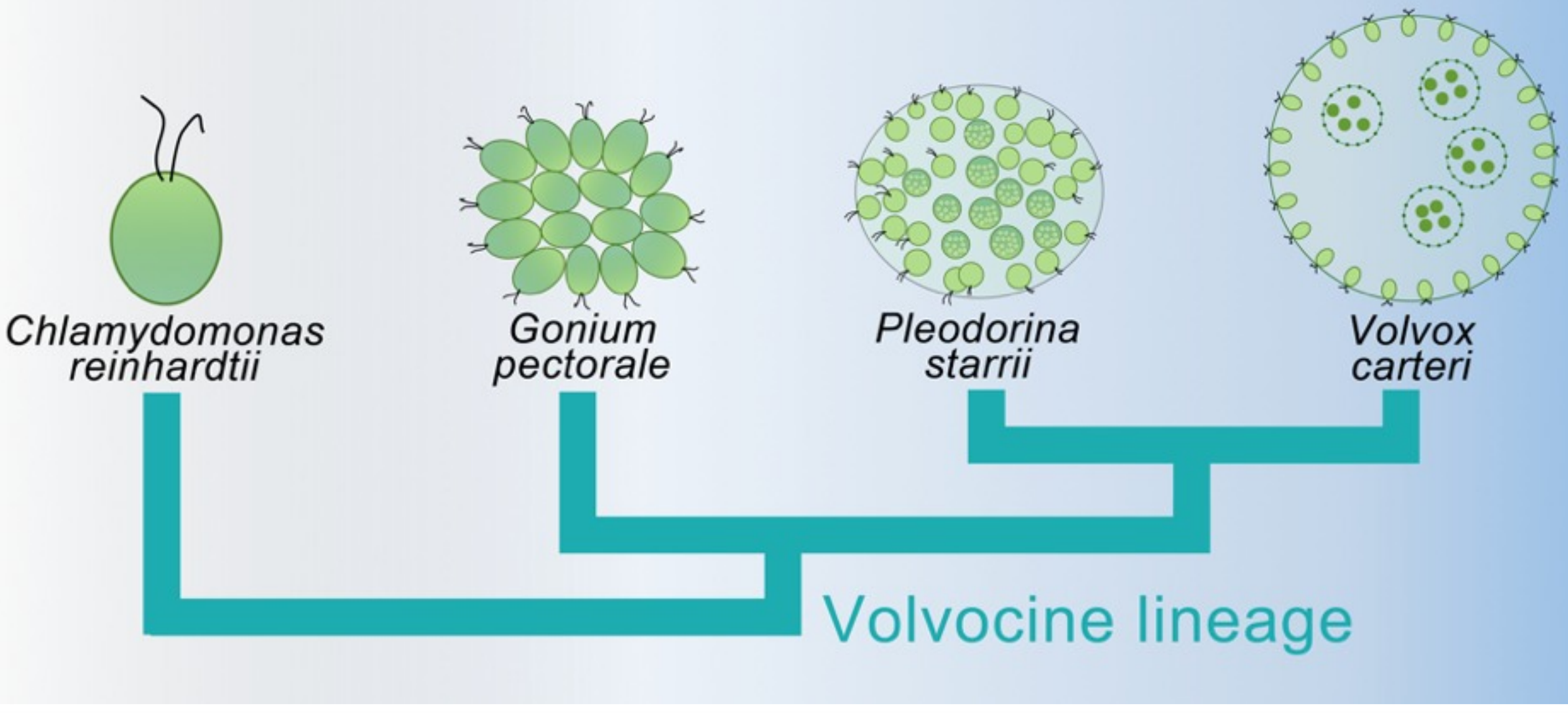
Pleodorina starrii



Volvox carteri

Volvocine lineage

MATING LOCUS EXPANSION



MATING LOCUS EXPANSION

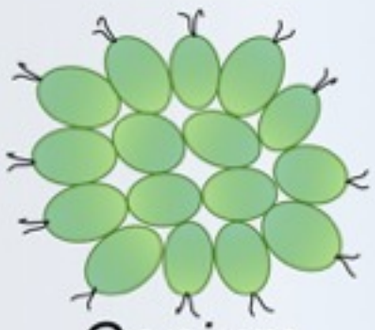
~250 kb

~450 kb

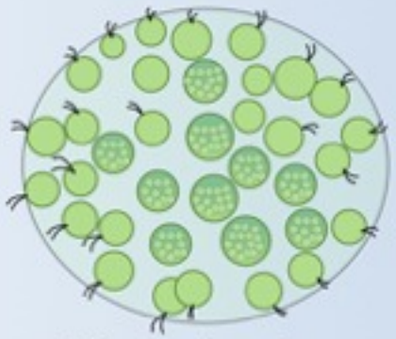
N/A

>1000 kb

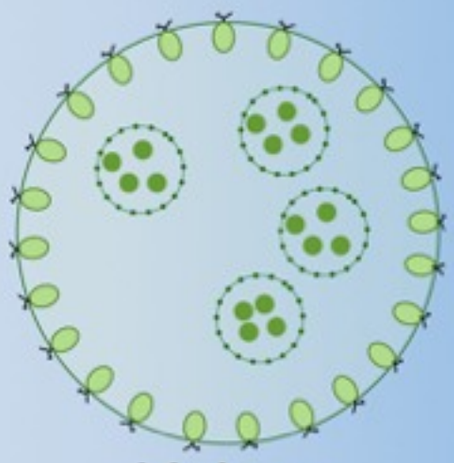
Chlamydomonas reinhardtii



Gonium pectorale



Pleodorina starrii



Volvox carteri

Volvocine lineage

MATING LOCUS EXPANSION

~250 kb

noncoding

Chlamydomonas reinhardtii

~450 kb

noncoding

Gonium pectorale

N/A

Pleodorina starrii

>1000 kb

noncoding

Volvox carteri

Volvocine lineage

MATING LOCUS EXPANSION

increase in mating locus silent-site diversity

~250 kb

noncoding

~450 kb

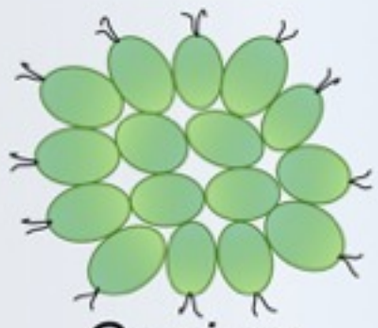
noncoding

N/A

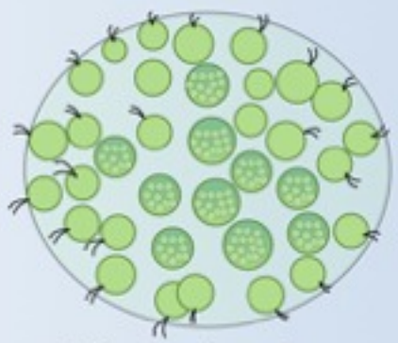
>1000 kb

noncoding

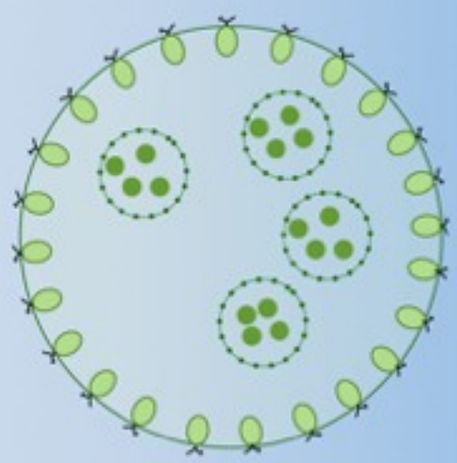
Chlamydomonas reinhardtii



Gonium pectorale



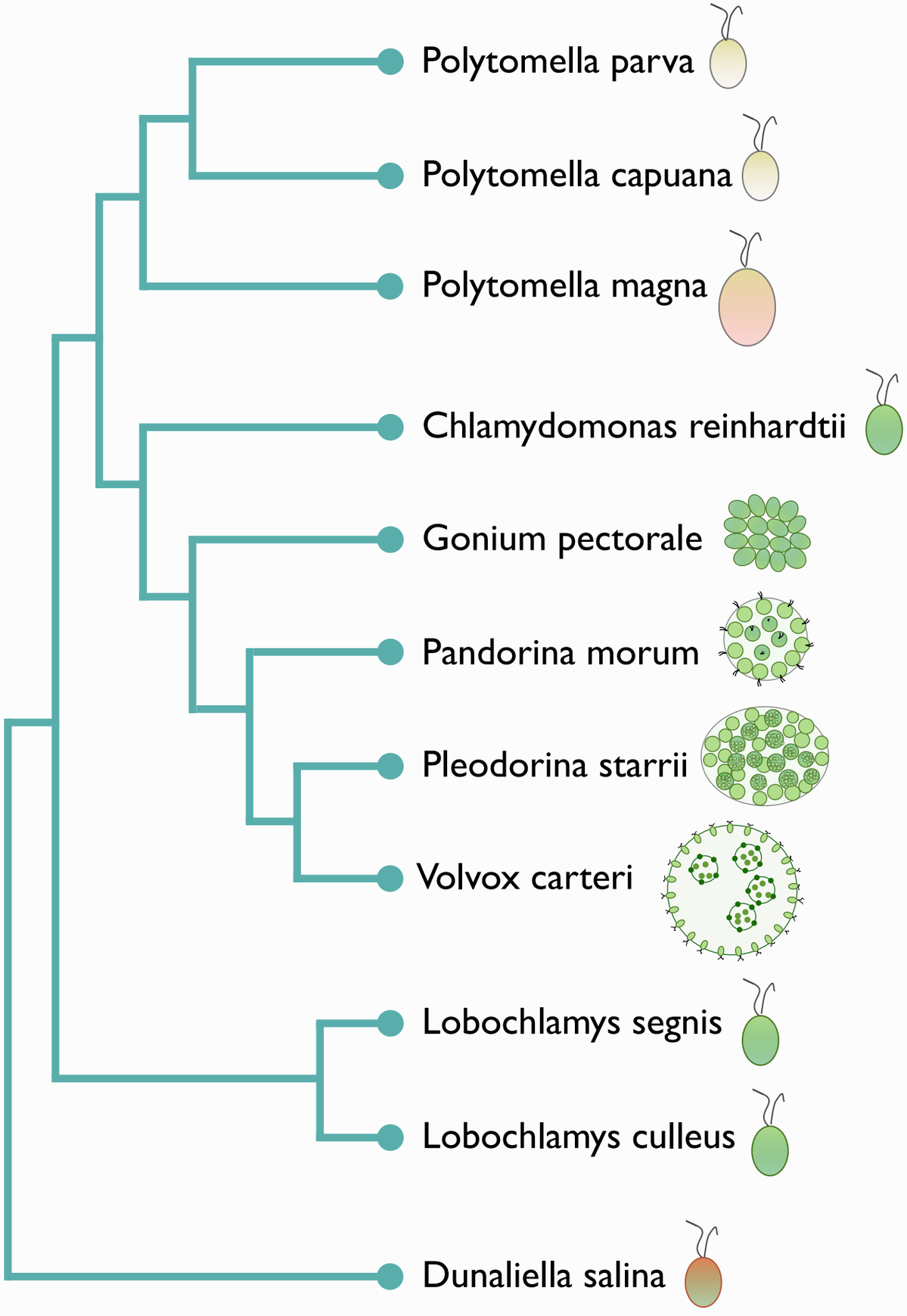
Pleodorina starrii



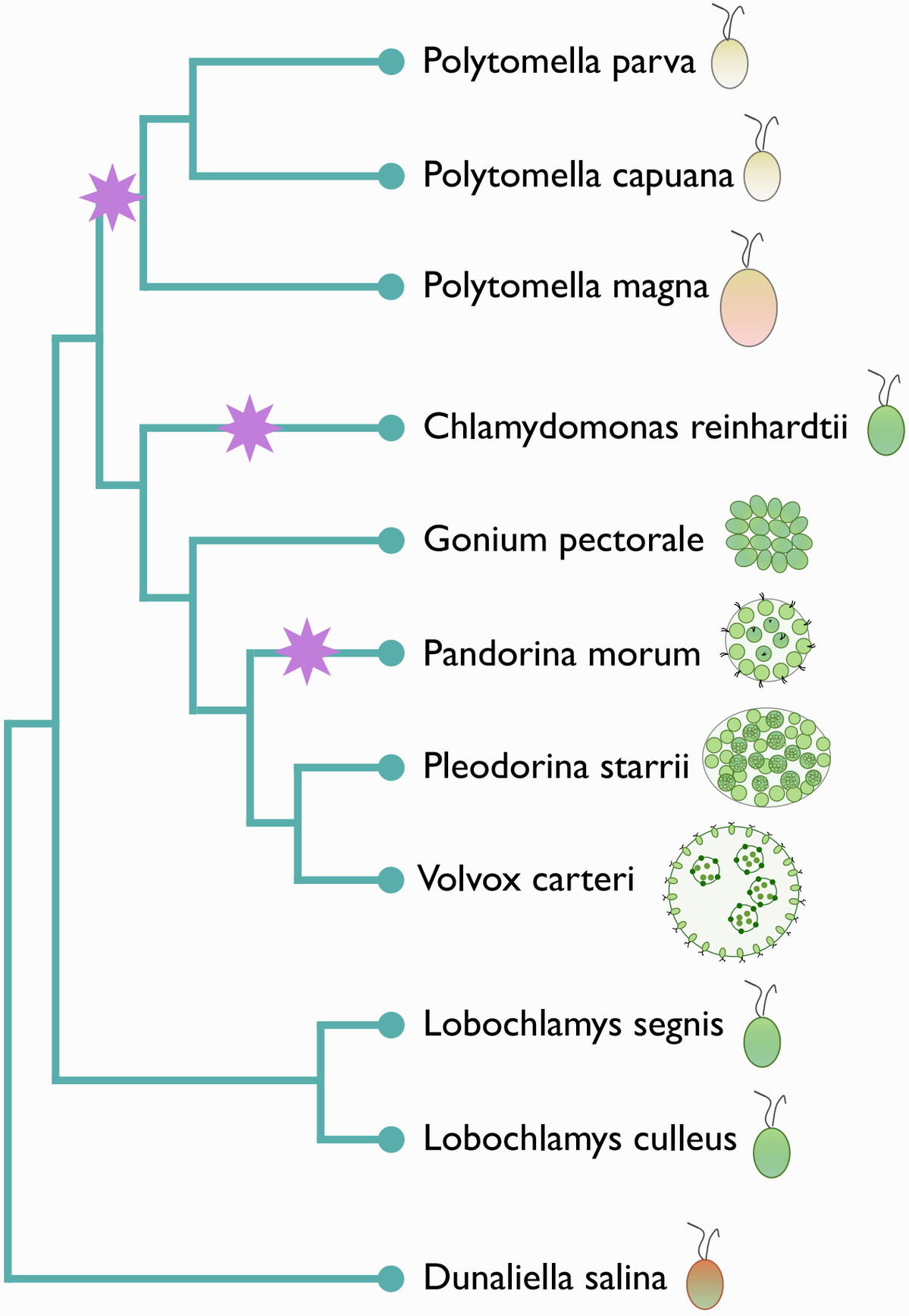
Volvox carteri

Volvocine lineage

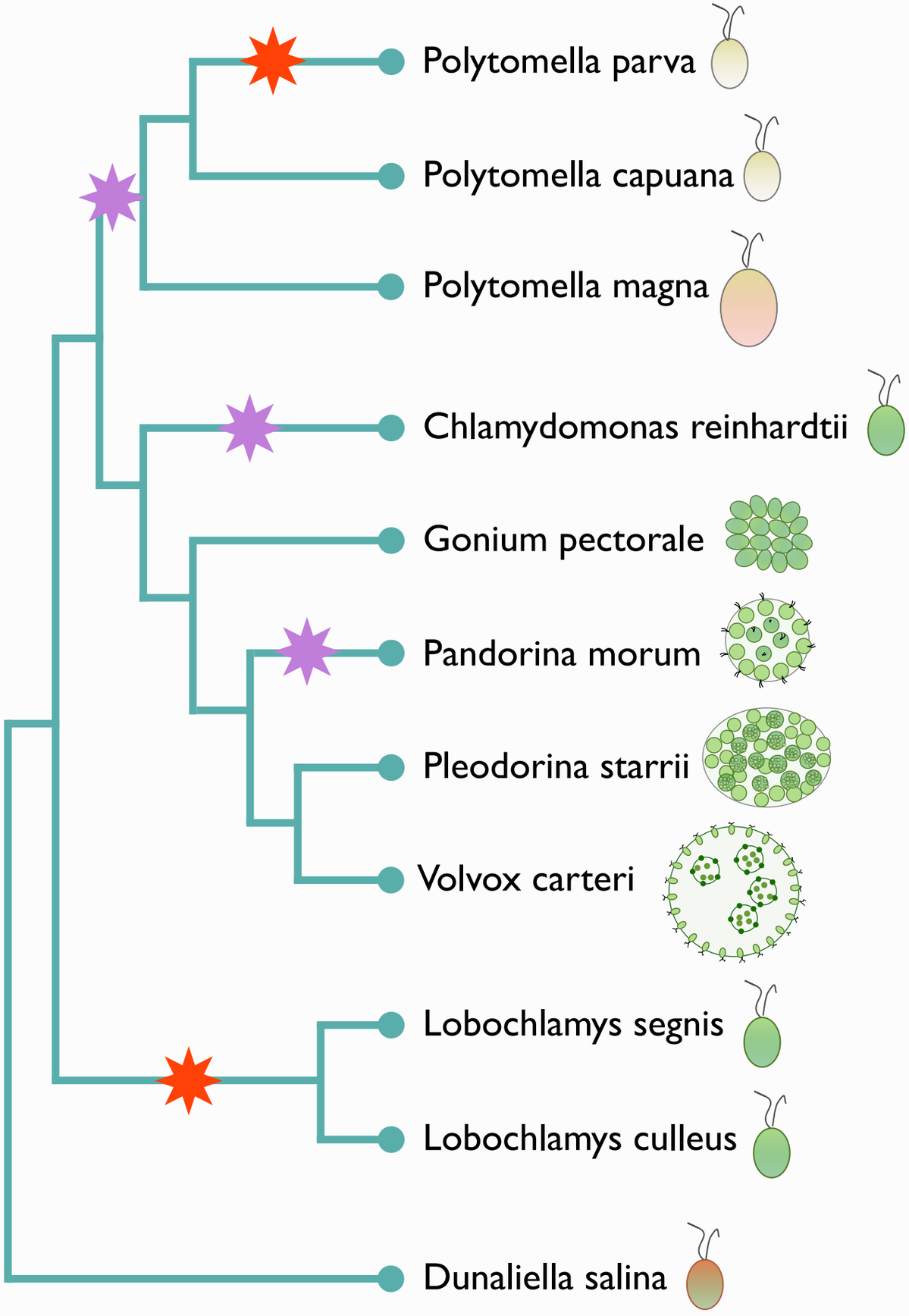
THE VOLVOCALES



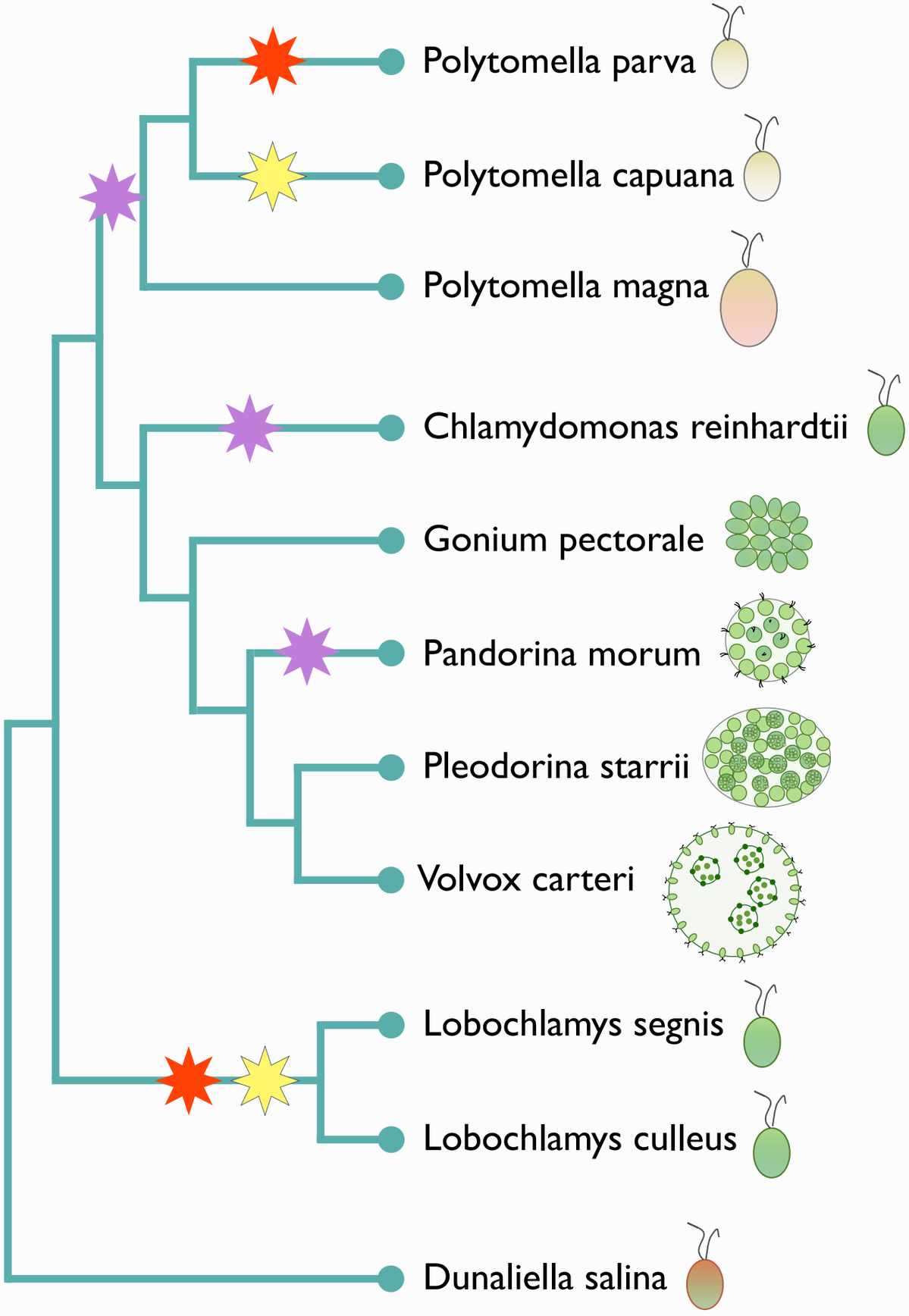
THE VOLVOCALES



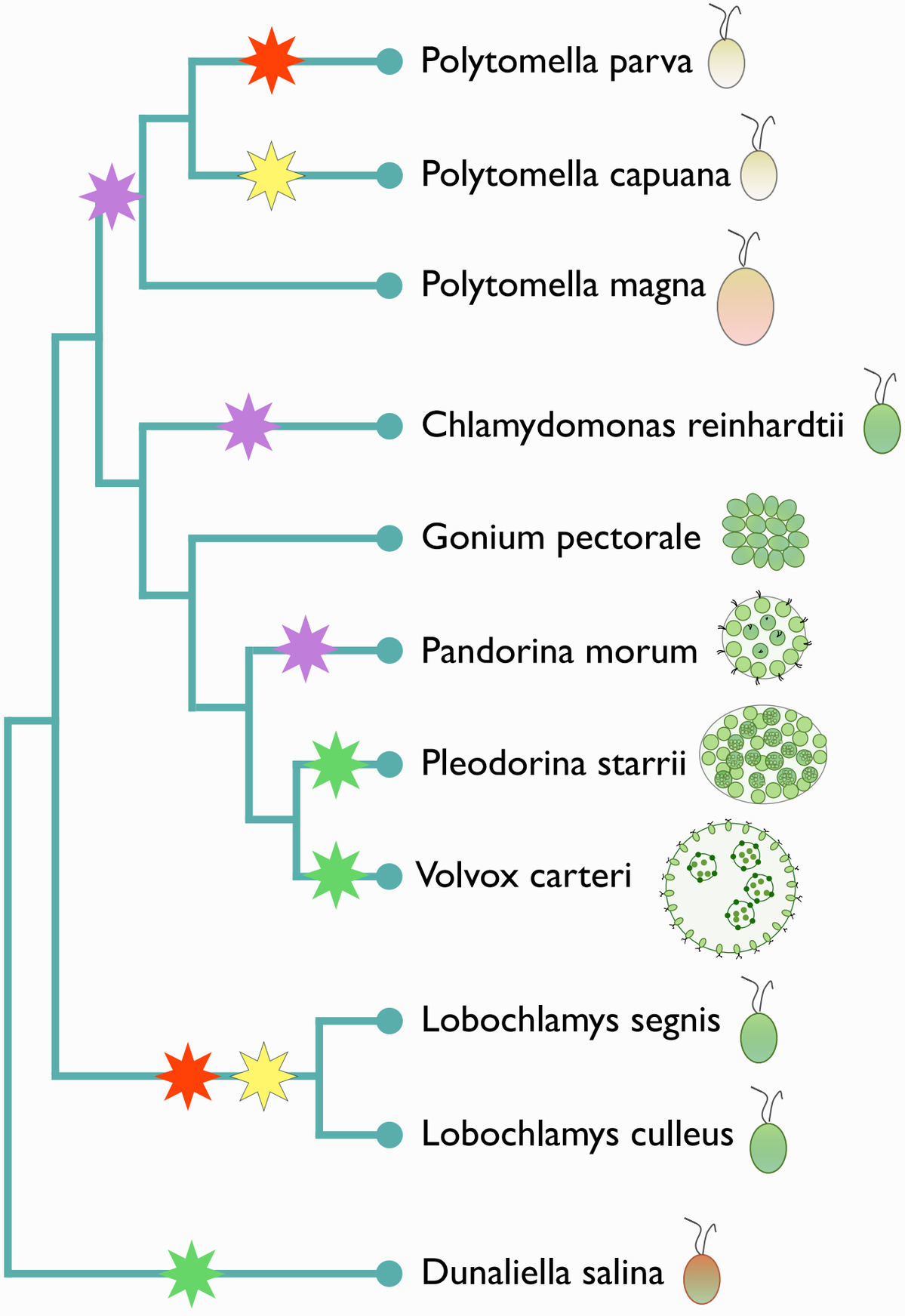
THE VOLVOCALES



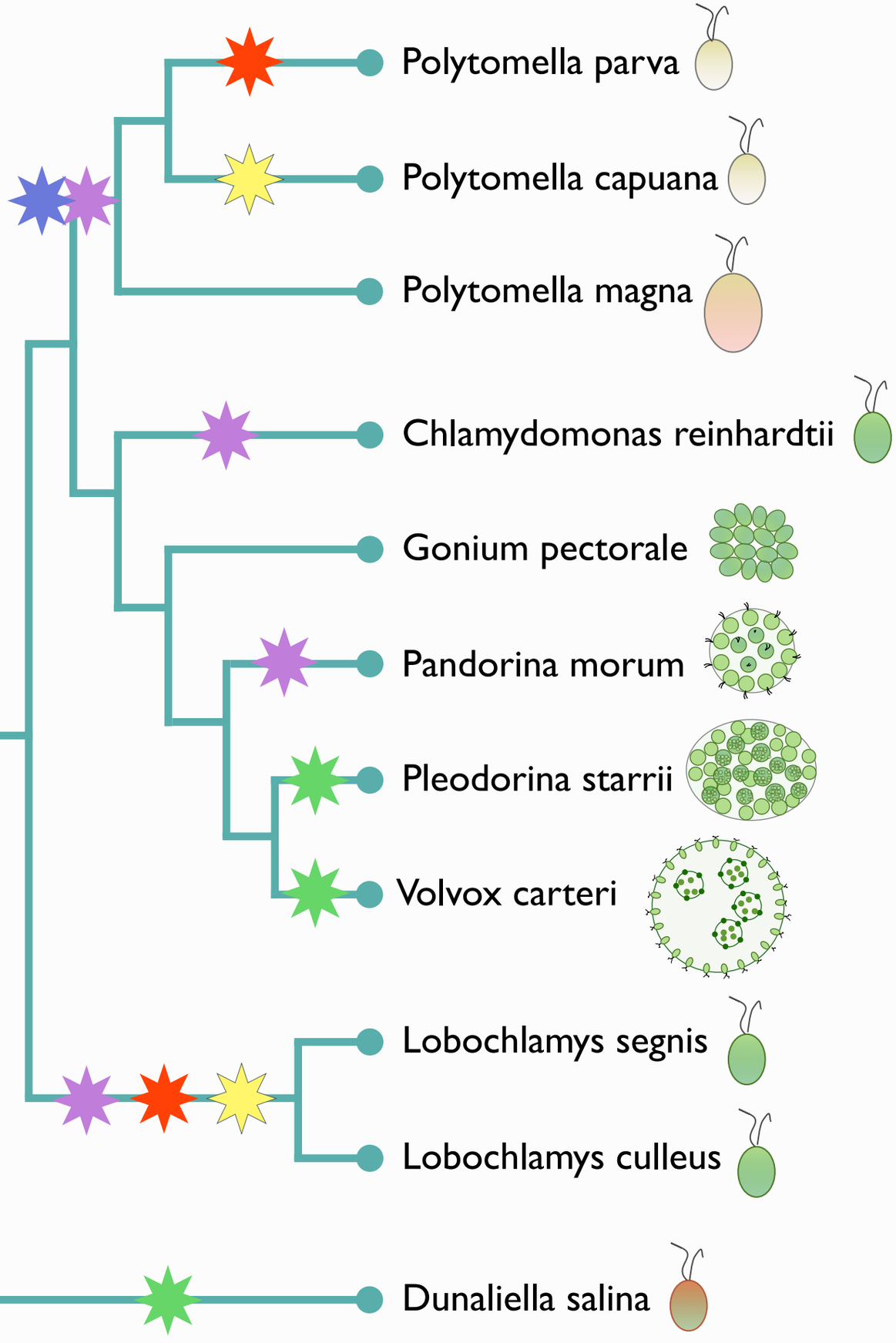
THE VOLVOCALES



THE VOLVOCALES



THE VOLVOCALES



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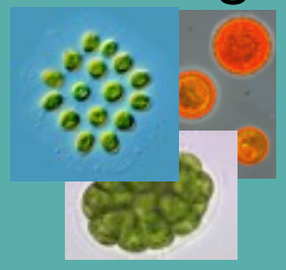

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"...I saw a very many great round particles, of the bigness of a great corn of sand drive and move in the water...This was to me a very pleasant sight, because the said particles, as often as I did look on them, did neither lye still, and that their motion did proceed from their turning round; and that the more, because I did fancy at first that they were small animals, and the smaller these particles were, the greener was their colour ... These particles had each of them within included 5, 6, 7, nay, some to 12 small round globules, of the same shape as the body wherein they were included." (van Leeuwenhoek, 1700)

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