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IRSA CNR Water Research Institute NATIONAL RESEARCH COUNCIL OF ITALY

Special Seminar on Biodiversity Conservation & Museum Management

"Evolution and Speciation Without Sex in Bdelloid Rotifers".

- SPEAKER -

LIVE

Dr. Diego Fontaneto

National Research Council,
Water Research Institute (CNR-IRSA), Italy

Moderators

Dr. Phannee Sa-ardrit

Assoc. Prof. Dr. Supiyanit Maiphae

21 February 2022

15.30-17.30 (GMT+7)

Join Us On ZOOM

Meeting ID : 912 9484 2644

Passcode : 991309

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Males and females: WHY?

Plants and animals (almost) always with separate sexes

Males and females: WHY?

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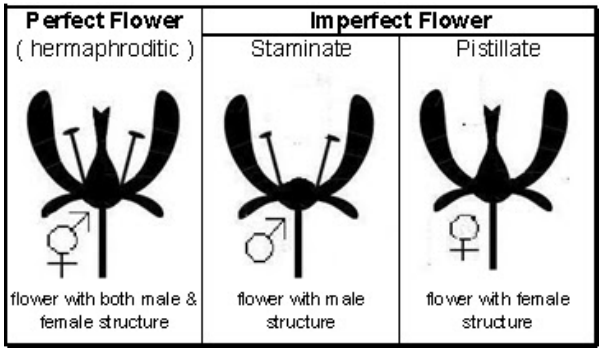
Males and females: WHY?

Plants and animals (almost) always with separate sexes



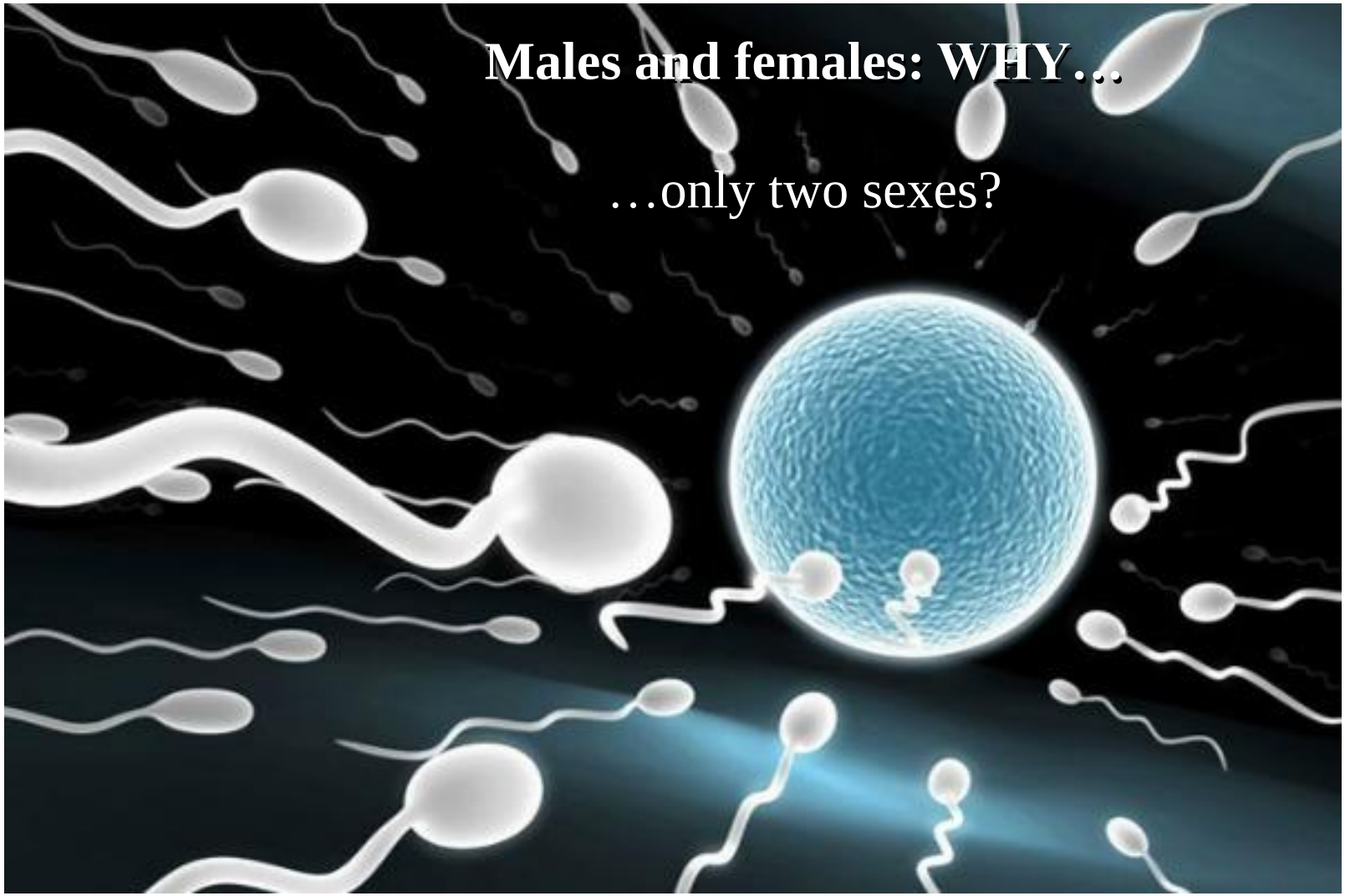
Males and females: WHY?

Plants and animals (almost) always with separate sexes

Males and females: WHY…

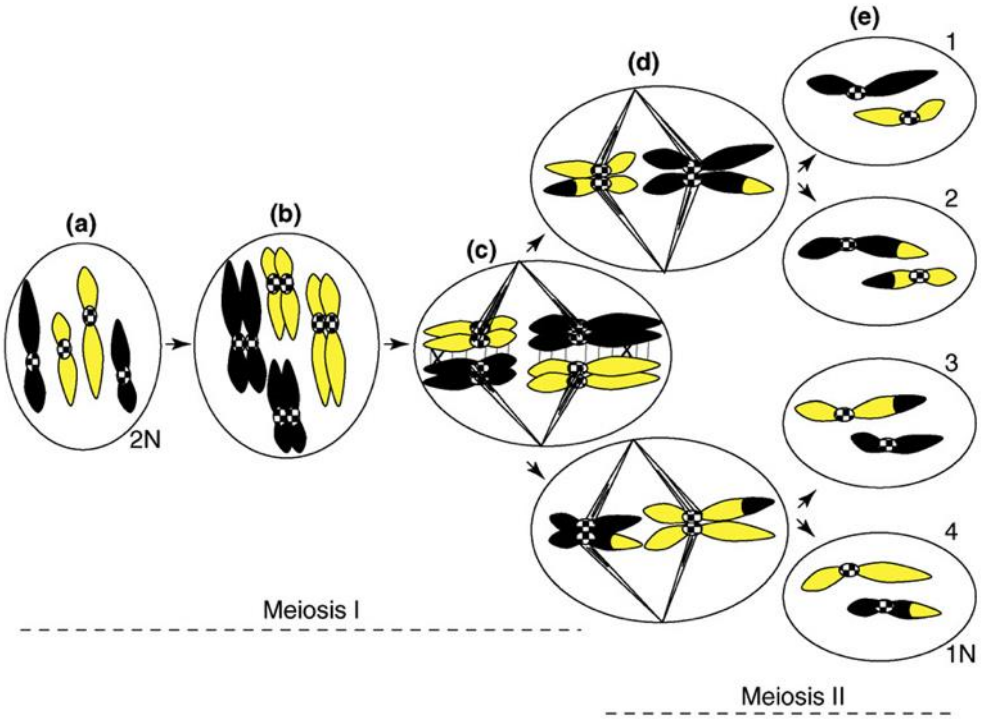
…only two sexes?

gametes



Gametes: what are they?

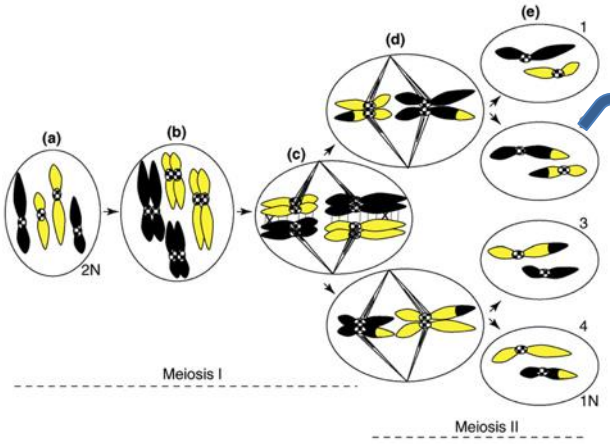
eukaryotic sex = meiosis



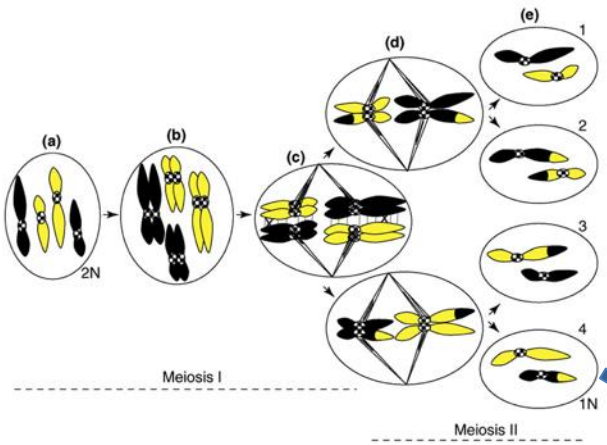
(Normark et al. 2003: Biol J Linnean Soc)

eukaryotic sex = meiosis

meiosis followed by the fusion of meiotic products

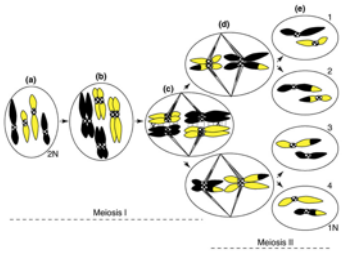


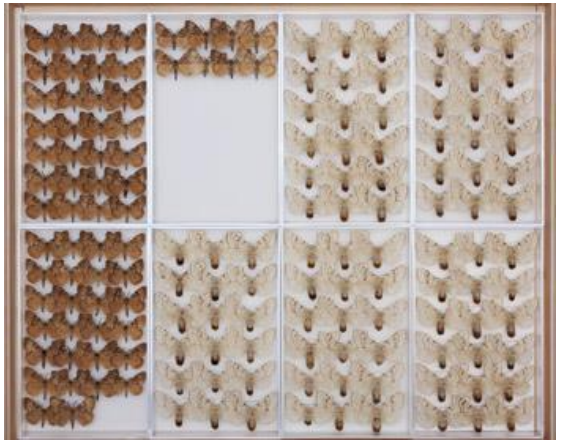
embryo



Sex: how does it work?

eukaryotic sex = meiosis + fertilisation





Sex => variability

Sex: consequences

Reproductive isolation promotes speciation

Biological Concept of Species:
"organisms are classified in the same species if they are potentially capable of **interbreeding** and producing fertile offspring"

Sex is important to originate and maintain diversity

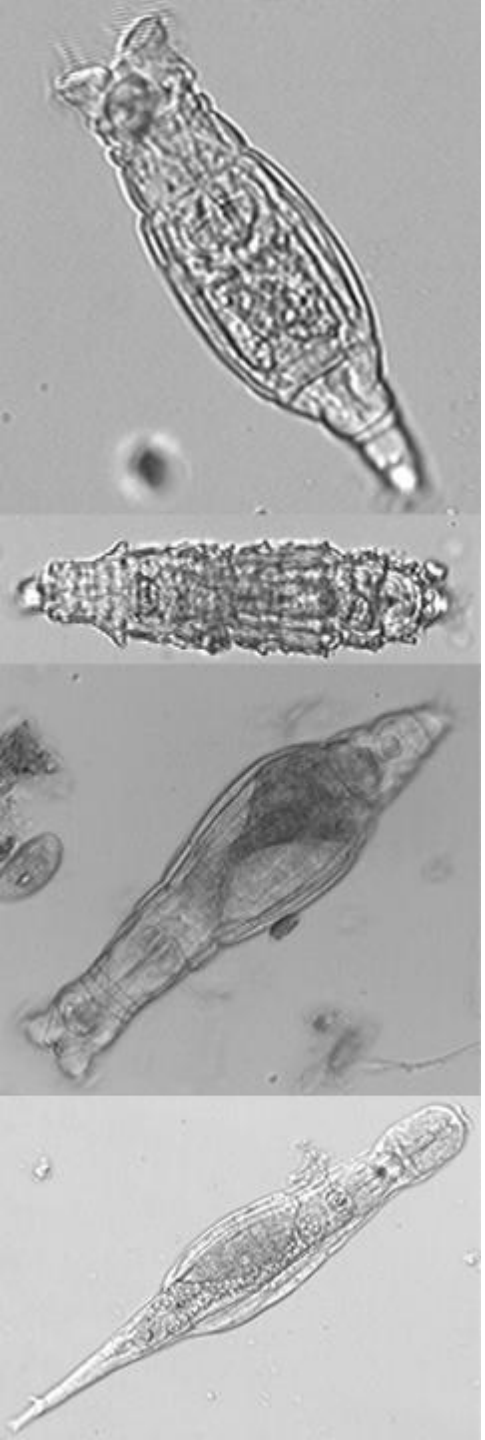
Speciation

--- highly controversial issue in evolutionary biology ---

Coyne & Orr, 2004. Speciation. Sinauer Associates, 545 pp.

reproductive isolation
with
interruption of **gene flow** between populations

Are there ‘species’ in parthenogenetic/asexual animals?

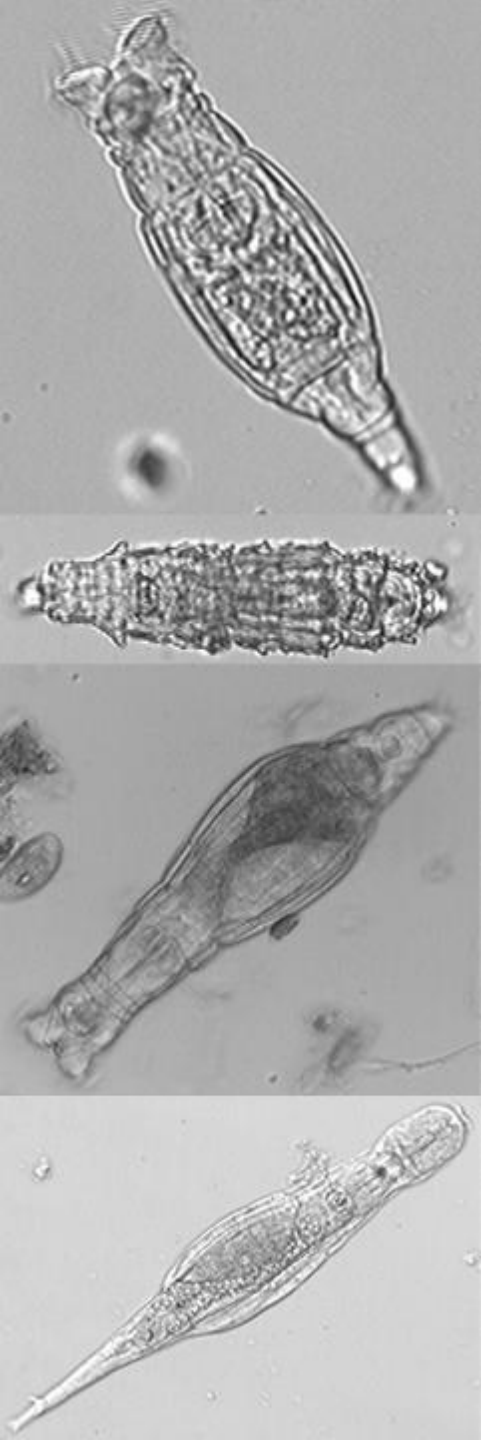


Bdelloid rotifers: MEIOFAUNA

- Obligate parthenogenesis

- ca. 450 recognised morphological species

EVOLUTIONARY SCANDAL



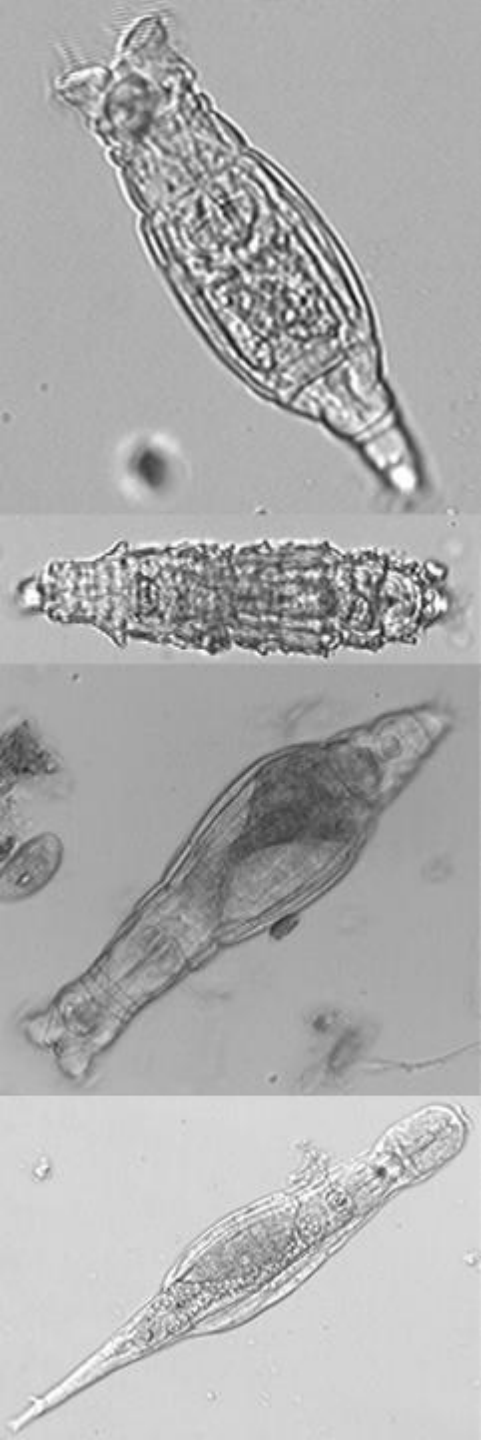
Three alternative hypotheses

1- Bdelloid rotifers have ‘hidden’ males

2- Bdelloid rotifers do not have species

3- Sex is not so important

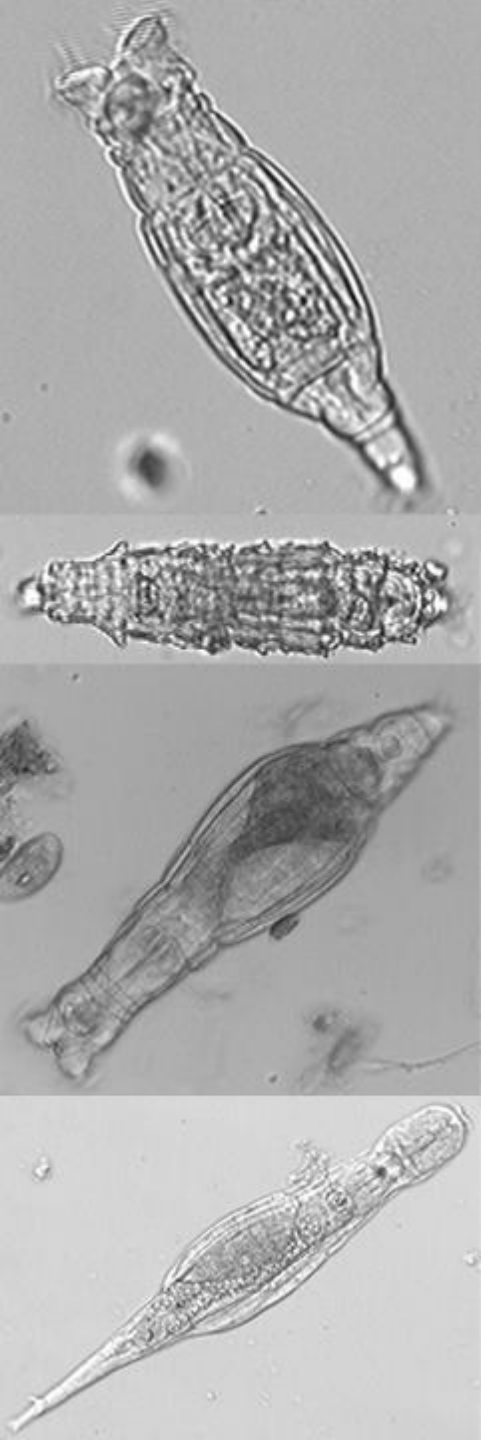
(Fontaneto & Barraclough 2015: Integr Comp Biol)



Bdelloid rotifers
Evidence of asexuality

- no males ever seen

(Shurko et al. 2009: Trends Ecol Evol)



Bdelloid rotifers

Evidence of asexuality

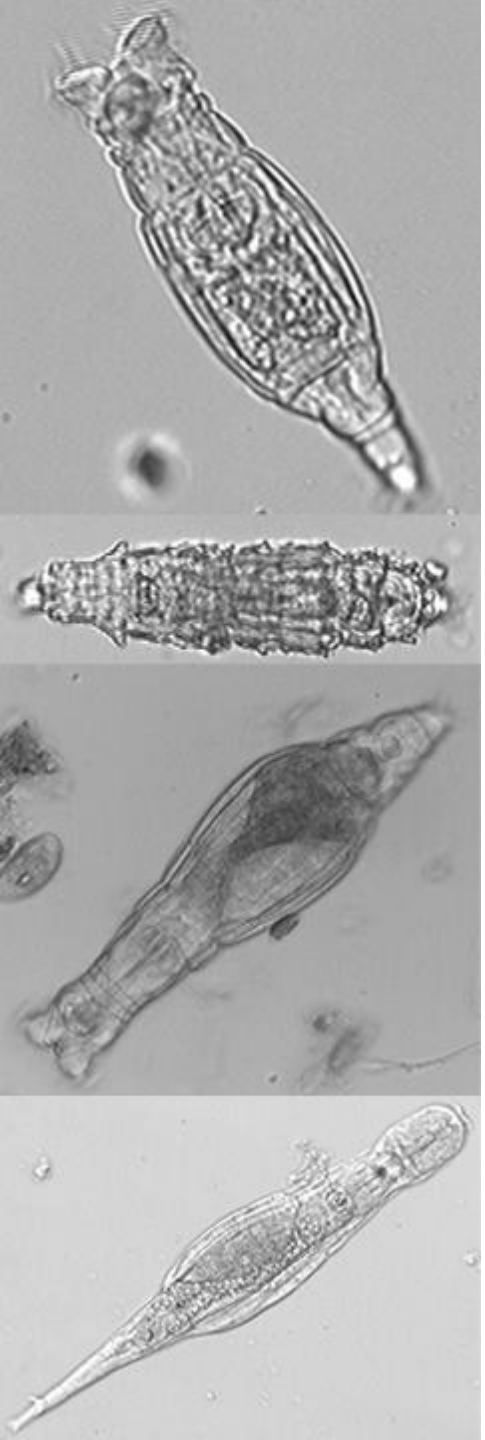
- no males ever seen

- accumulation of deleterious mutations

- transposable elements

- etc.

(Shurko et al. 2009: Trends Ecol Evol)



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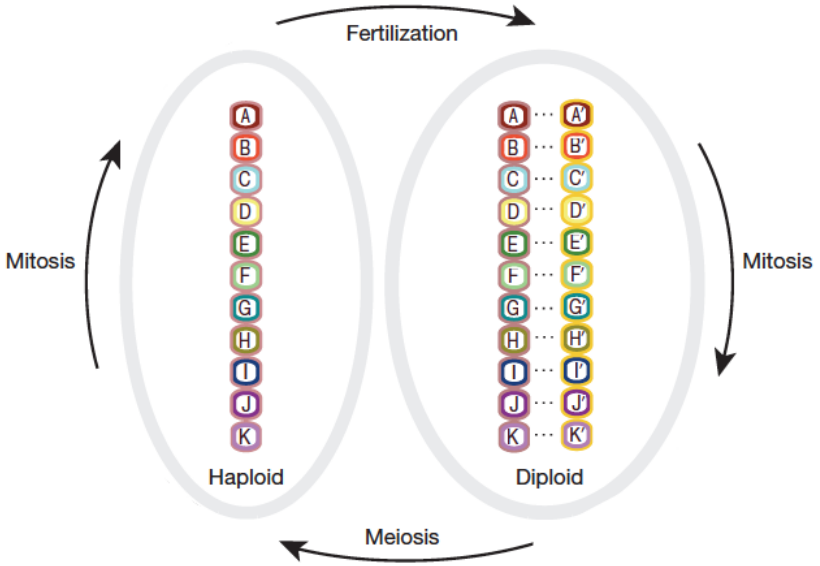
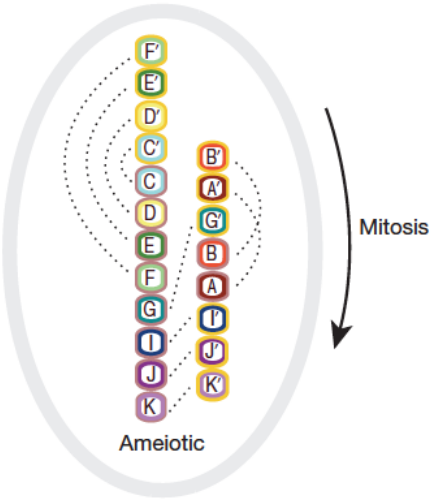
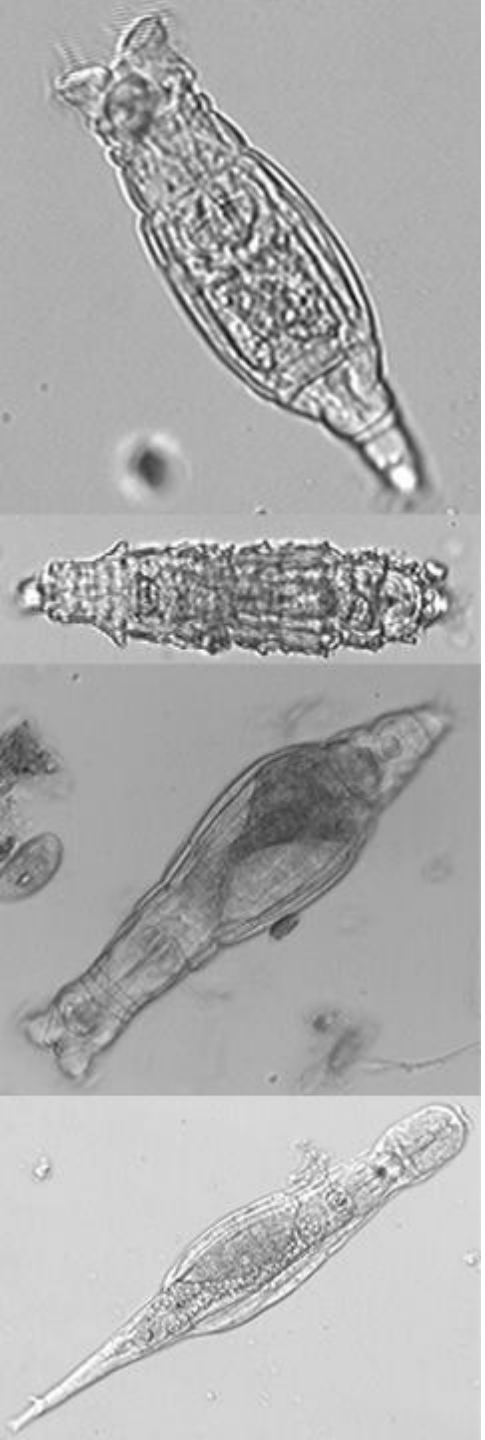




(Flot et al. 2013: Nature)



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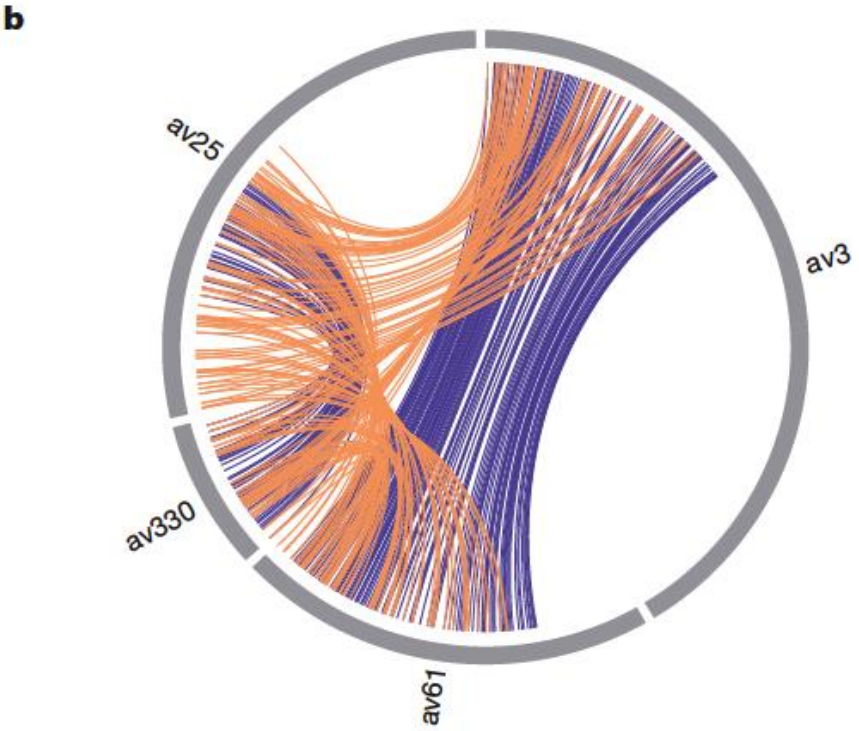
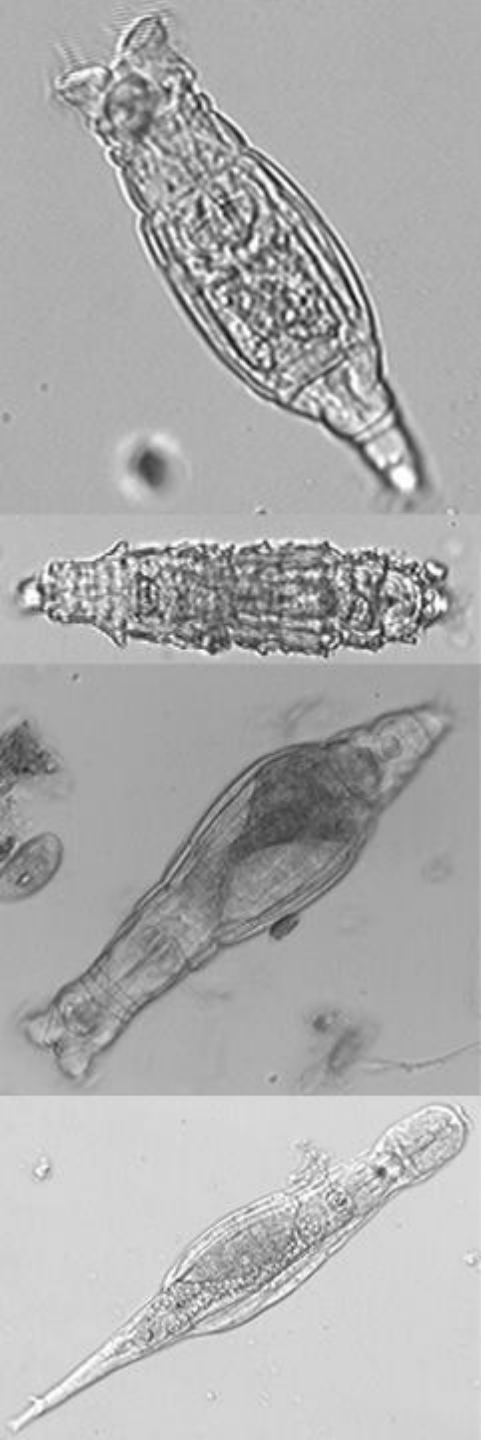


Figure 2 | A locally tetraploid genome.

b, Example of a genomic quartet of four scaffolds: allelic gene pairs are connected with violet curves and ohnologous gene pairs with orange curves.

(Flot et al. 2013: Nature)



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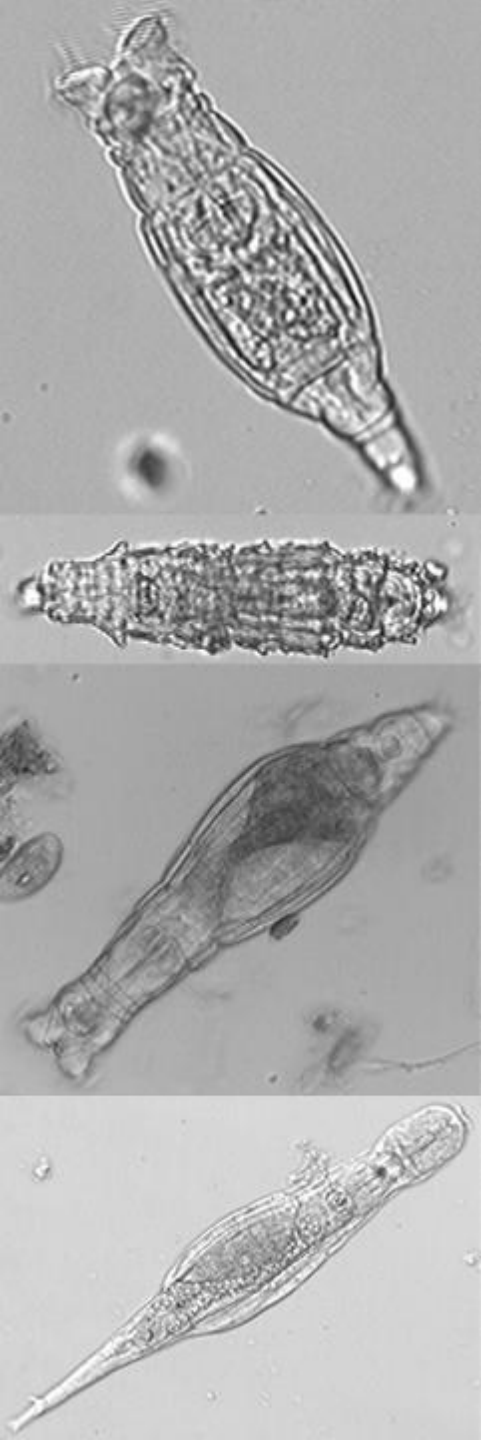
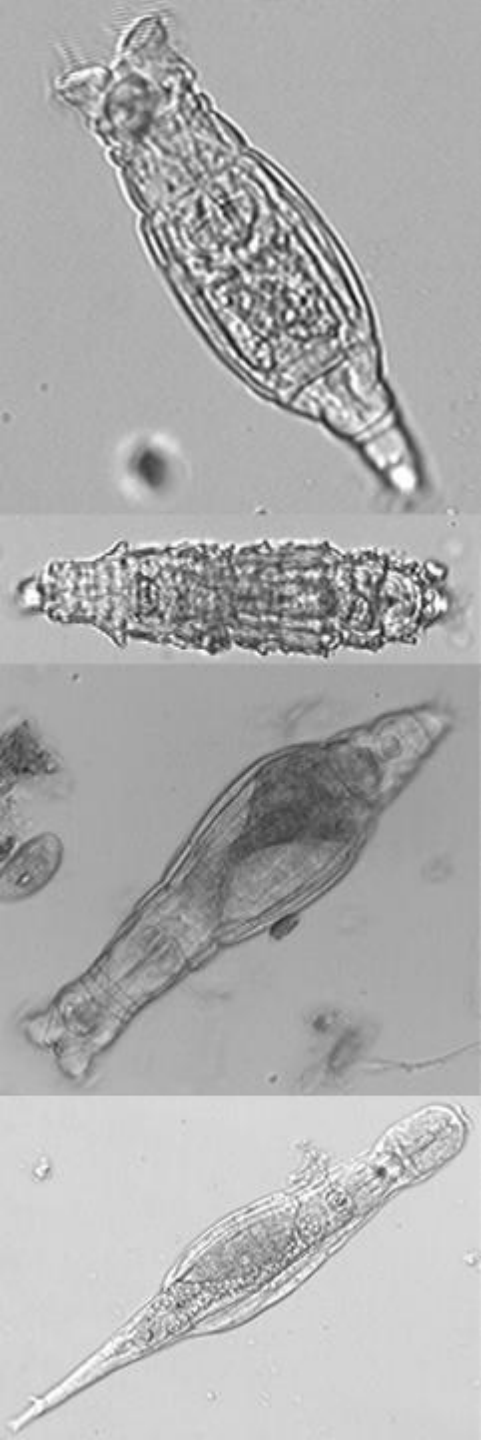


Bdelloid rotifers
speciation

ca. 450 species from morphology

Are they real,

or figments of taxonomists' imagination?



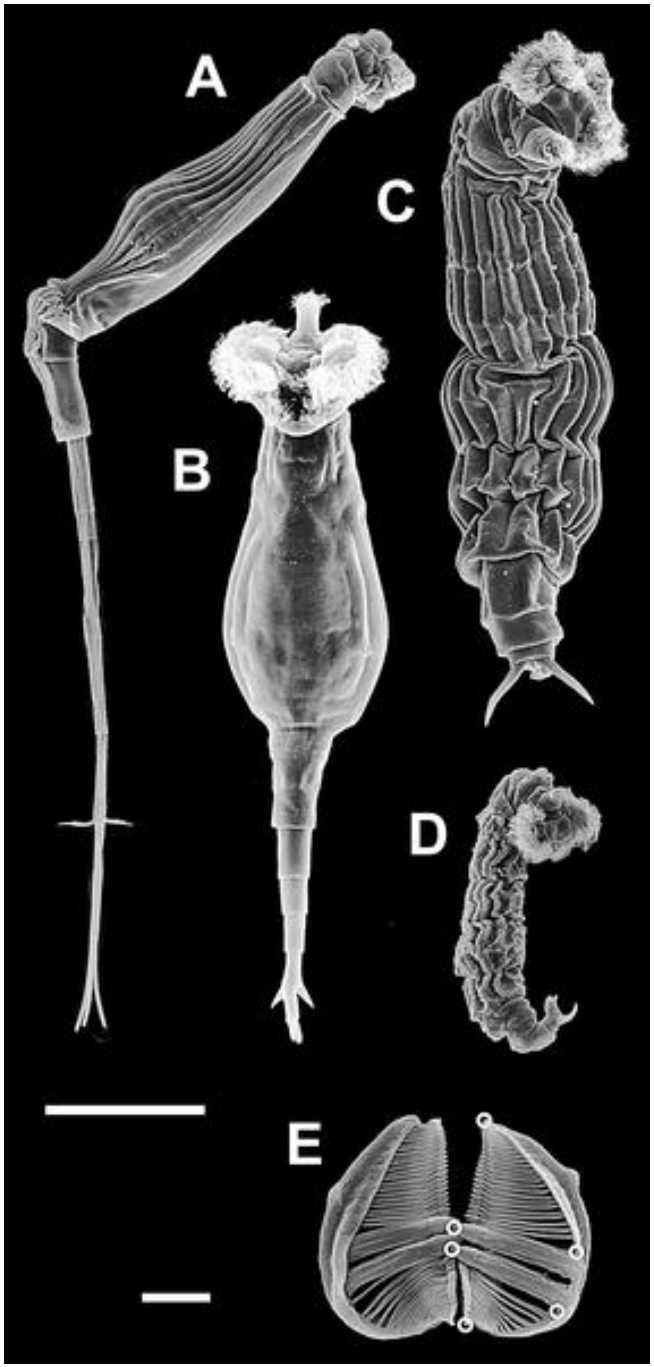
Evidence of speciation: asexuals

H0: Entire group is a single species

swarm of clones

H1: Group has diversified into independently evolving sub-lineages

geographic isolation or divergent selection



Evidence of speciation

Genus *Rotaria*

several individuals from 9 species

from Europe, N. America, Africa, Australia

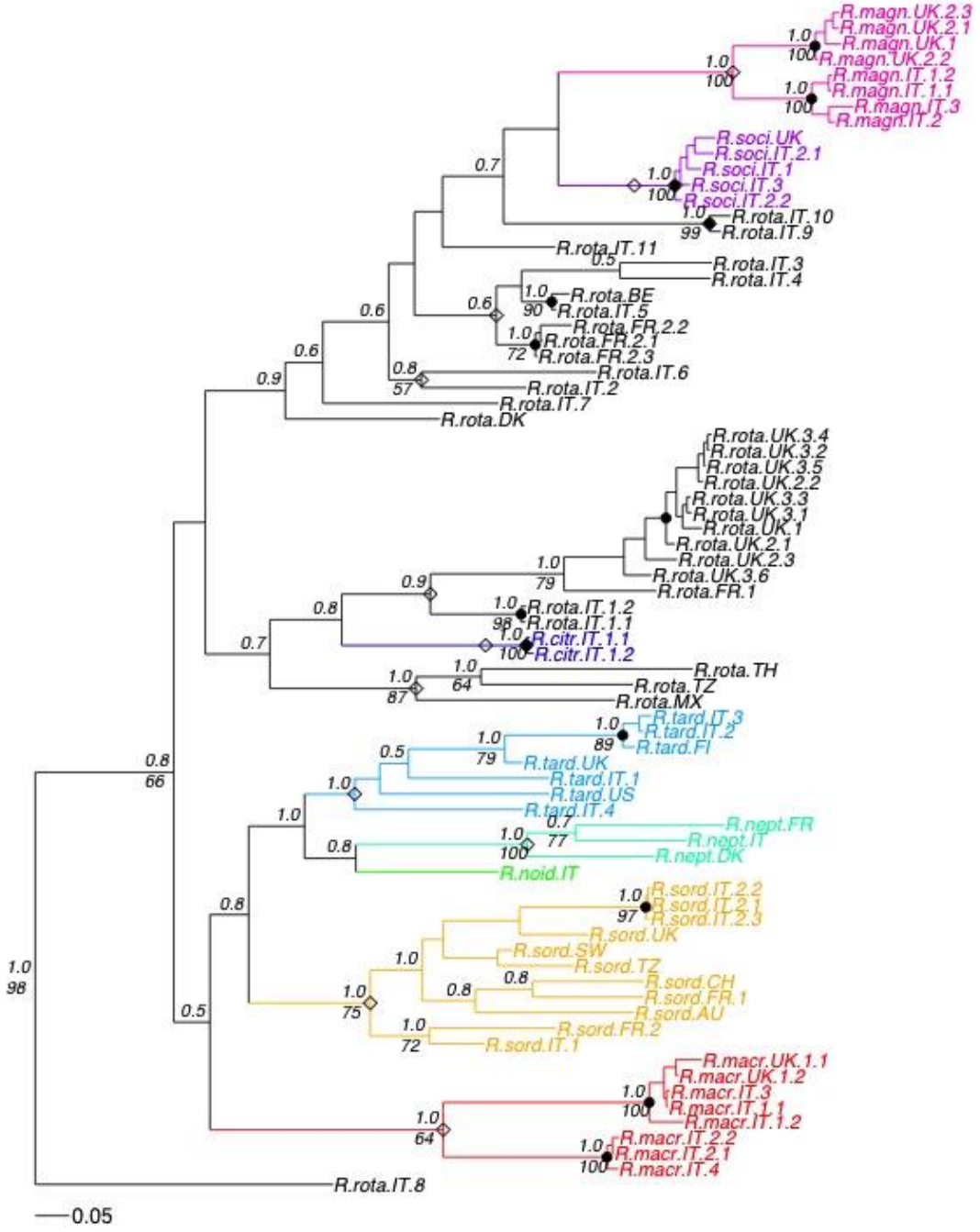
COI mtDNA and
28S rDNA

Geometric morphometrics of feeding morphology

(Fontaneto et al. 2007: PLoS Biol)

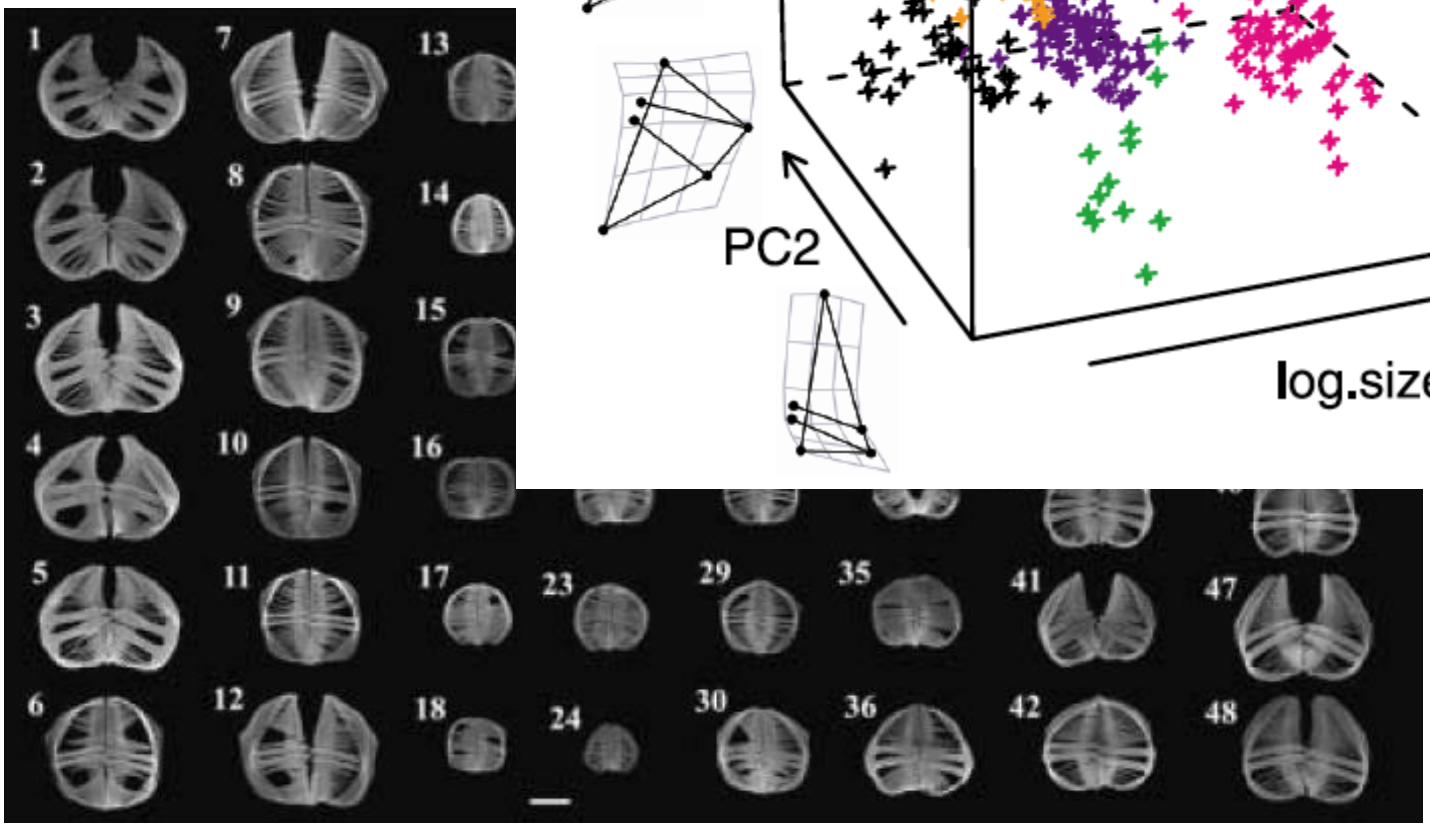
Evidence of speciation

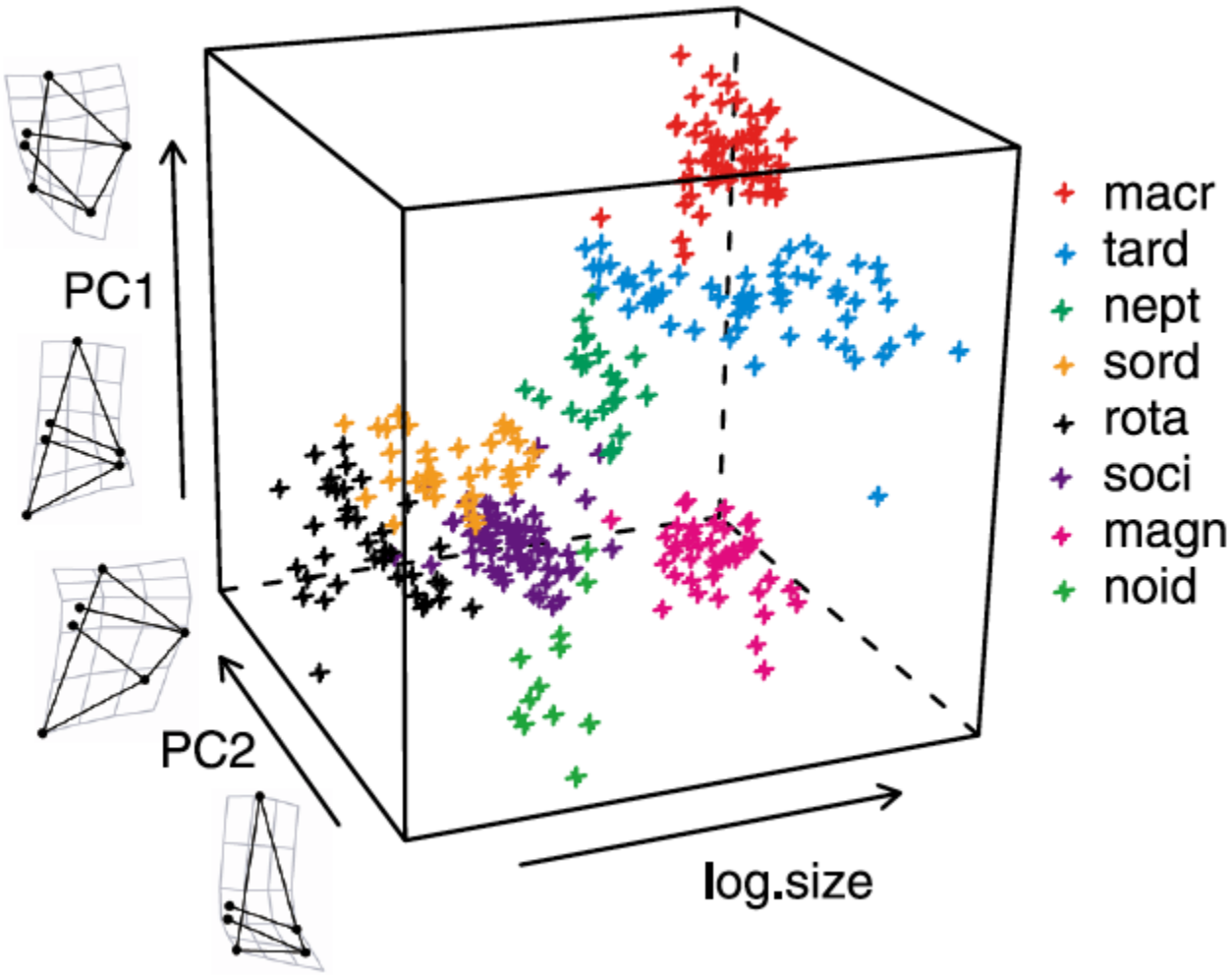
Species are monophyletic on DNA trees

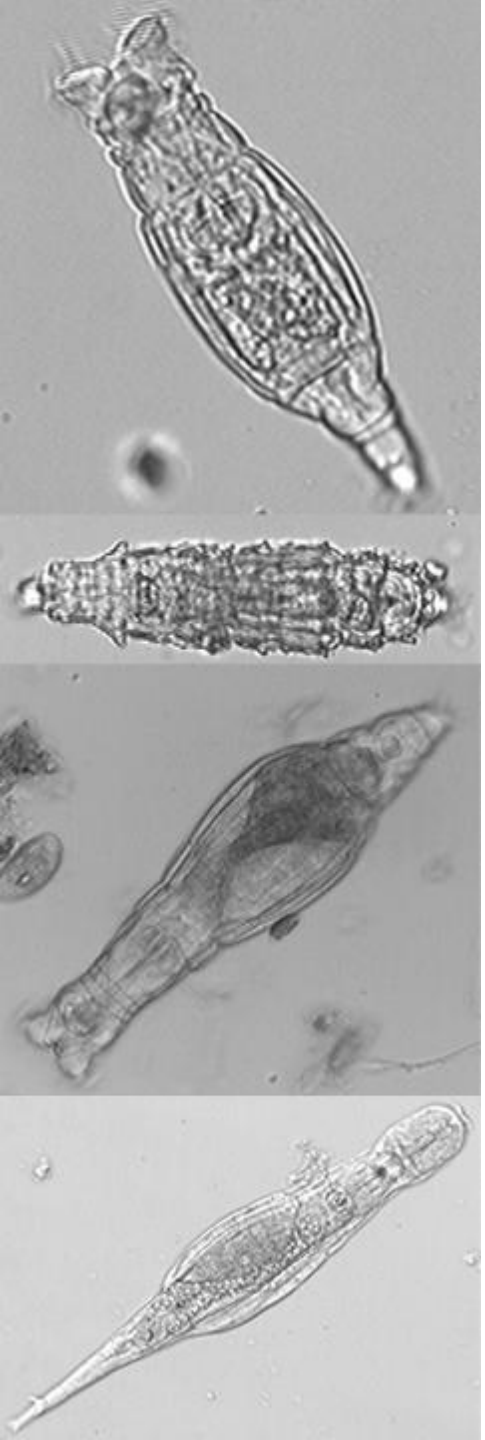


Evidence of speciation

Species form morphological clusters







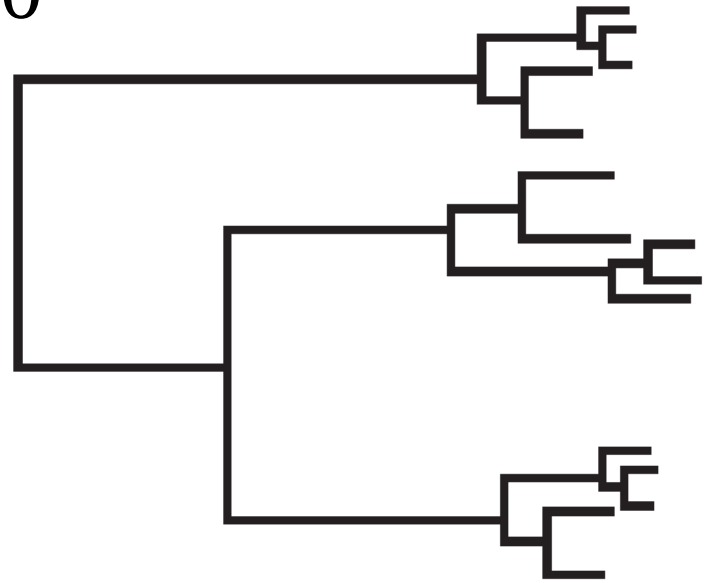
Hypotheses for bdelloid diversity

Taxonomic figment

Clades within a single species?
swarm of clones

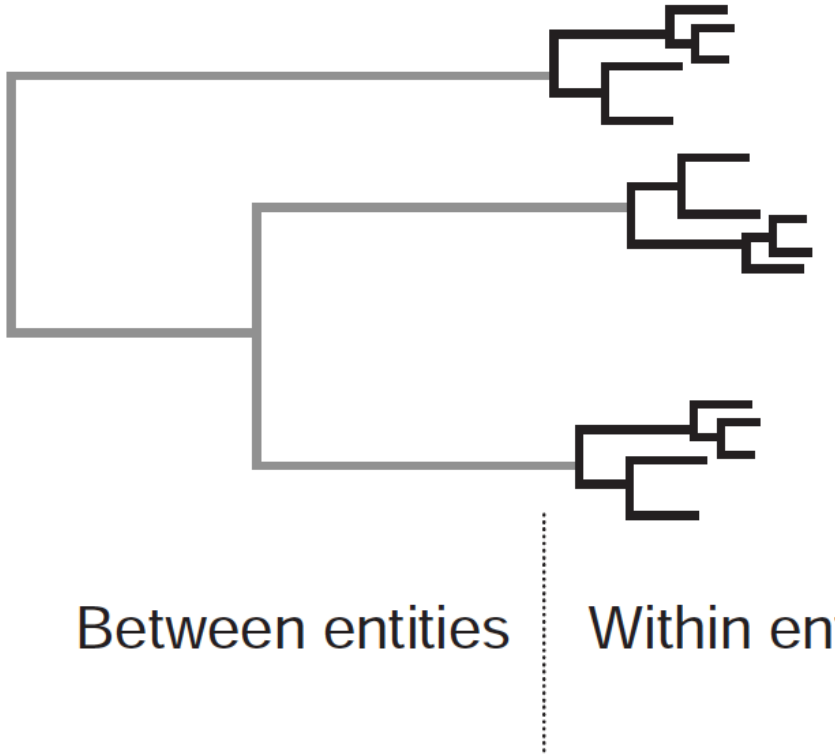
(a) Single population

H0



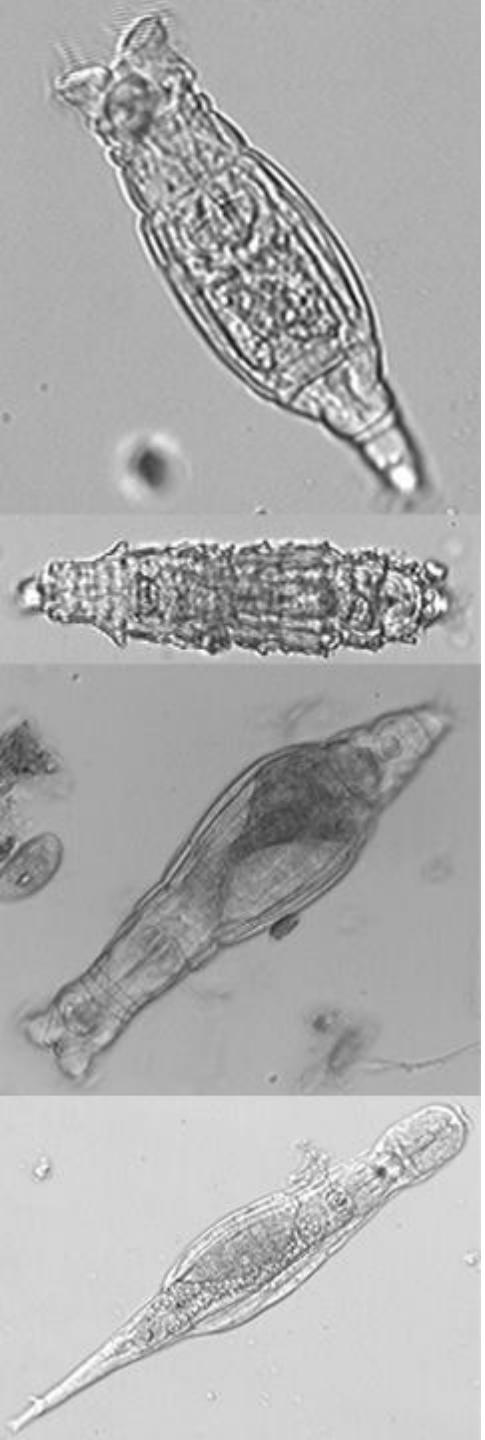
(b) Independently evolving entities

H1



Compare likelihood of H0 and H1 => H1 is higher

(Barraclough et al. 2009: Speciation & Patterns of Diversity)



Hypotheses for bdelloid diversity

~~H0: Entire clade is a single species~~

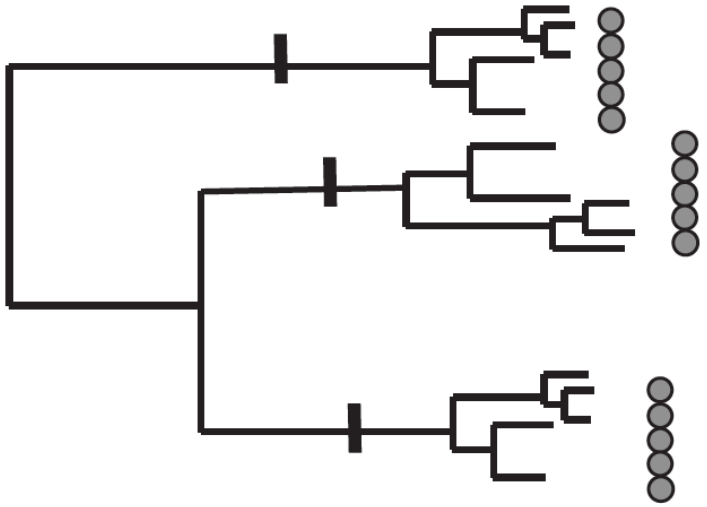
H1: Clade has diversified into independently evolving lineages

H1a: <u>divergent selection</u> and ecologically distinct species?

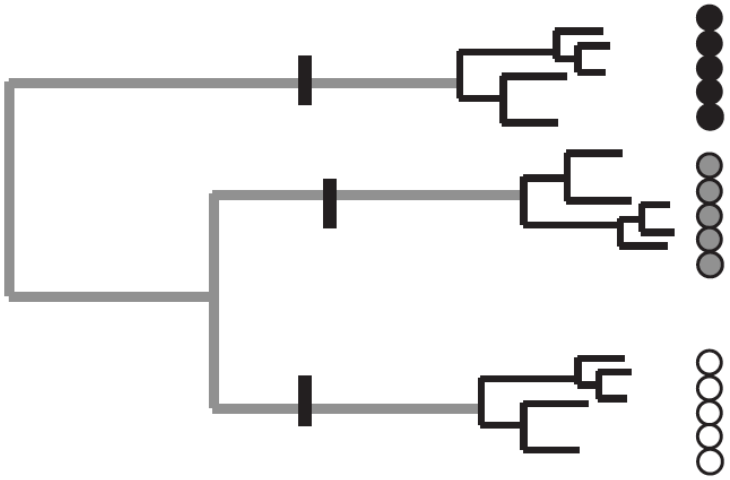
H1b: complete or partial <u>geographic isolation</u>?

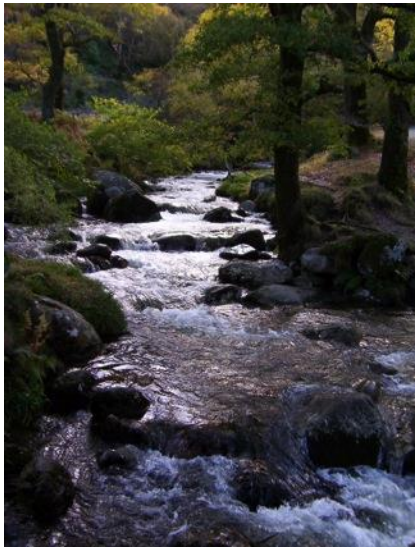
H1a: Divergent ecology

(a)



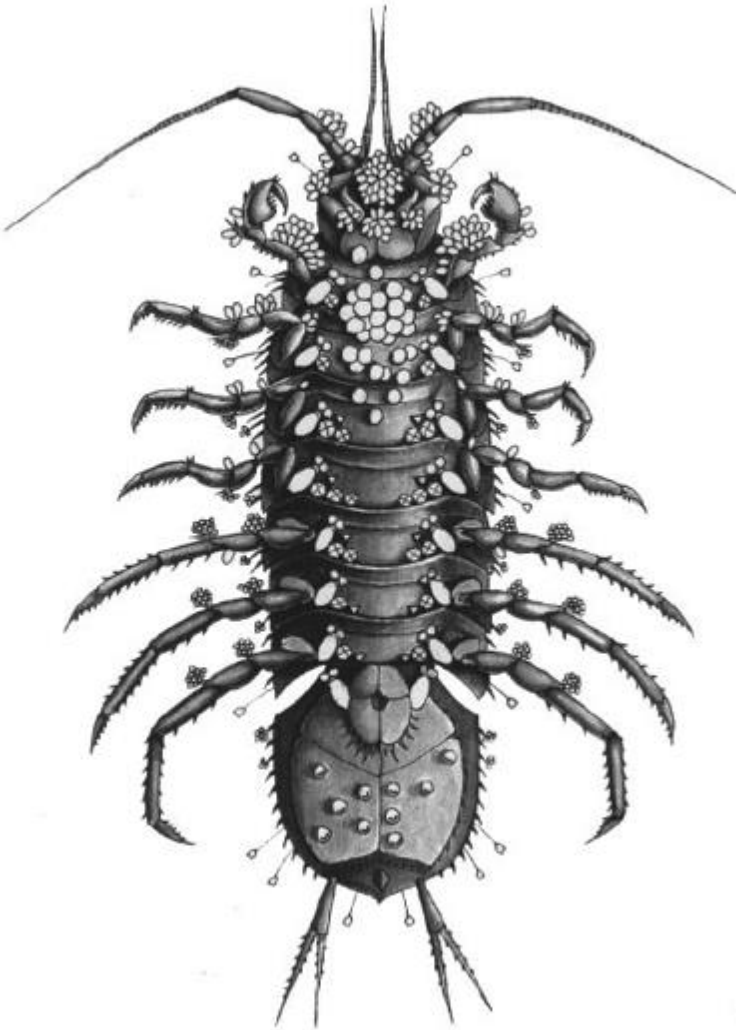
(b)





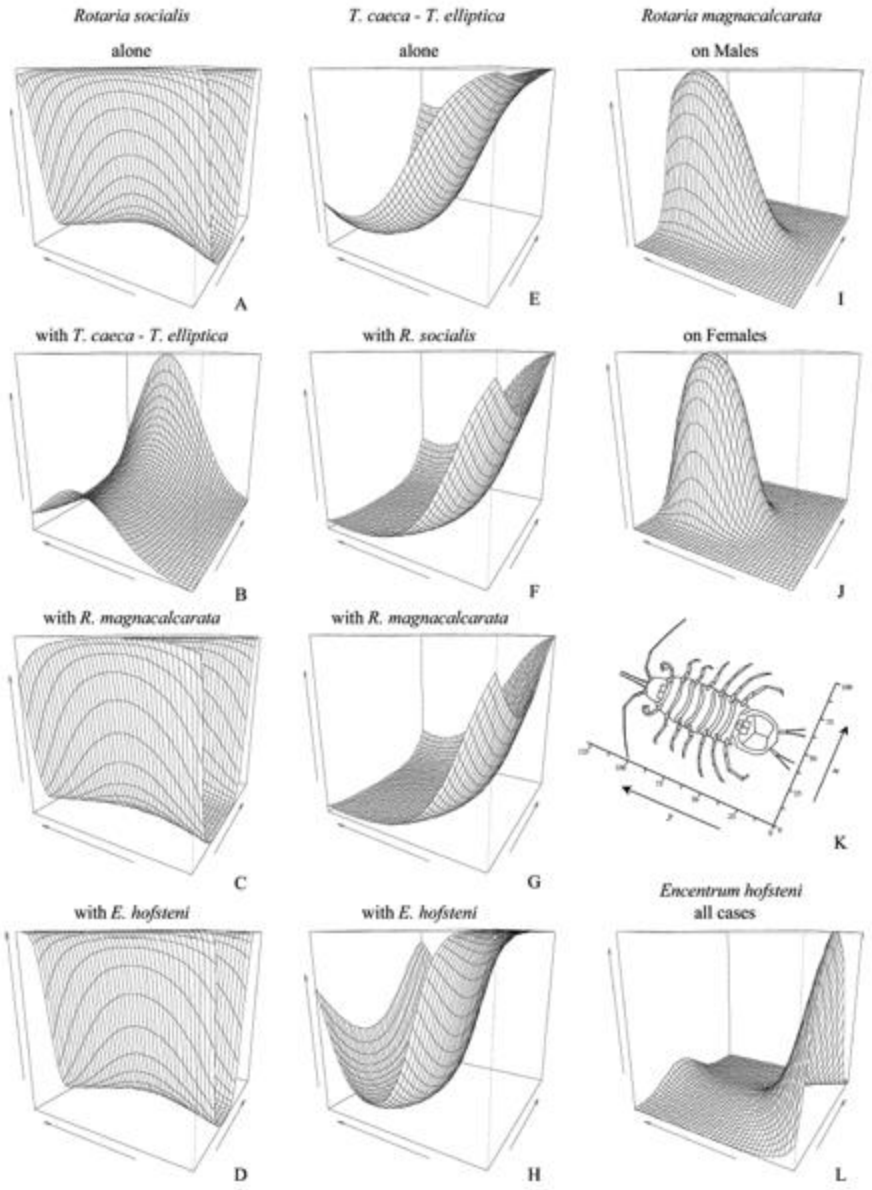
(Fontaneto et al. 2009: Mol Phyl Evol)

H1a: Divergent ecology



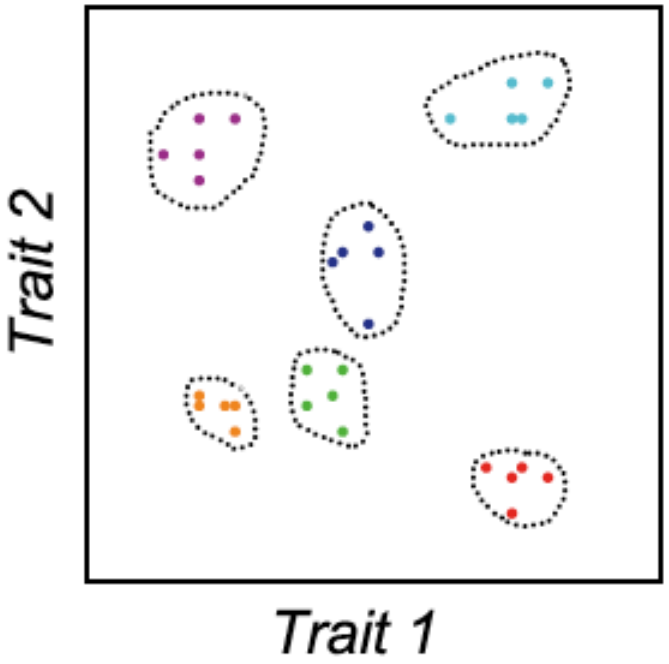
(Fontaneto & Ambrosini 2010: Limnol Oceanogr)

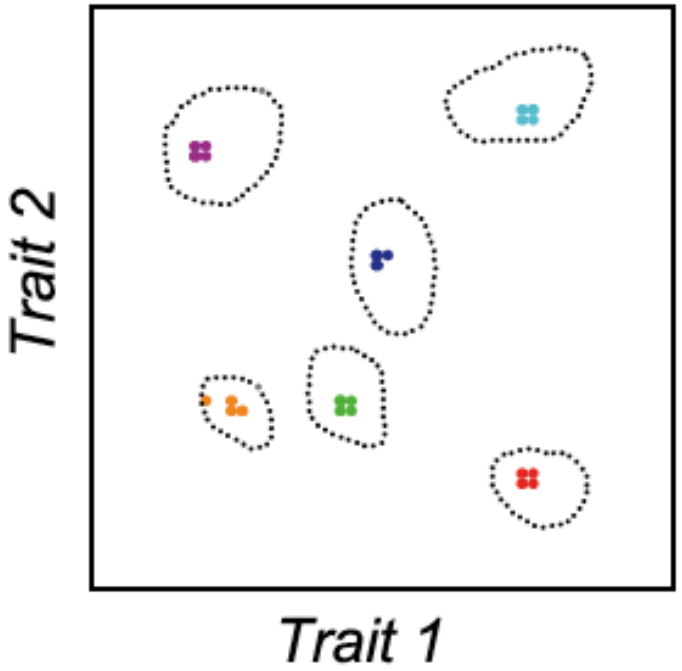
H1a: Divergent ecology

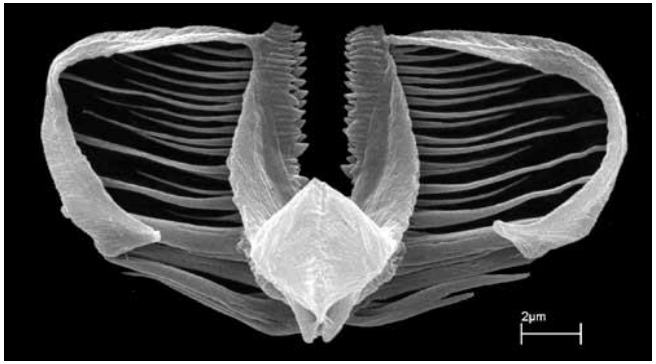


(Fontaneto & Ambrosini 2010: Limnol Oceanogr)

H1a: Divergent selection







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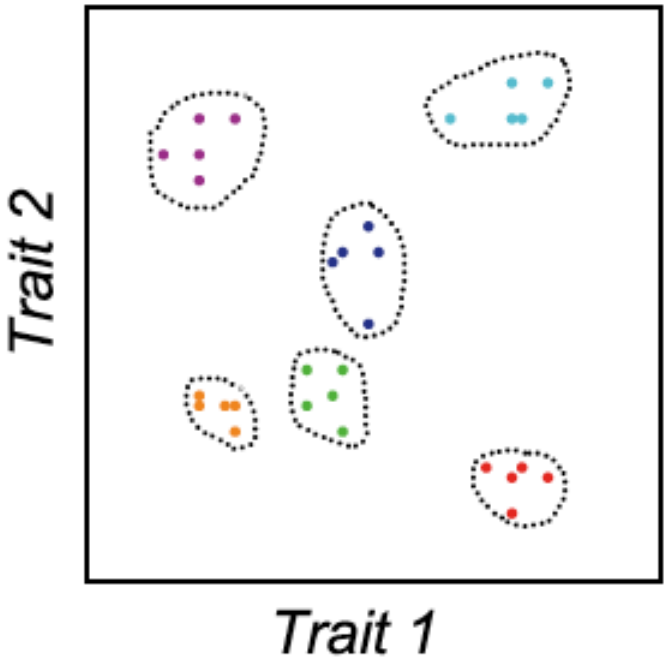
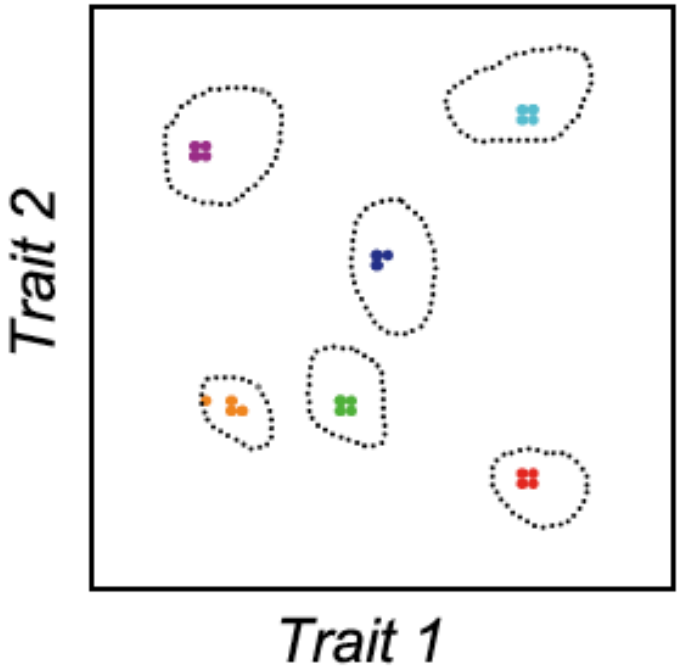
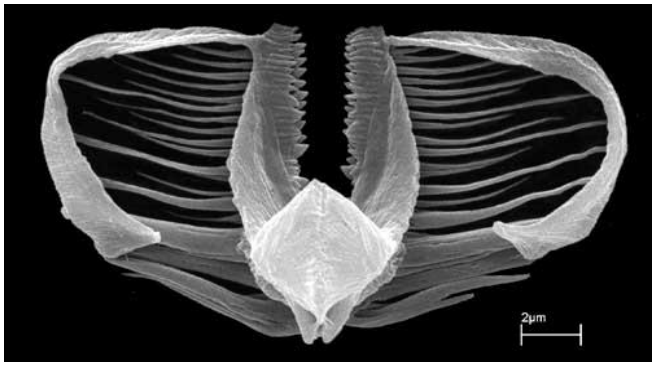




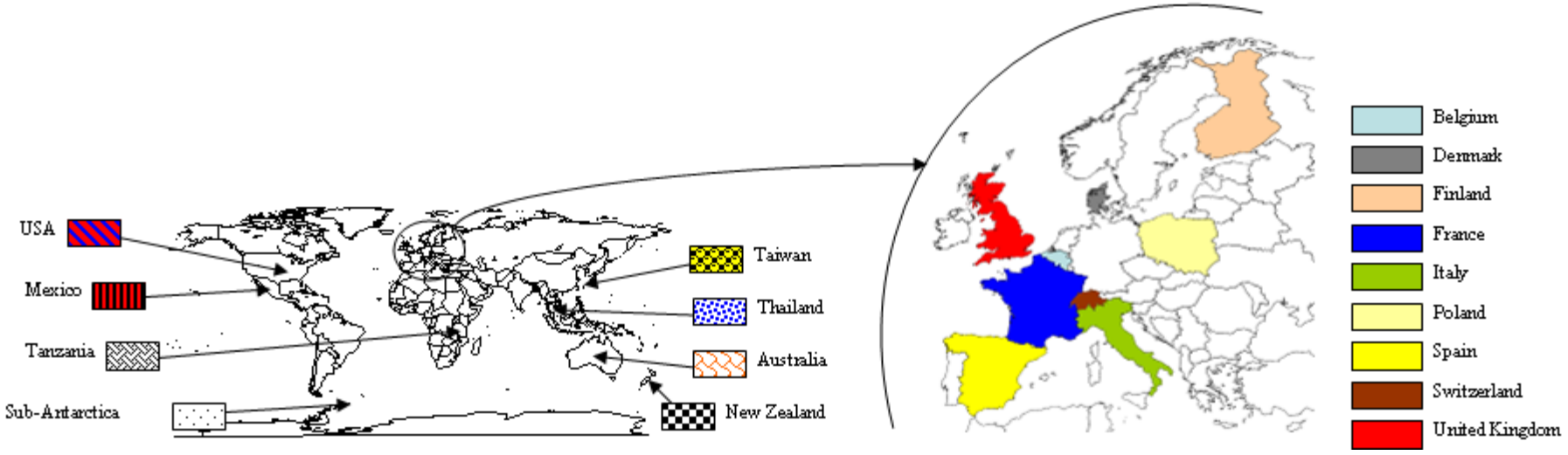


(Fontaneto et al. 2007: PLoS Biol)

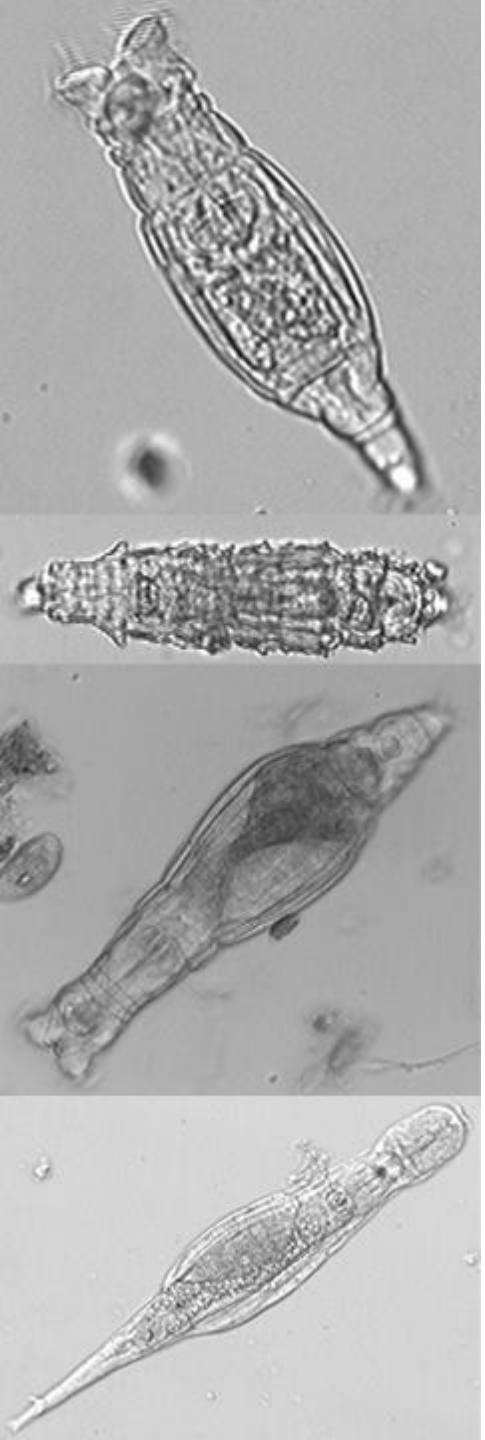
H1b: Geographic isolation

(i) species, (ii) lineages and (iii) clusters

significant correlation
between genetic and geographic distances



(Fontaneto et al. 2008: Mol Ecol)

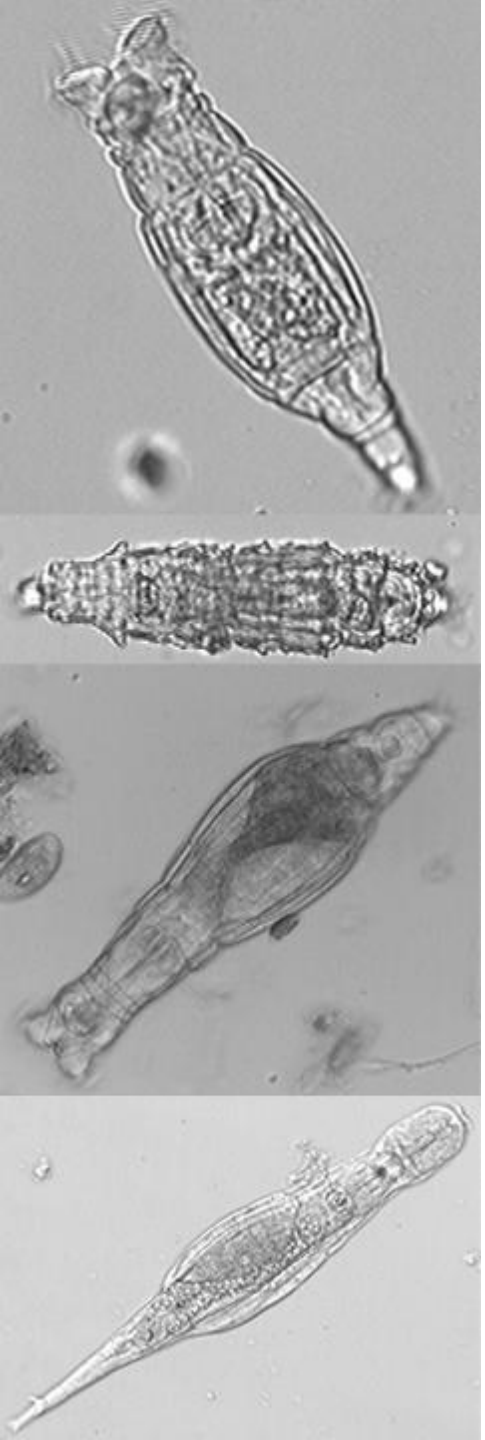


Evidence of speciation in asexuals

Bdelloid rotifers
have diversified into independently evolving entities akin to species in sexual organisms

through

divergent selection
and
geographic isolation



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(Fontaneto & Barraclough 2015: Integr Comp Biol)

Theory of speciation: sexuals

1. Geographic isolation:

   genetic divergence + reproductive isolation (RI)

2. Divergent selection:

   selection drives divergence + origin of RI

Genetic & phenotypic clusters

Theory of speciation: sexuals

1. Geographic isolation:

genetic divergence + reproductive isolation (RI)

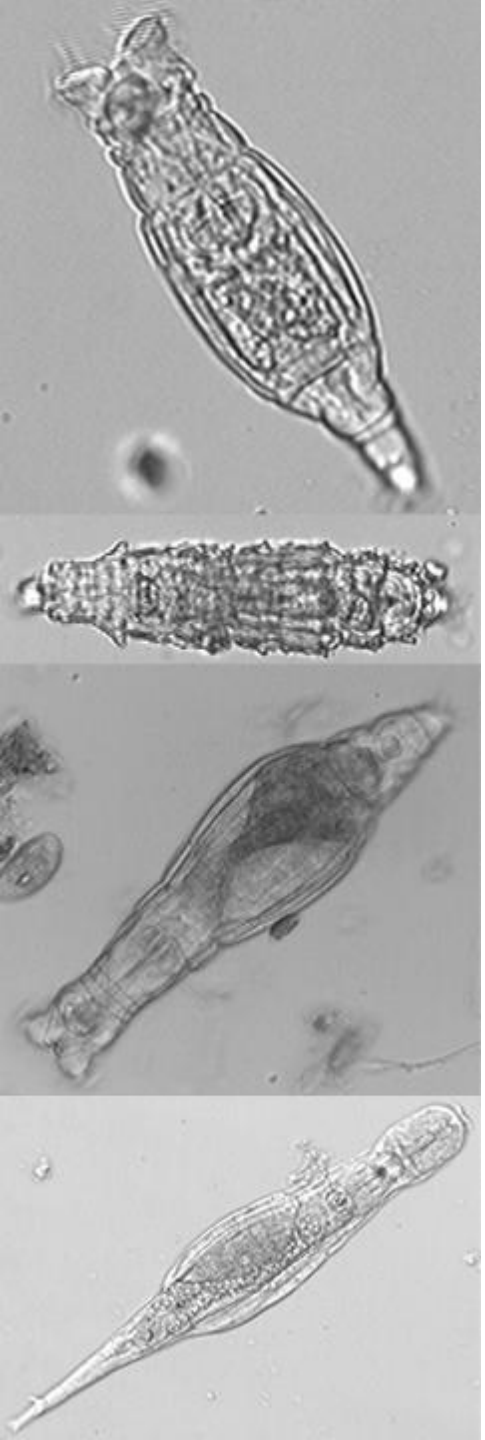
2. Divergent selection:

selection drives divergence + origin of RI

Genetic & phenotypic clusters

SEXUAL REPRODUCTION
&
SPECIATION

(Felsenstein 1981: Evolution)



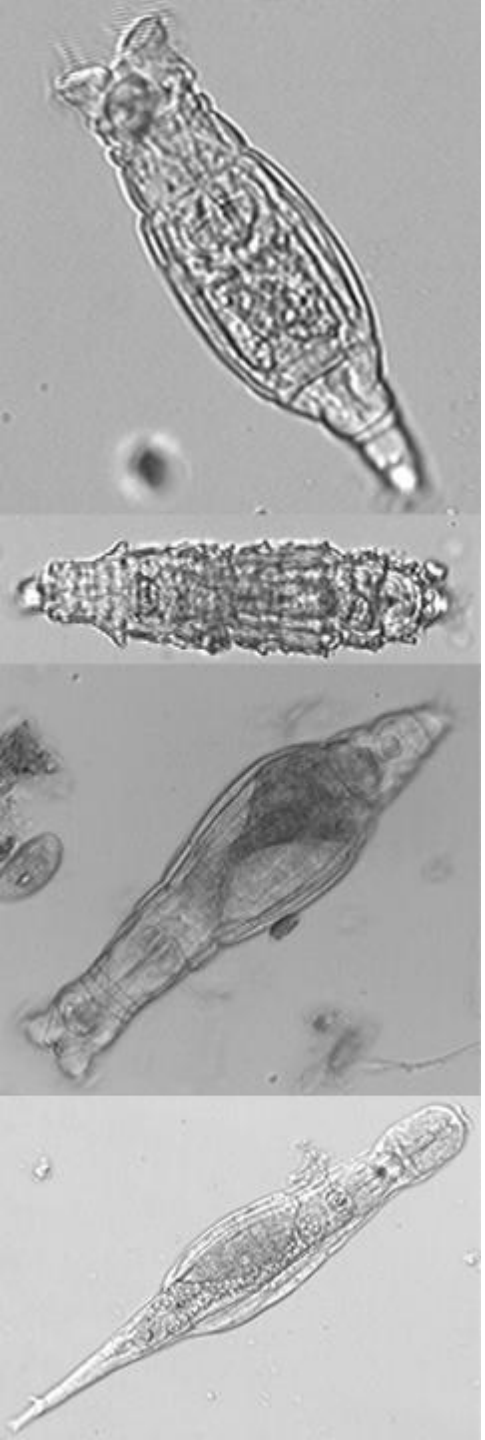
Evidence of speciation in asexuals

Actually: a lot of diversification!
Cryptic species

Abrochtha meselsoni/kingi	2
Adineta gracilis	4
Adineta steineri	2
Adineta vaga	>30
Macrotrachela ehrenbergii	2
Macrotrachela latior	4
Macrotrachela quadricornifera	>20
Philodina acuticornis	2
Philodina citrina	8
Philodina flaviceps	9
Philodina plena	7
Philodina roseola	2
Pleuretra lineata	5
Rotaria macrura	2
Rotaria magnacalcarata	2
Rotaria rotatoria	>70
Rotaria sordida	>10
Rotaria tardigrada	5

…

(Fontaneto 2014: Int Rev Hydr)



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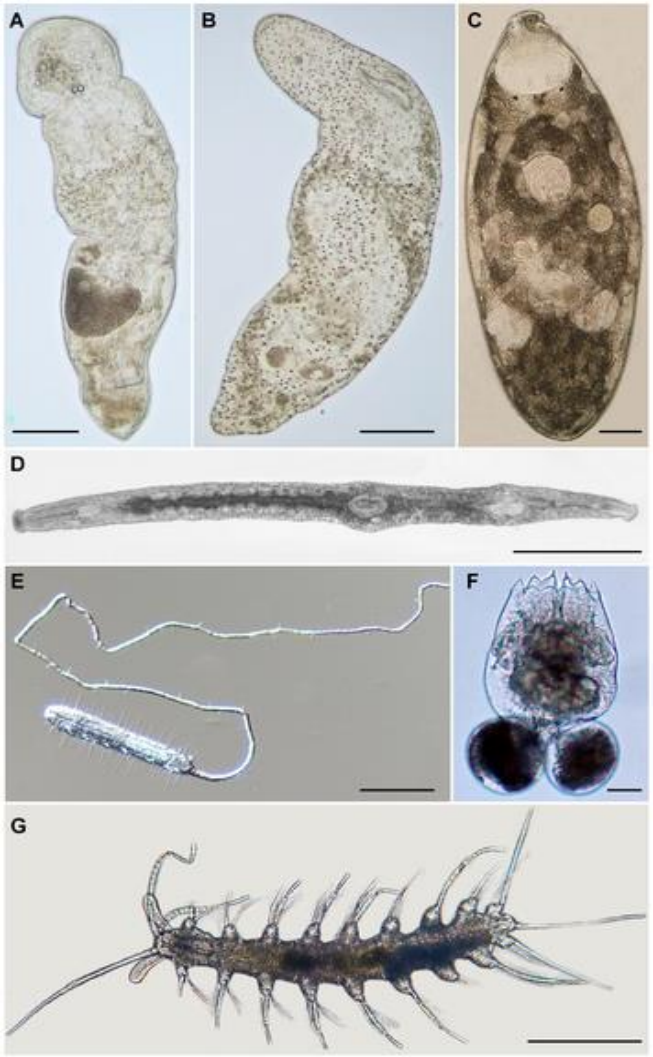
Philodina flaviceps
Philodina plena
Philodina roseola
Pleuretra lineata
Rotaria macrura
Rotaria magnacalcarata
Rotaria rotatoria
Rotaria sordida
Rotaria tardigrada
…

Sexual monogonont rotifer species

Ascomorpha ovalis
Brachionus calyciflorus
Brachionus falcatus
Brachionus plicatilis
Brachionus urceolaris
Epiphanes senta
Kellicottia longispina
Keratella cochlearis
Keratella quadrata
Lecane bulla
Lecane cornuta
Polyarthra dolichoptera
Polyarthra vulgaris
Synchaeta pectinata
Synchaeta obtusa
Synchaeta vulgaris
Testudinella clypeata
Testudinella patina
…

(Fontaneto 2014: Int Rev Hydr)

Cryptic species



Small microscopic animals
Almost no morphological features

Meiofauna

12,000 individuals sequenced

55 taxa

8 phyla

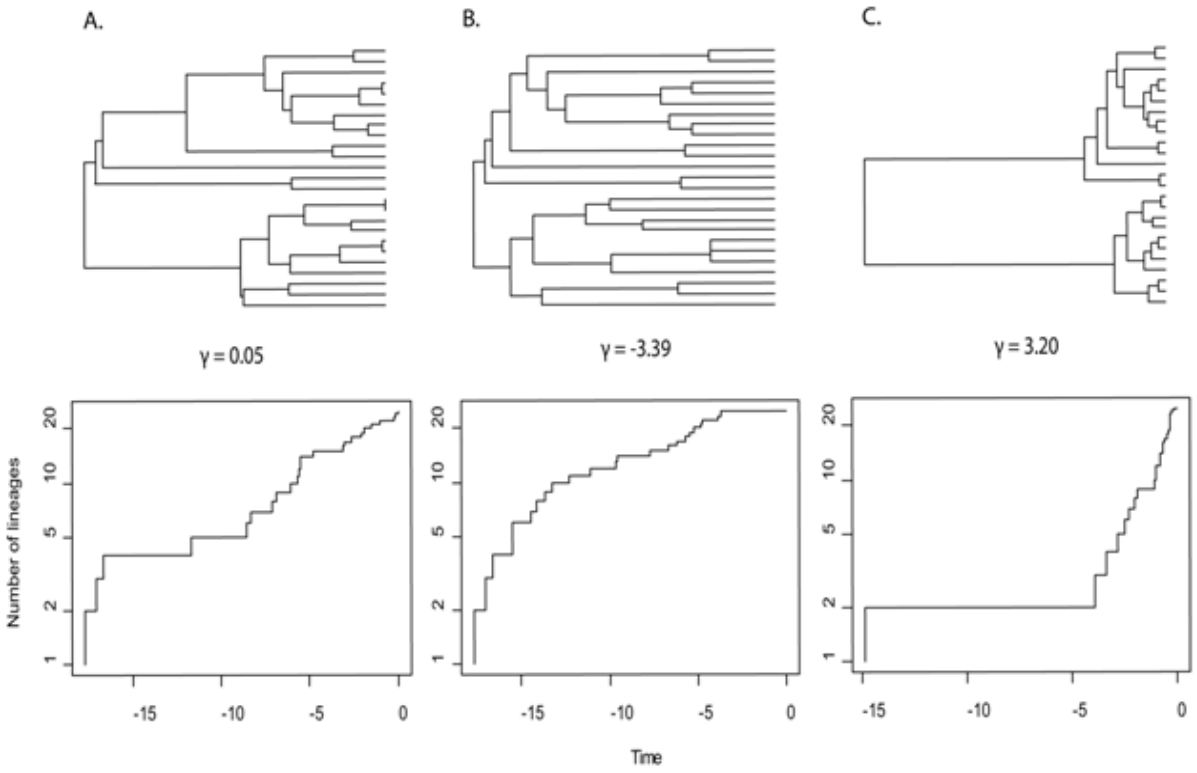
COI vs 18S

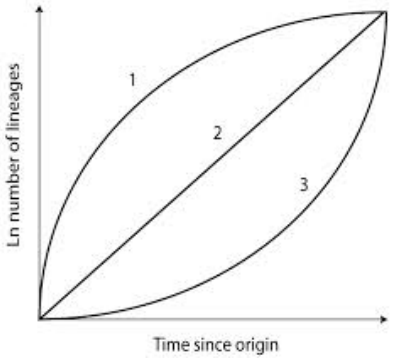
(Tang et al. 2012: PNAS)

(Felsenstein 1981: Evolution)

Differences between sexuals and asexuals?

Lineage-Through-Time plots and gamma statistics

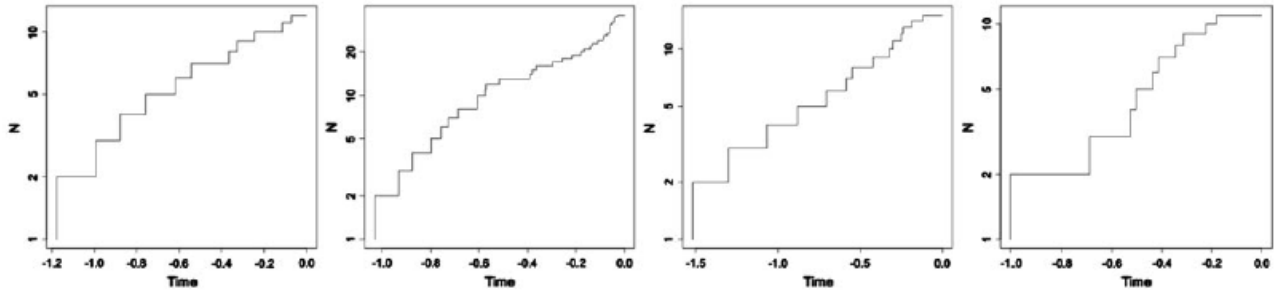




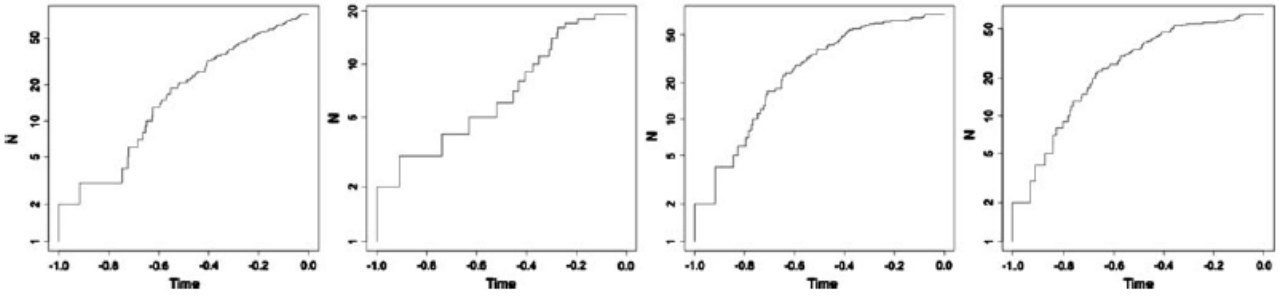
(Pybus & Harvey 2000: Proc R S London B)

Differences between sexuals and asexuals?

Monogononts
(with sex)



Bdelloids
(without sex)

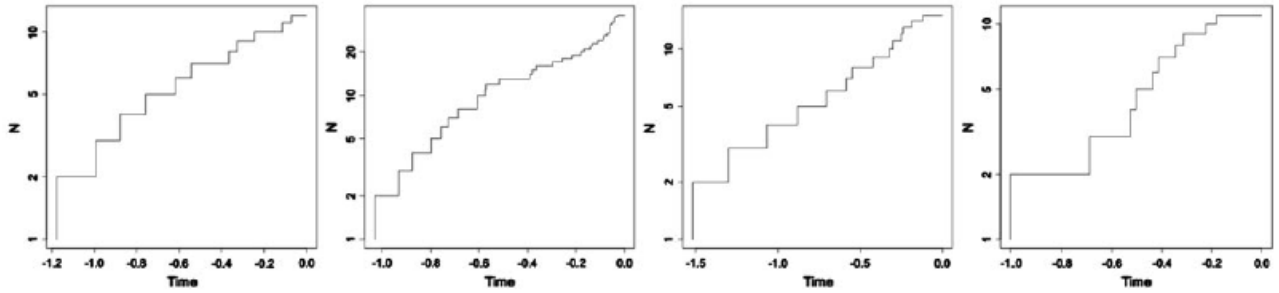


(Fontaneto et al. 2012: Evol Biol)

Differences between sexuals and asexuals?

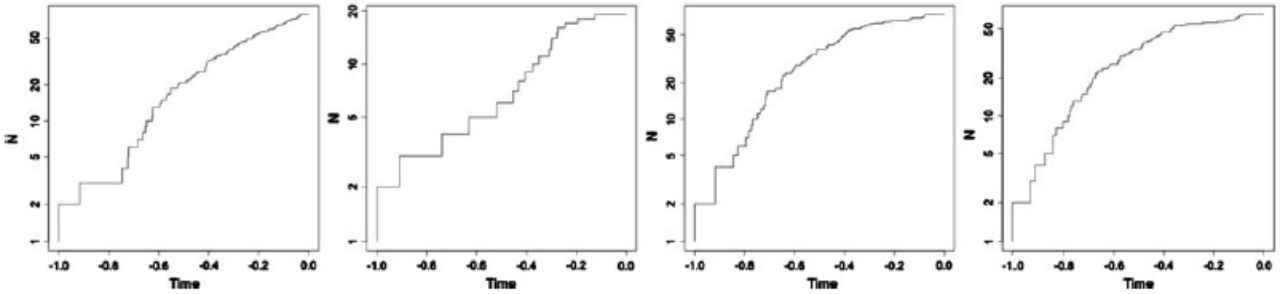
Monogononts
(with sex)

CONSTANT



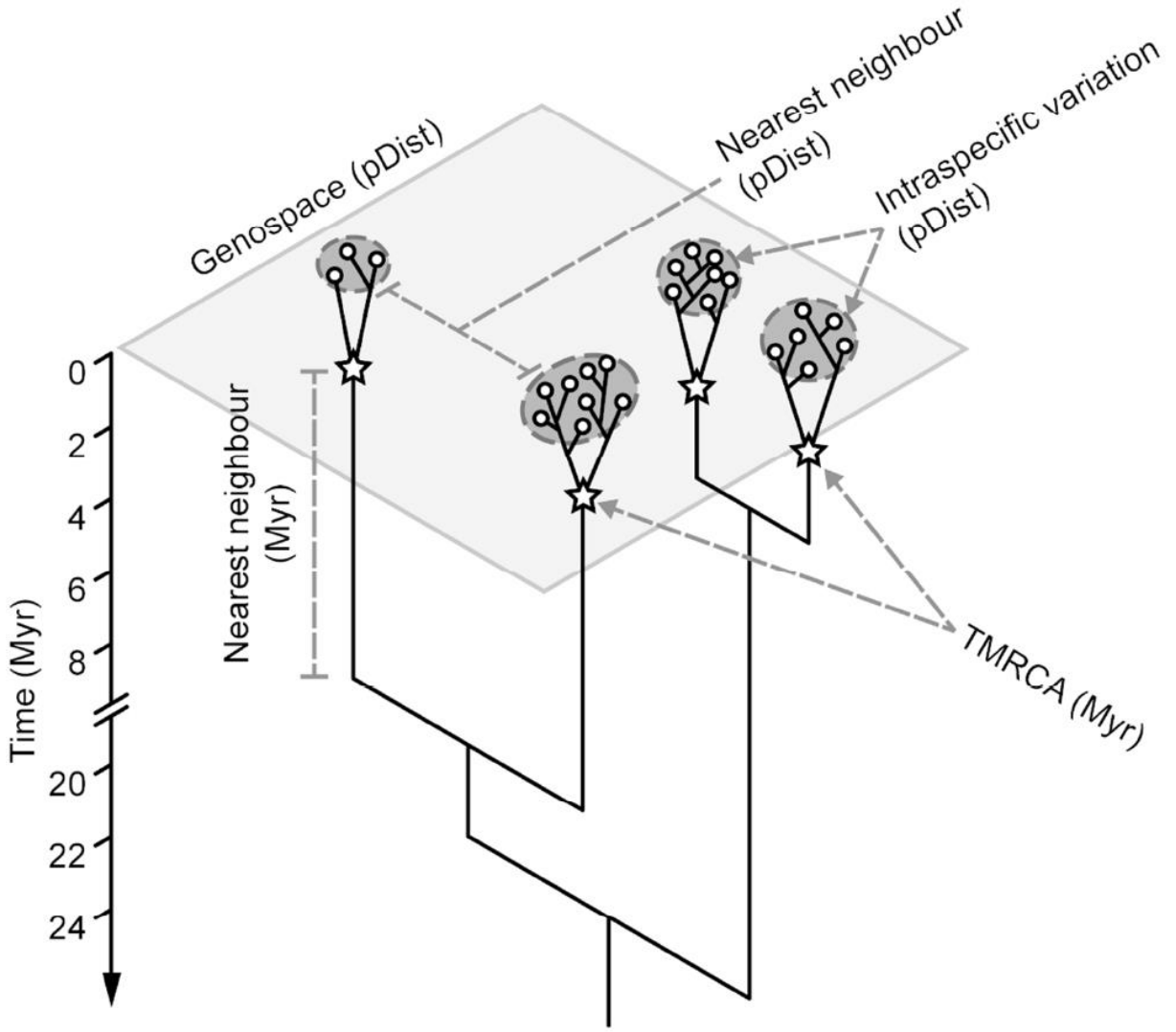
Bdelloids
(without sex)

DECREASING



(Fontaneto et al. 2012: Evol Biol)

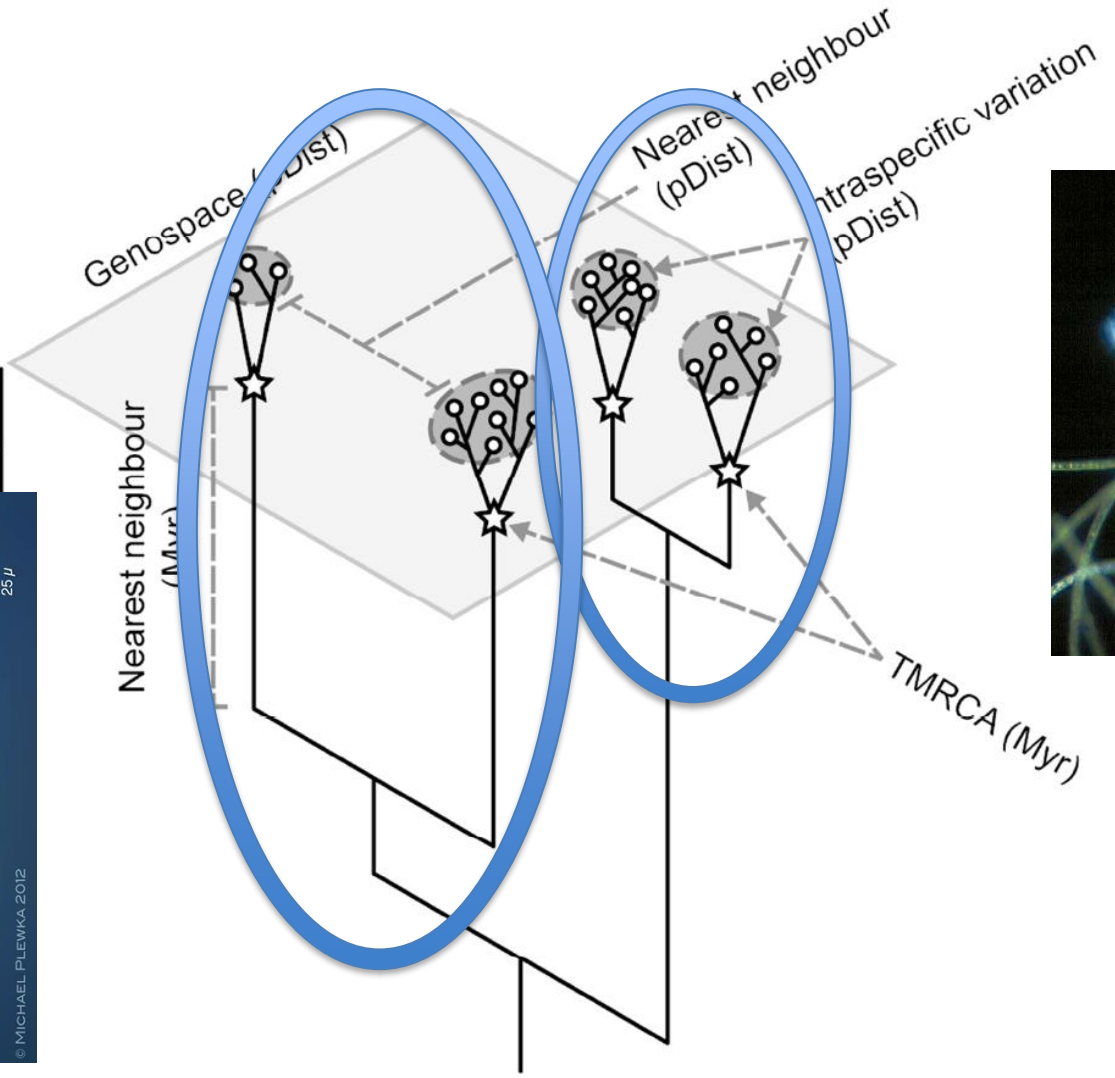
Differences between sexuals and asexuals?



(Tang et al. 2014: Evolution)

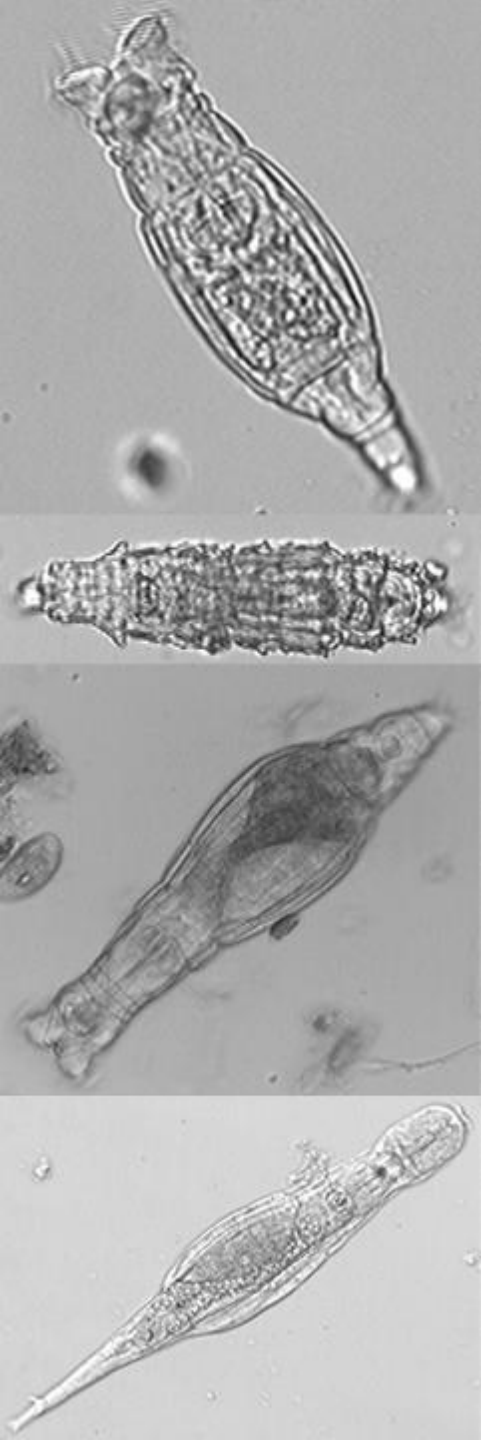
Differences between sexuals and asexuals?

Monogononts
(with sex)



Bdelloids
(without sex)

(Tang et al. 2014: Evolution)



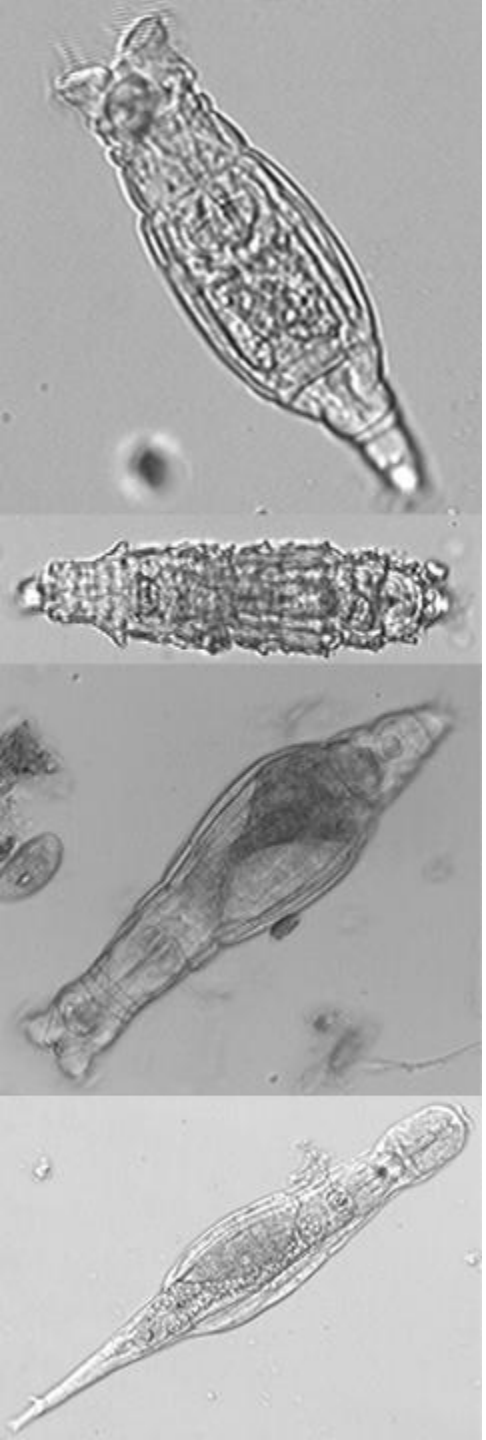
Three alternative hypotheses

1- Bdelloid rotifers have ‘hidden’ males -- NO

2- Bdelloid rotifers do not have species -- NO

3- Sex is not so important -- HINDRANCE

(Fontaneto & Barraclough 2015: Integr Comp Biol)



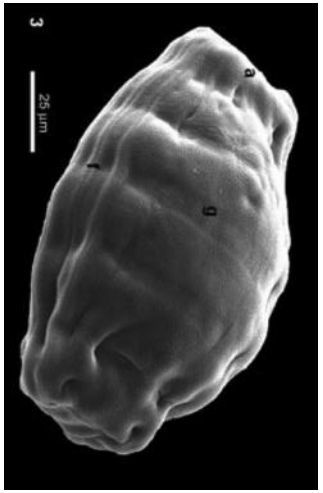
Bdelloid rotifers: other peculiarities

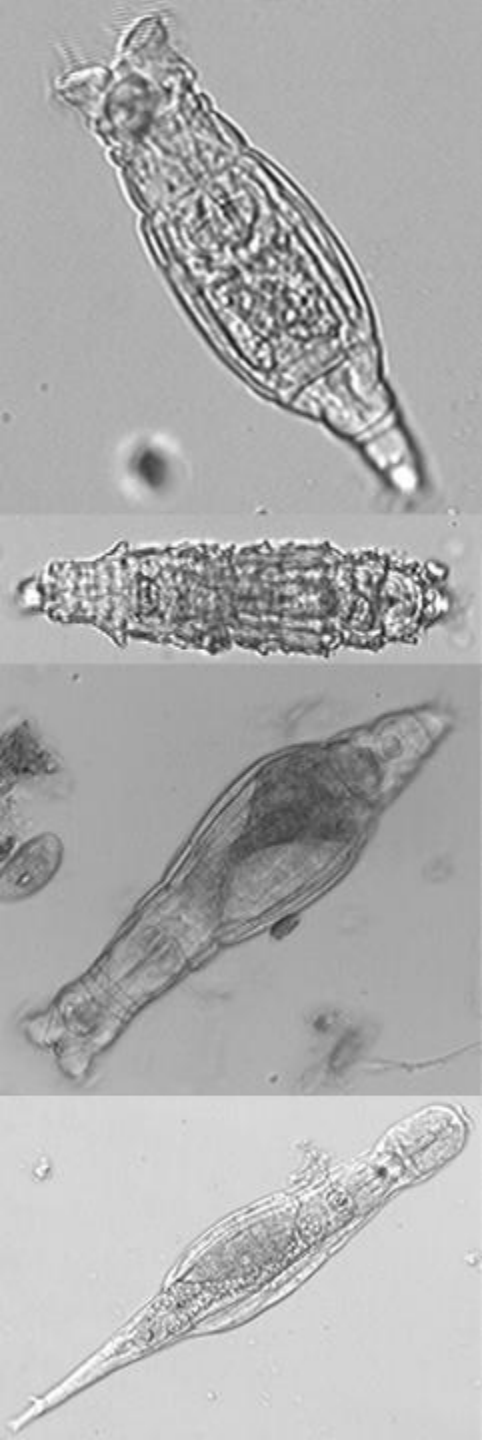
Able to survive desiccation and freezing

active

retracted

desiccated





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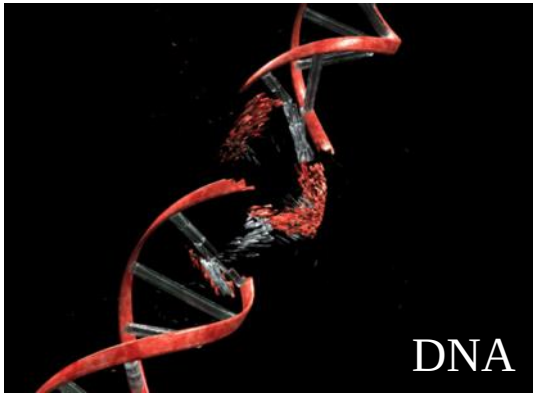
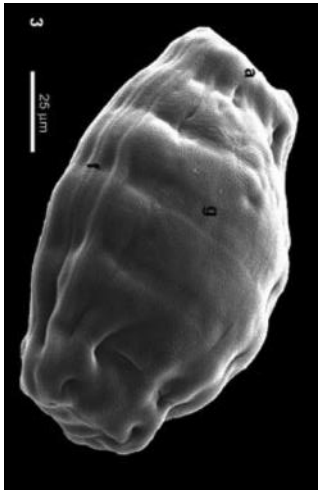
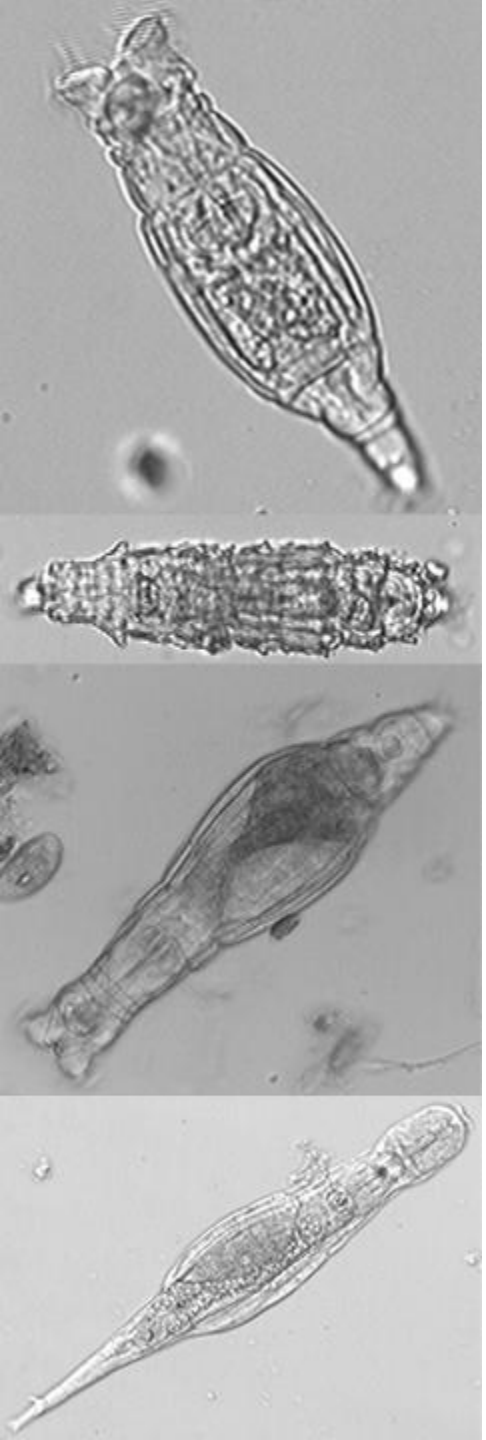


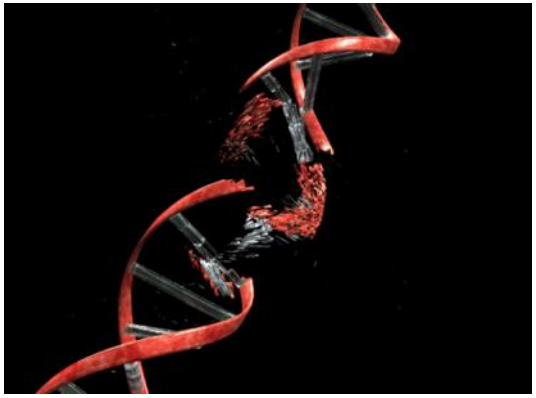
desiccated

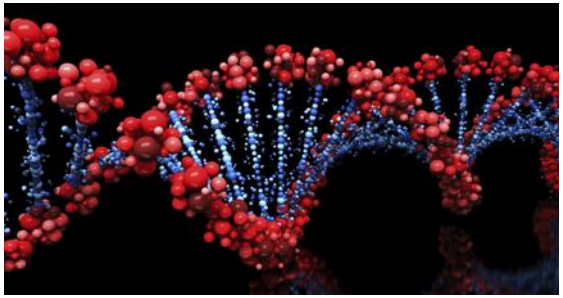




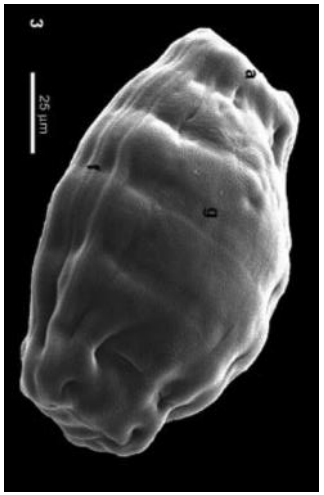
Bdelloid rotifers: other peculiarities

DNA repair mechanisms



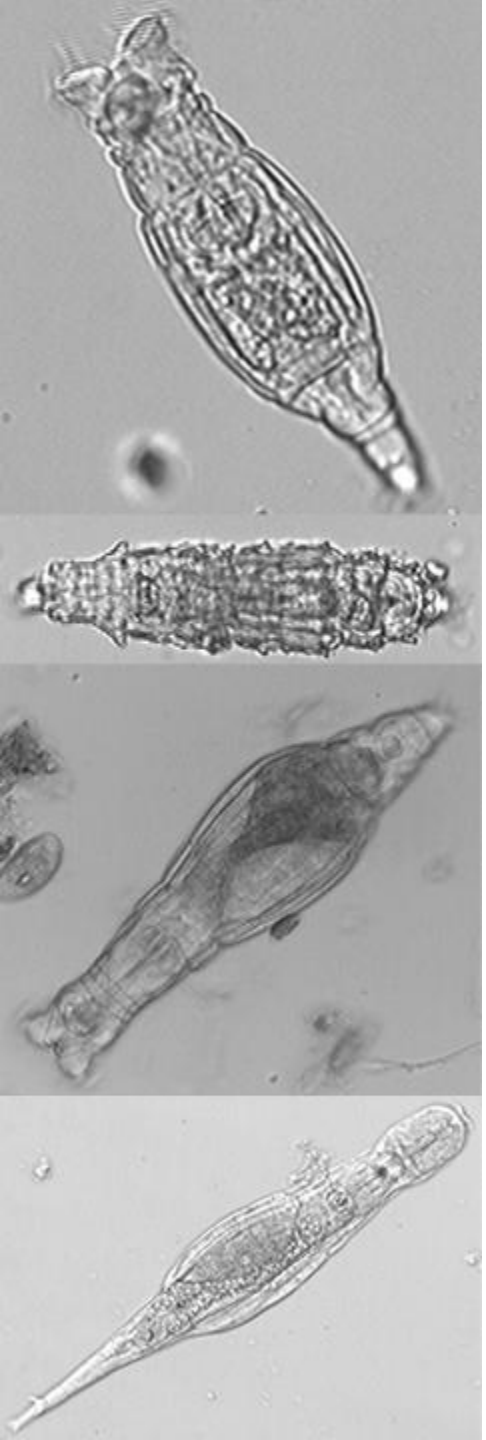


desiccated



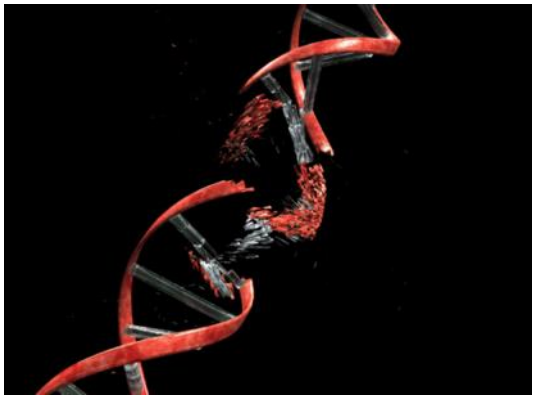
in water

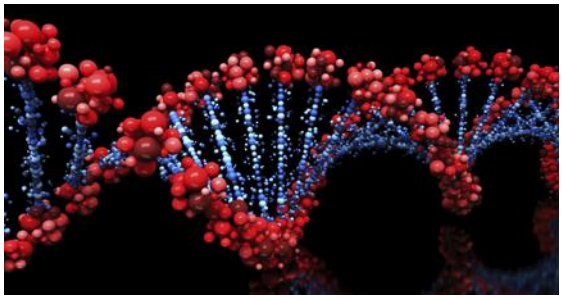
active

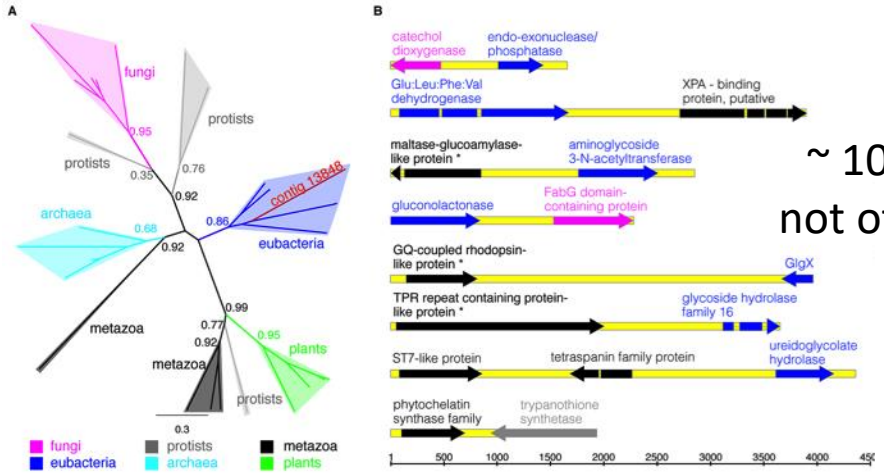


Bdelloid rotifers: other peculiarities

‘foreign’ DNA



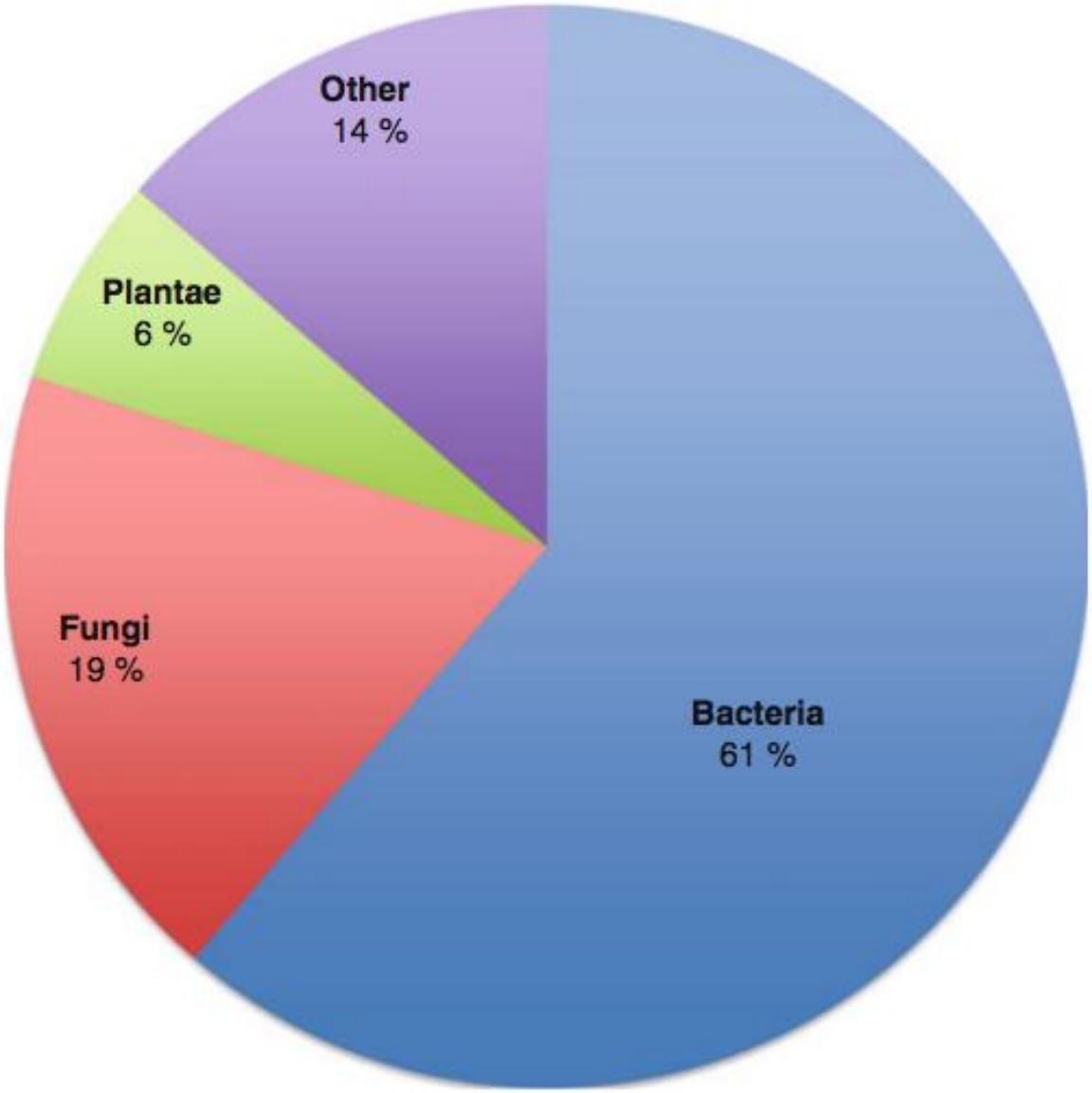




~ 10% of the genome not of metazoan origin

(Flot et al. 2013: Nature)

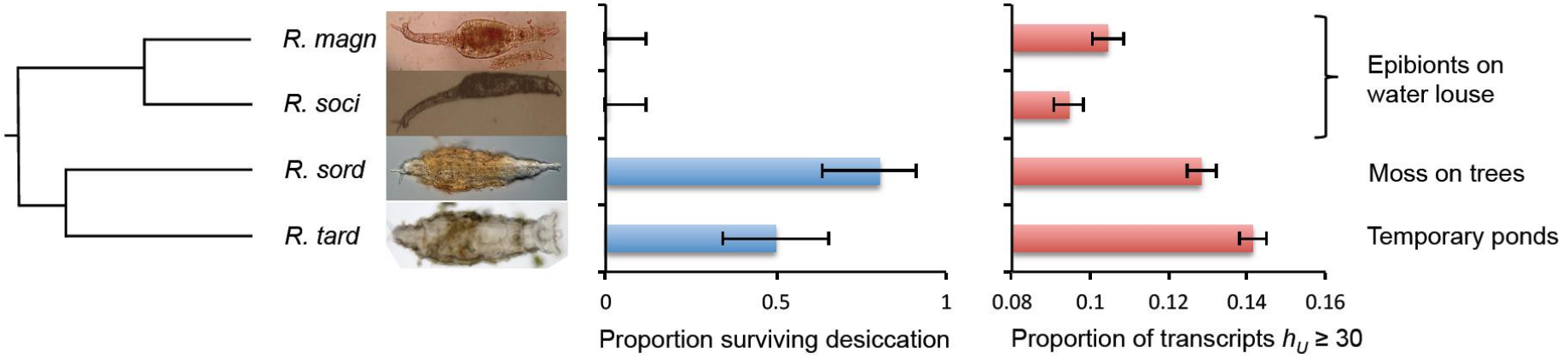
BUT: Horizontal Gene Transfer…



In bdelloids
8-10% of the genome
not of Metazoa

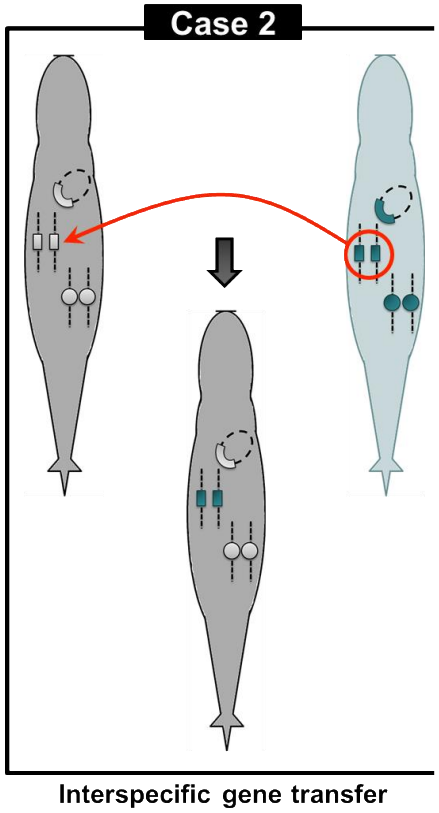
(Hespeels et al. 2014: Evol Biol)

More common during desiccation…



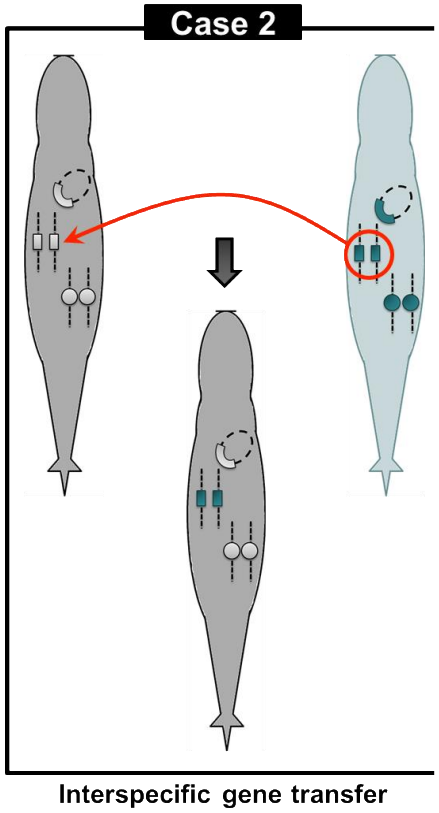
(Eyres et al. 2015: BMC Biol)

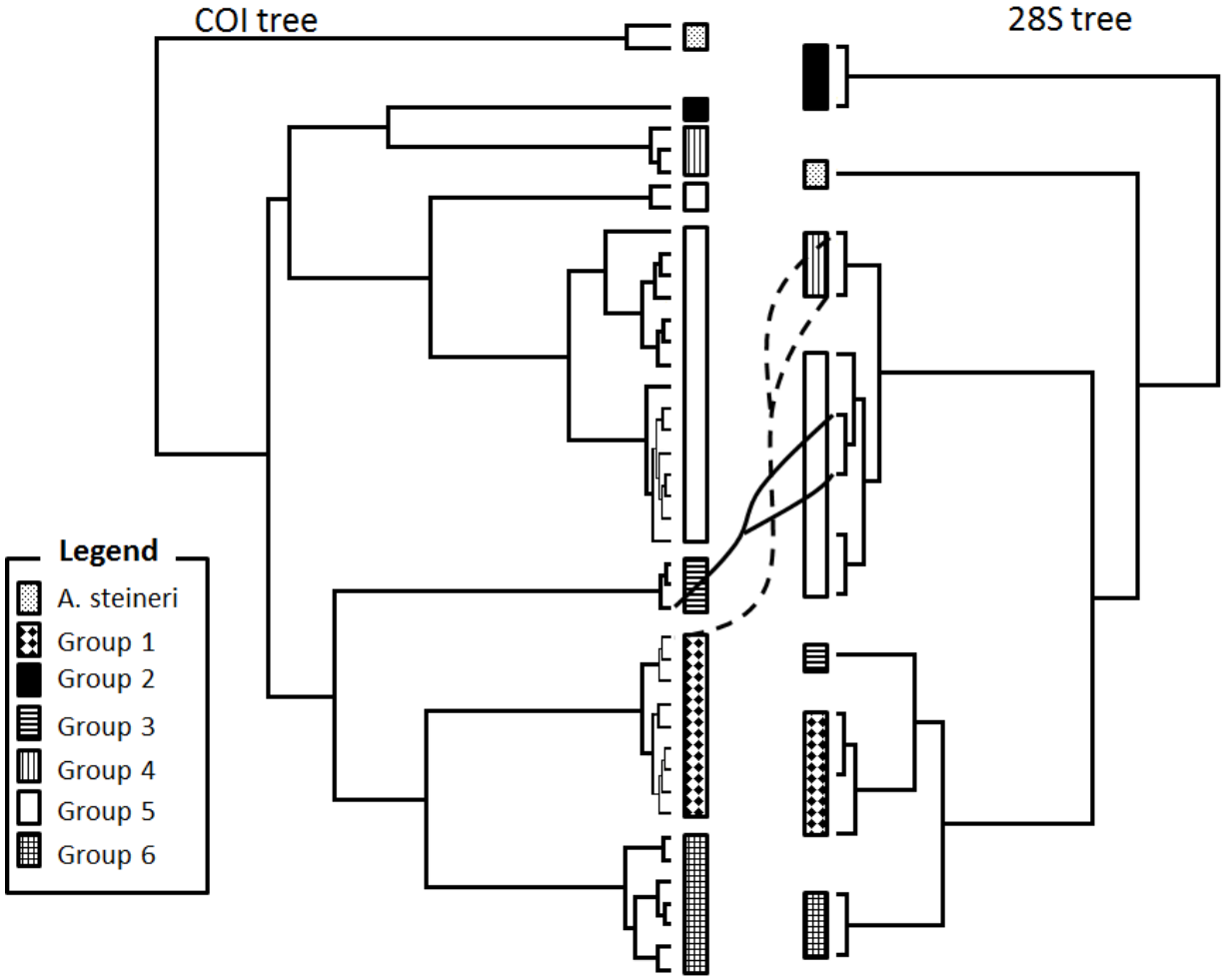
Can HGT happen between species?



(Debortoli et al. 2016: Curr Biol)

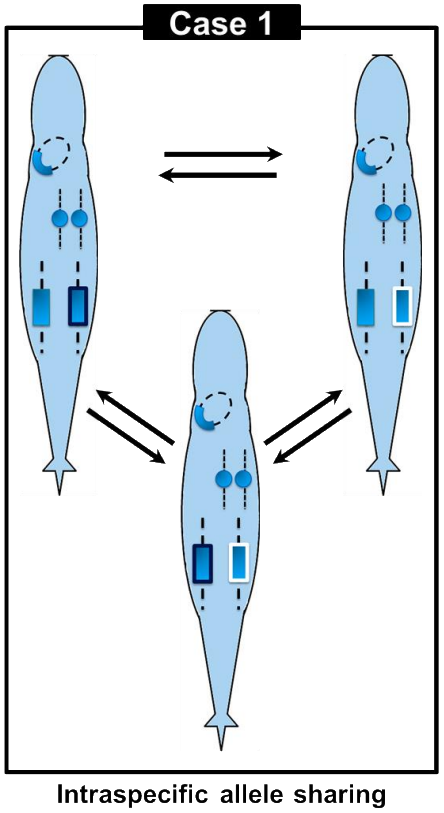
Can HGT happen between species?





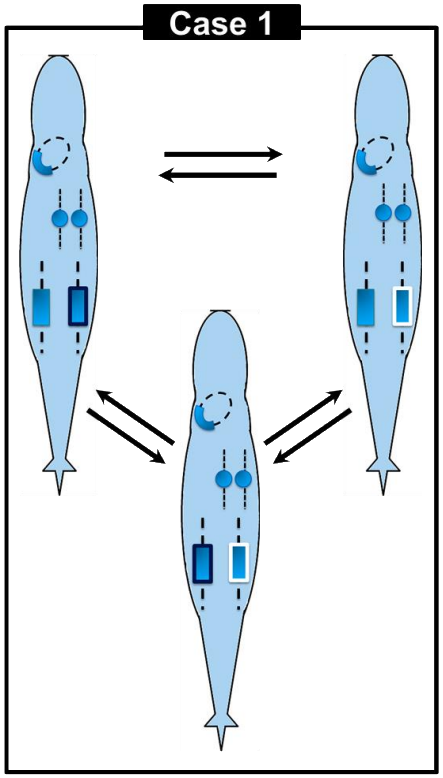
(Debortoli et al. 2016: Curr Biol)

Can HGT happen within species?

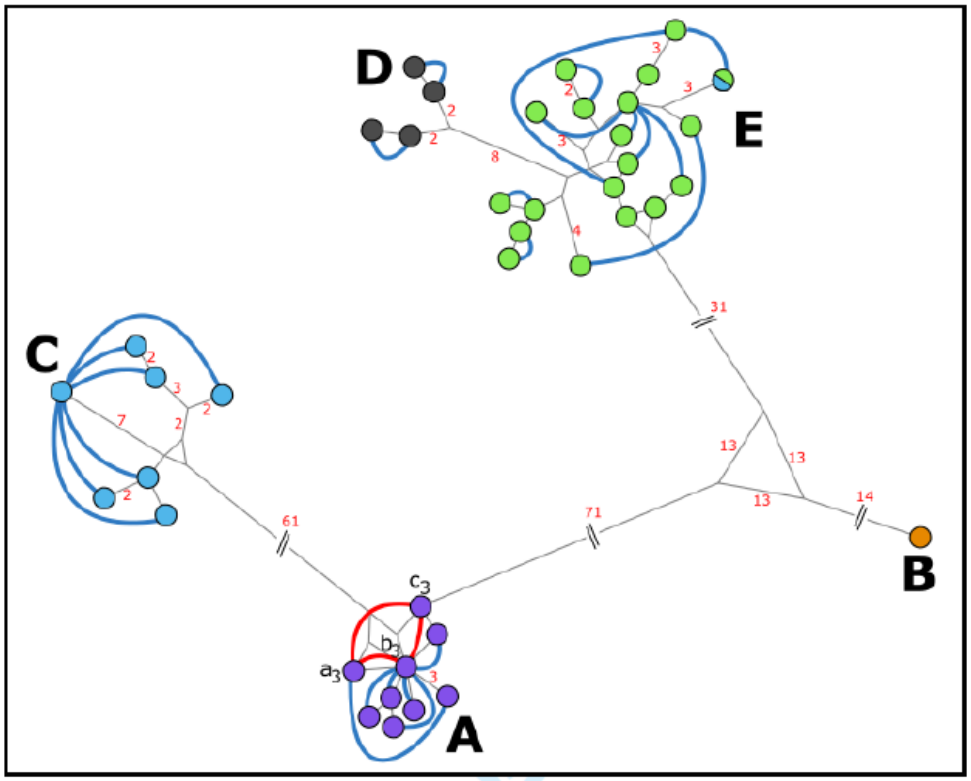


(Signorovitch et al. 2015: Genetics)
(Debortoli et al. 2016: Curr Biol)

Can HGT happen within species?



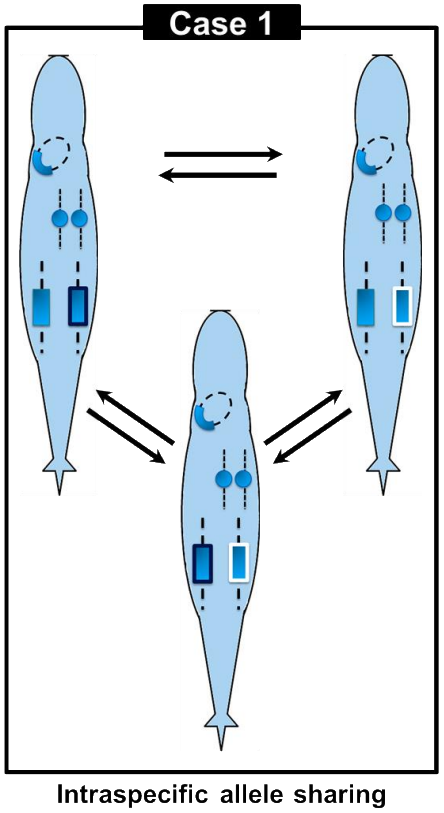
Intraspecific allele sharing

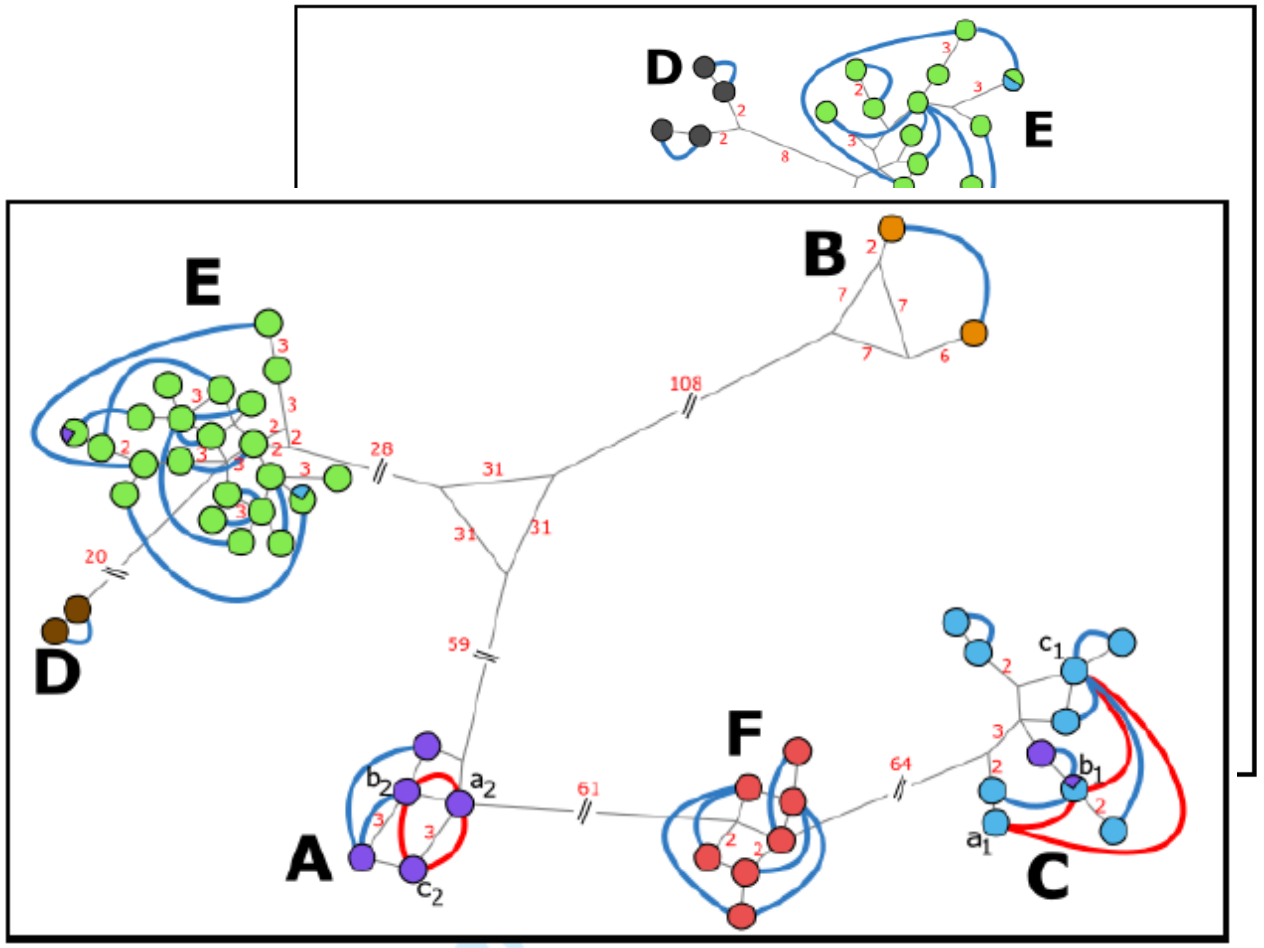


Nu1054 marker

(Signorovitch et al. 2015: Genetics)
(Debortoli et al. 2016: Curr Biol)

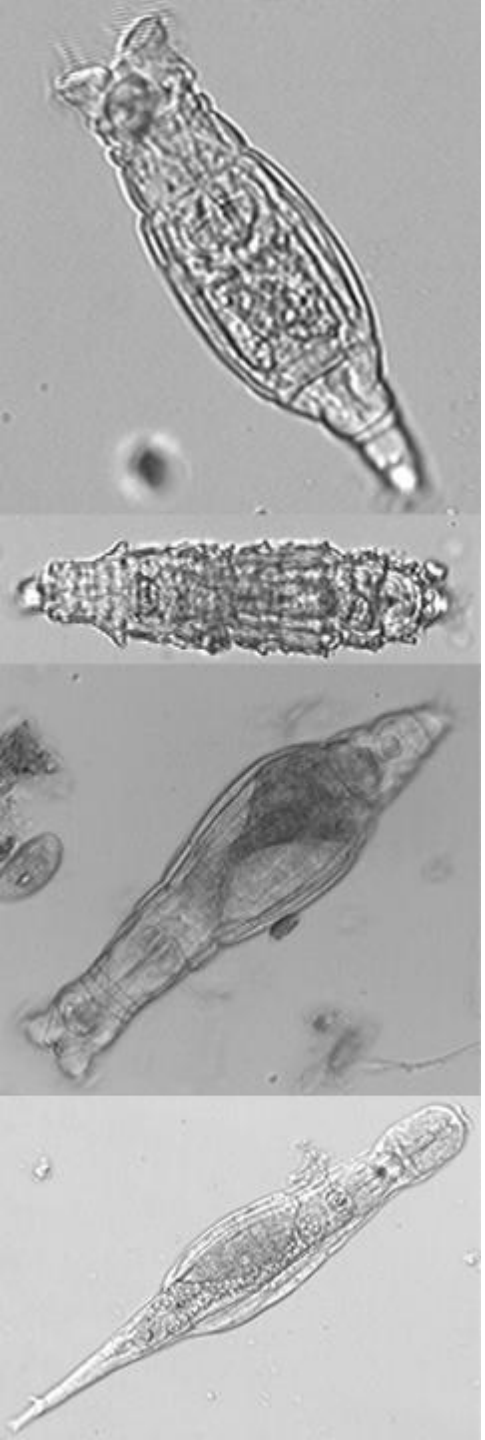
Can HGT happen within species?





EPIC25 marker

(Signorovitch et al. 2015: Genetics)
(Debortoli et al. 2016: Curr Biol)



Three alternative hypotheses

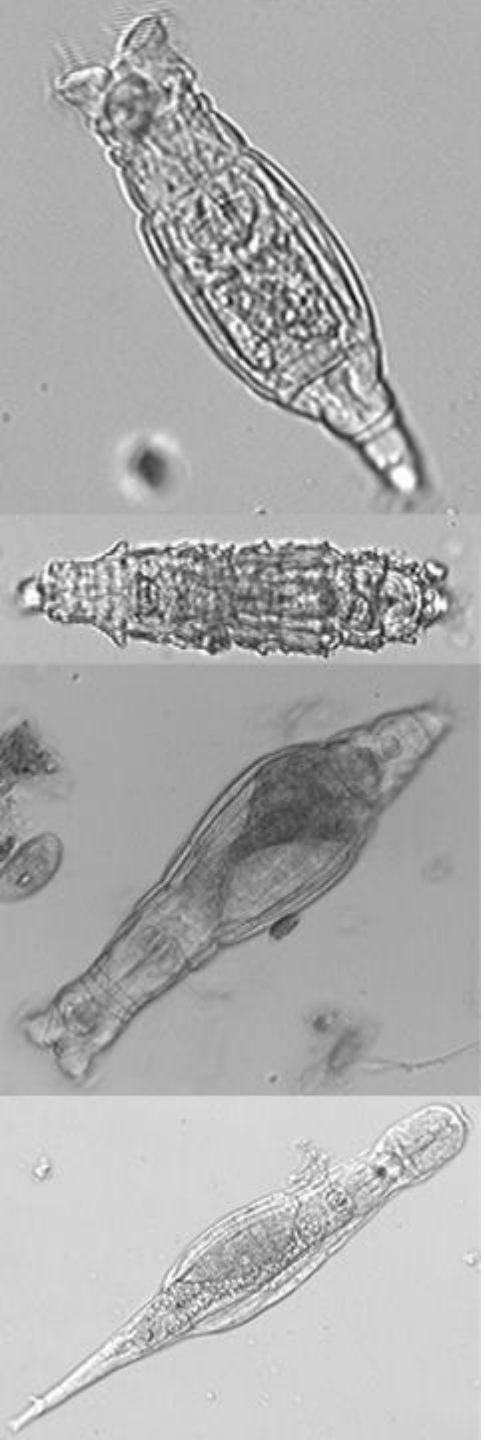
1- Bdelloid rotifers have ‘hidden’ males -- NO

2- Bdelloid rotifers do not have species -- NO

3- Sex is not so important -- IT DEPENDS…

…alternative ways of sex!

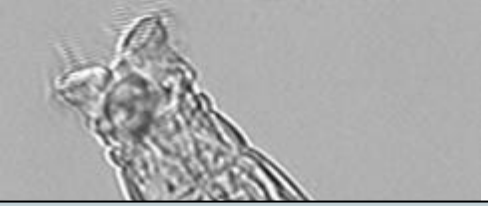
(Fontaneto & Barraclough 2015: Integr Comp Biol)



1- Genome -> evidence of asexuality

2- Desiccation -> more HGT

3- Population genetics -> HGT within species



1- Genome -> evidence of asexuality NO

nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-020-19614-y OPEN

Check for updates

Genomic signatures of recombination in a natural population of the bdelloid rotifer *Adineta vaga*

Olga A. Vakhrusheva[1✉], Elena A. Mnatsakanova[2], Yan R. Galimov[3], Tatiana V. Neretina[4,5,6], Evgeny S. Gerasimov[4,5,7], Sergey A. Naumenko[5,8], Svetlana G. Ozerova[3,13], Arthur O. Zalevsky[9,10], Irina A. Yushenova[11], Fernando Rodriguez[11], Irina R. Arkhipova[11], Aleksey A. Penin[5], Maria D. Logacheva[1,5,6], Georgii A. Bazykin[1,5] & Alexey S. Kondrashov[6,12]

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PLOS | BIOLOGY

RESEARCH ARTICLE

Comparative genomics of bdelloid rotifers: Insights from desiccating and nondesiccating species

Reuben W. Nowell[1]*, Pedro Almeida[1¤a], Christopher G. Wilson[1], Thomas P. Smith[1], Diego Fontaneto[2], Alastair Crisp[3¤b], Gos Micklem[4], Alan Tunnacliffe[3], Chiara Boschetti[3,5☯]*, Timothy G. Barraclough[1☯]*

1- Genome -> evidence of asexuality **NO**

2- Desiccation -> more HGT **NO**

3- Population genetics -> HGT within species **NO**

CellPress

Current Biology
Report

Cross-Contamination Explains "Inter and Intraspecific Horizontal Genetic Transfers" between Asexual Bdelloid Rotifers

Christopher G. Wilson,[1,2,*] Reuben W. Nowell,[1] and Timothy G. Barraclough[1]

Rotaria macrura (Schrank 1803)

The Evolutionary Biology of Species

Timothy G. Barraclough

OSEE

Oxford Series in Ecology and Evolution

2019

nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-020-19614-y OPEN

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2020

SCIENCE ADVANCES | RESEARCH ARTICLE

GENETICS

Chromosome-level genome assembly reveals homologous chromosomes and recombination in asexual rotifer *Adineta vaga*

Paul Simion[1*†], Jitendra Narayan[1†], Antoine Houtain[1], Alessandro Derzelle[1], Lyam Baudry[2,3], Emilien Nicolas[1,4], Rohan Arora[1,4], Marie Cariou[1,5], Corinne Cruaud[6], Florence Rodriguez Gaudray[7], Clément Gilbert[8], Nadège Guiglielmoni[7], Boris Hespeels[1], Djampa K. L. Kozlowski[9], Karine Labadie[6], Antoine Limasset[10], Marc Llirós[1,11], Martial Marbouty[2], Matthieu Terwagne[1], Julie Virgo[1], Richard Cordaux[12], Etienne G. J. Danchin[9], Bernard Hallet[13], Romain Koszul[2], Thomas Lenormand[14], Jean-Francois Flot[7,15*], Karine Van Doninck[1,4*]

2021

CORRECTED PROOF

Genomic signature of sexual reproduction in the bdelloid rotifer *Macrotrachella quadricornifera*

Veronika N Laine, Timothy B Sackton, Matthew Meselson ✉

Genetics, iyab221, https://doi.org/10.1093/genetics/iyab221

Published: 09 December 2021 **Article history** ▾

2022

Rotaria macrura (Schrank 1803)

Evolution and speciation without sex in bdelloid rotifers?

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