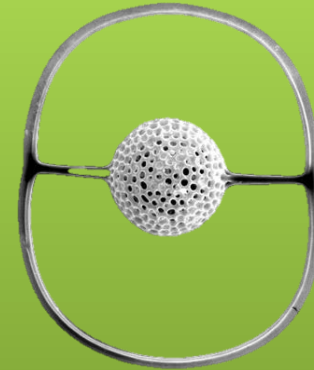
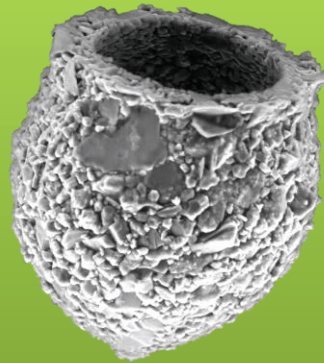


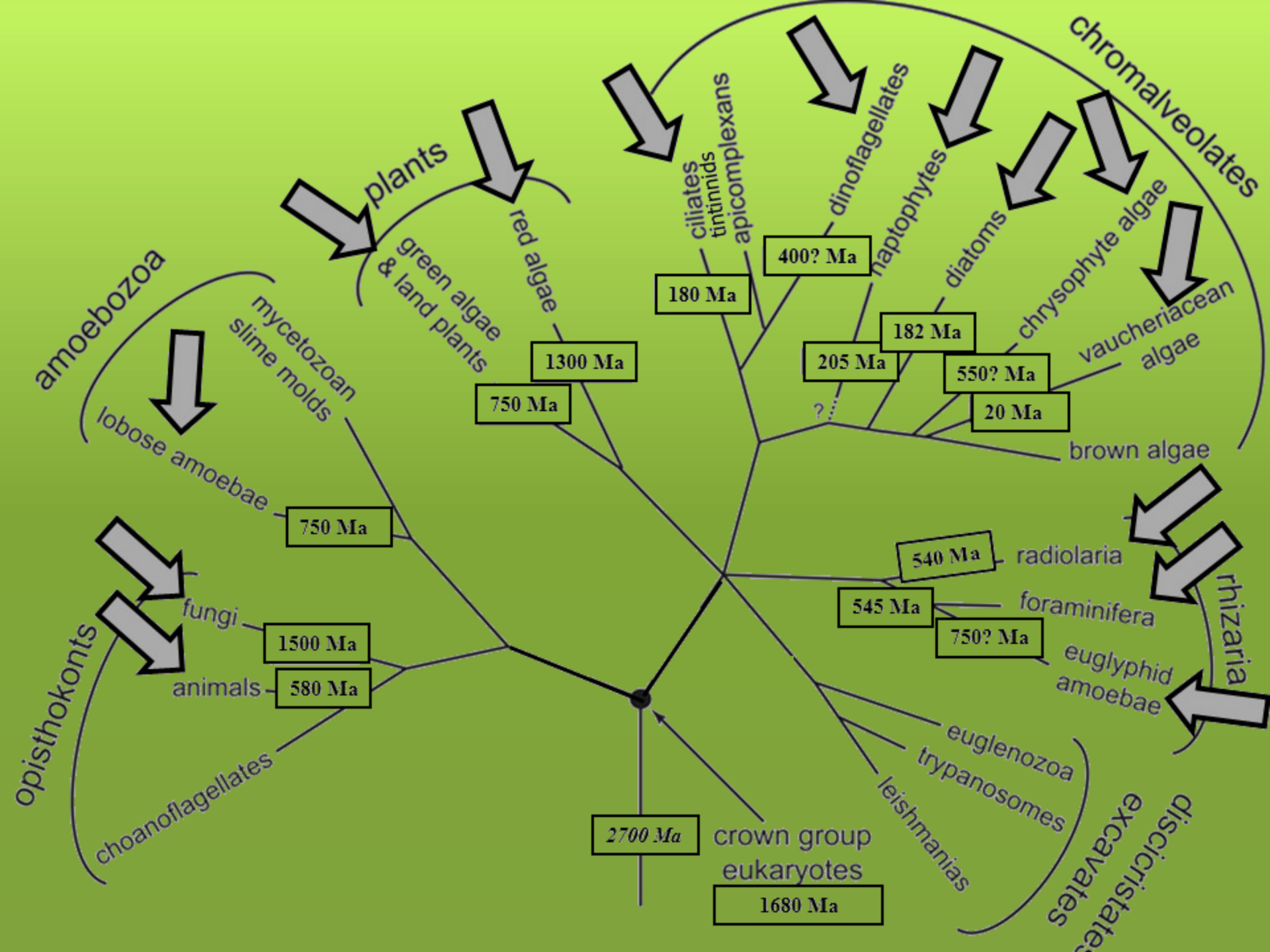
# Origin of Protists & Metazoans: Fossil & Genomic Evidence



**Jere H. Lipps<sup>1</sup>, Yoshi Ishitani<sup>2</sup>,  
Yurika Ujiie<sup>3</sup>, and Michele Weber<sup>4</sup>**

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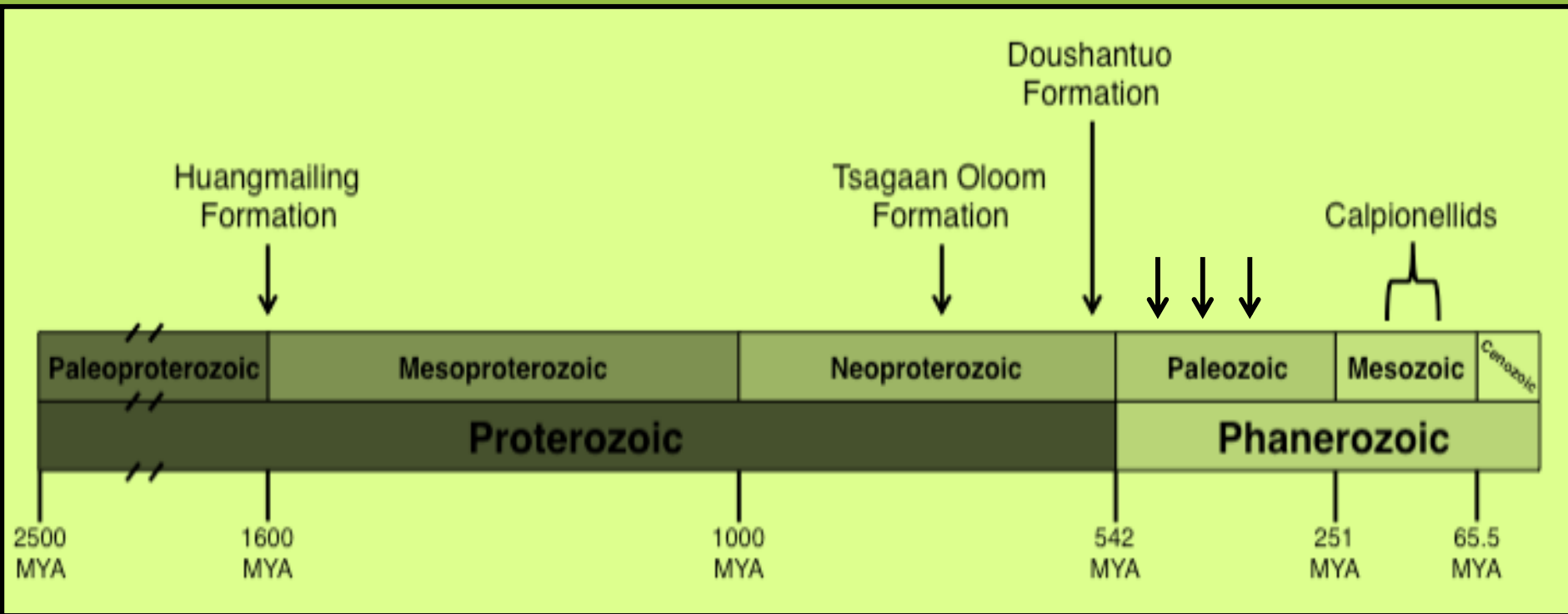
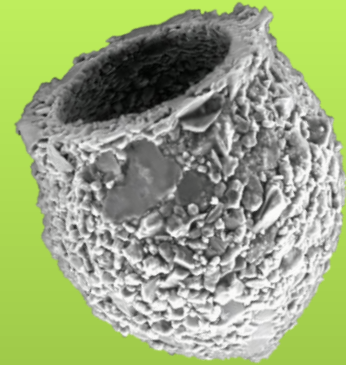
# **Problem: Molecular Clock Estimates Exceed Fossil Dates**

**Forams: 800 vs 545 my**

## **Hypotheses**

- 1. Small populations.\***
- 2. Widely spaced geographically.\***
- 3. Absence of hard parts.\***
- 4. Failure of hard parts to preserve.\***
- 5. Undiscovered.\***
- 6. Incorrect age assignments for the fossils.**
- 7. Molecular clock estimates problematic due to insufficient taxonomic sampling & fewer gene datasets.**

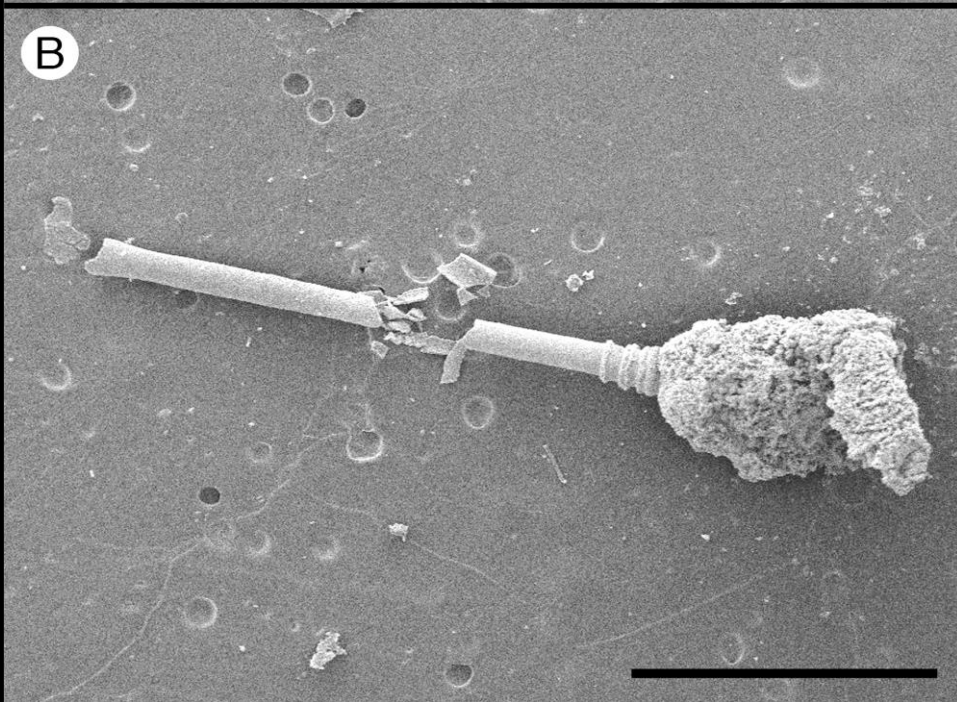
# Tintinnids?





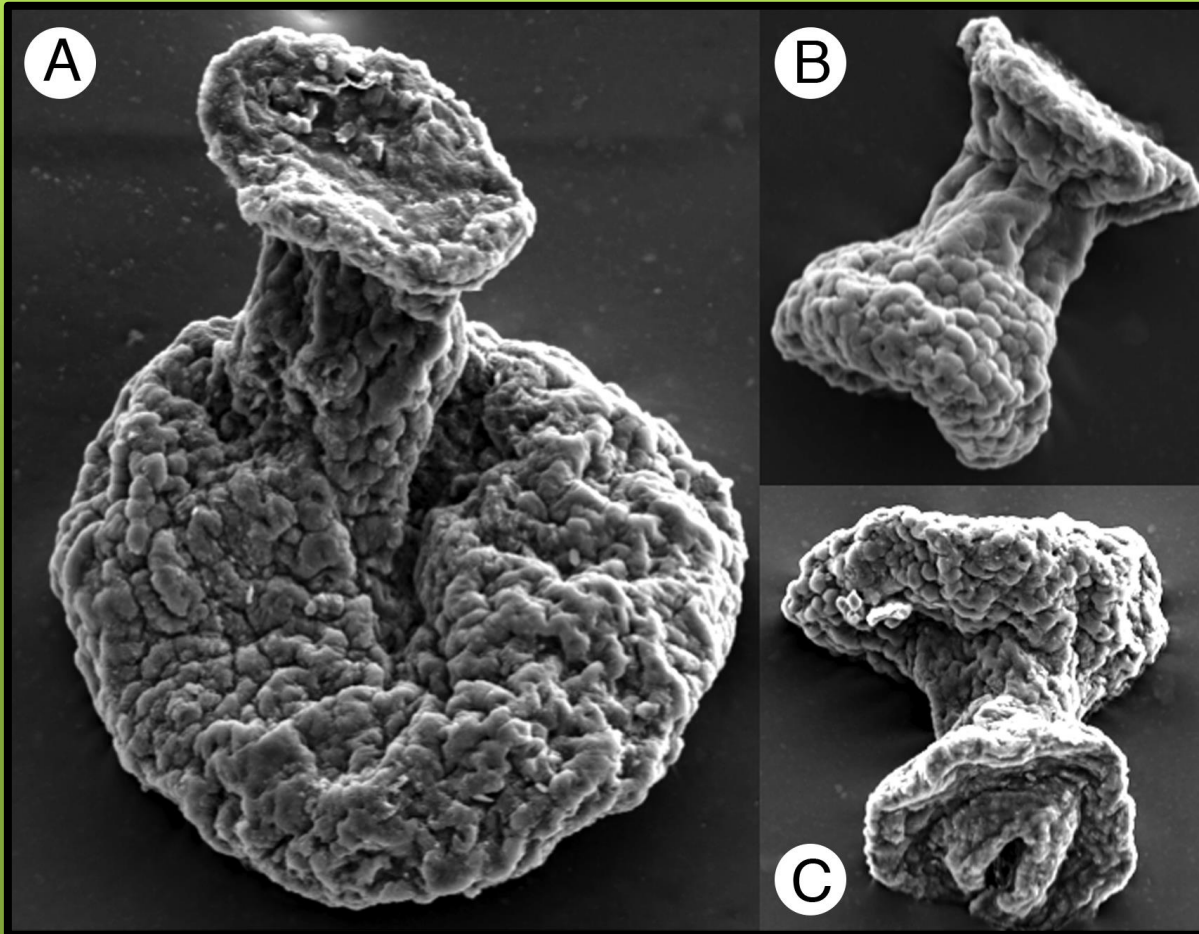


**Tintinnids**  
**= metamorphic**  
**shards/contamination**



**1600 mya**  
**Mesoproterozoic**  
**Huangmailing Formation**  
**(China)**

**Li & Zhan, 2006**  
**Li et al., 2009**



# Tintinnids = algae?

635-715 mya  
Tsagaan Oloom  
Formation  
(Mongolia)

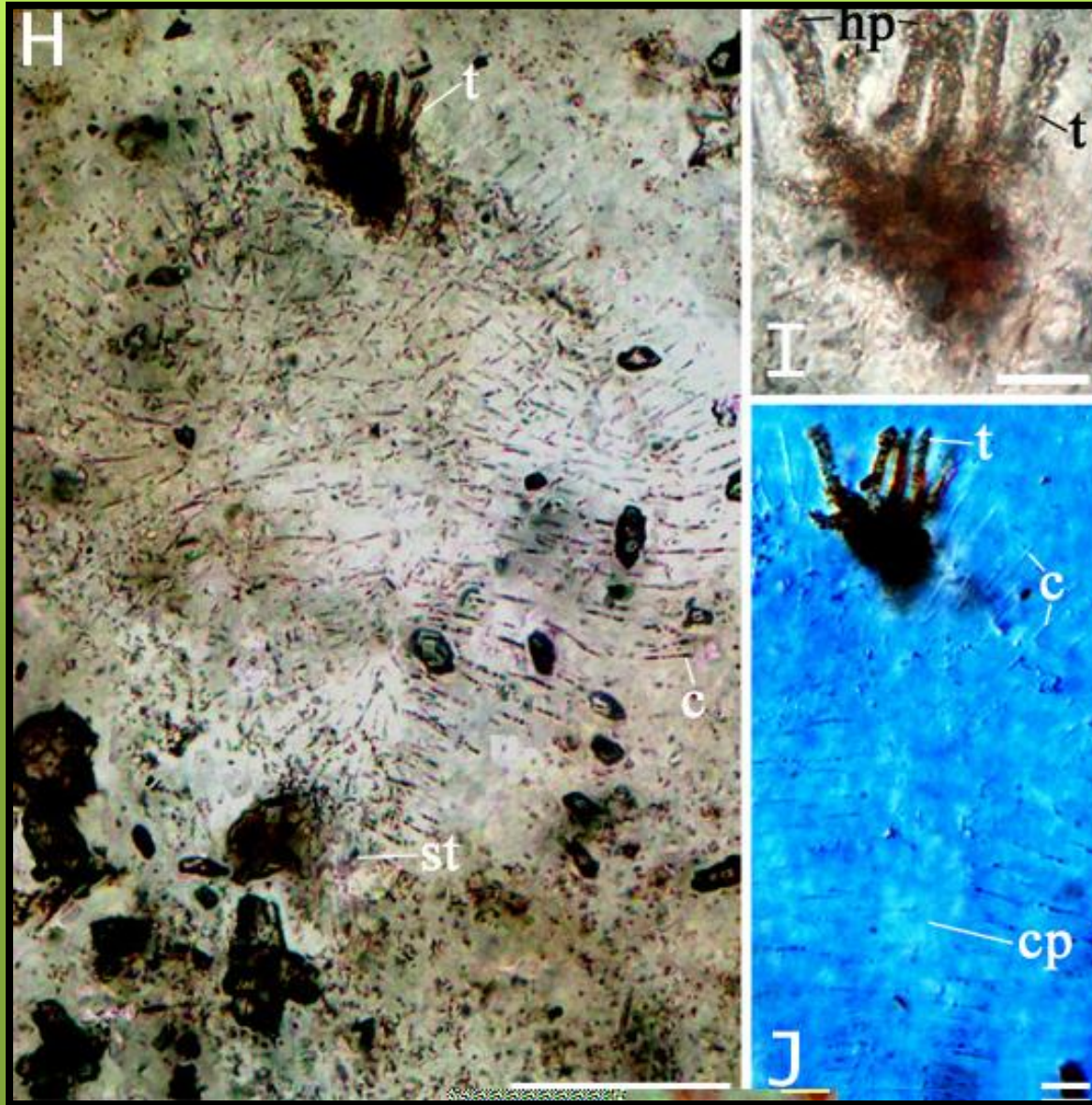
Bosak et al. (2011)



# Ciliate Suctorian = Acritarch

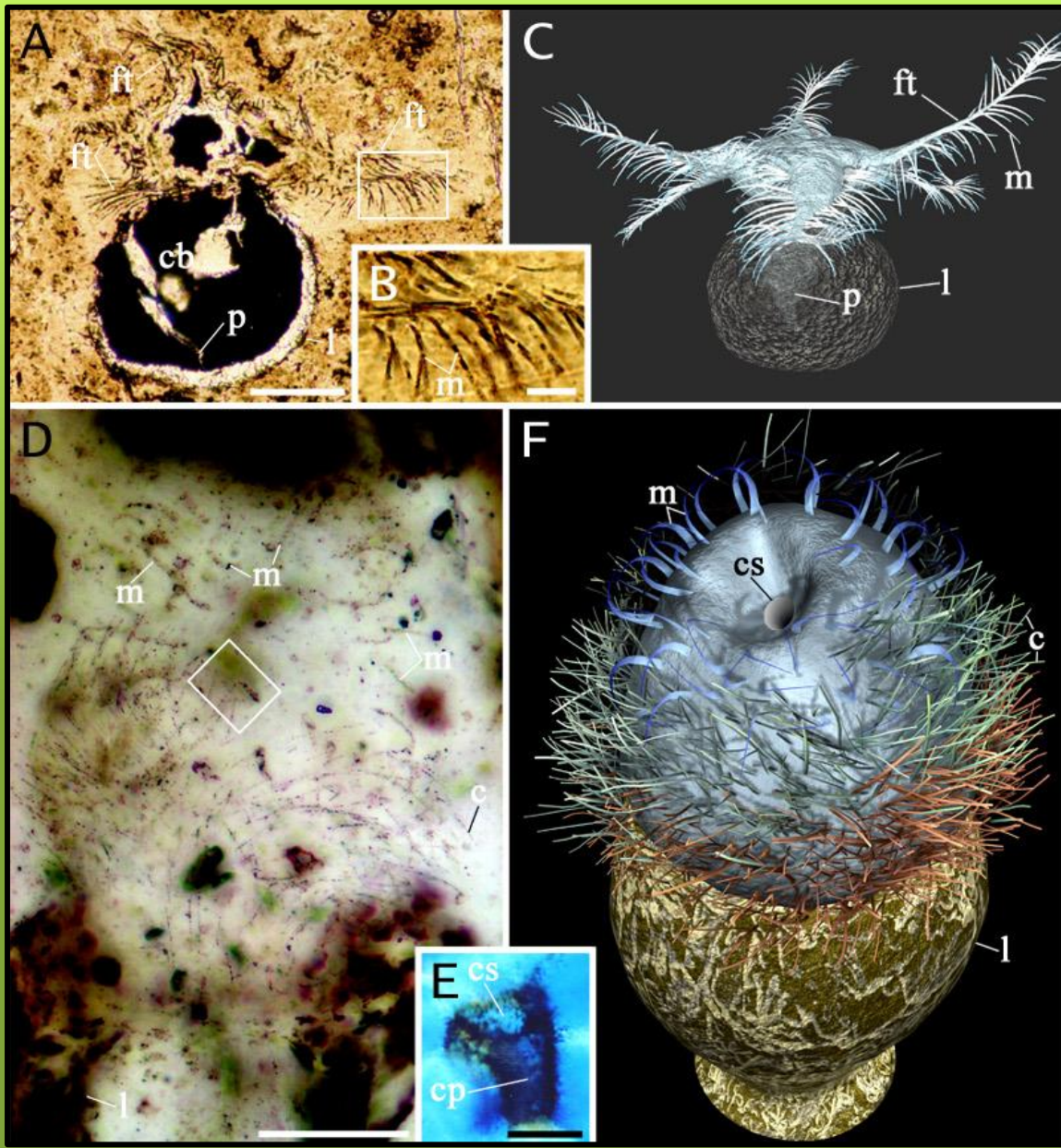
580 mya  
Wengan Phosphate  
Member  
Doushantou  
Formation  
(China)

Li, Chen,  
Lipps, Gao,  
Chi & Wu 2007



*Yonyangella ovalis*





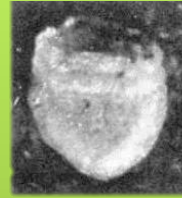
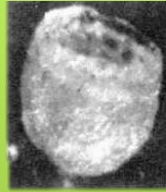
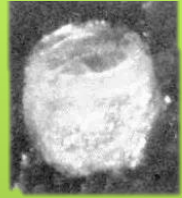
# Tintinnids = Acritarchs

580 mya  
Wengan Phosphate  
Member  
Doushantou  
Formation  
(China)

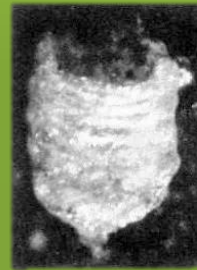
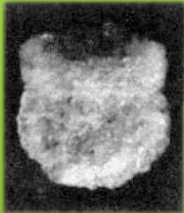
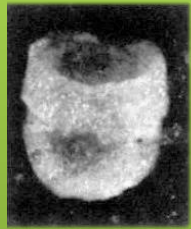
Dunthorn, Lipps, & Stoeck  
2010

*Eotintinnopsis pinniforma* &  
*Wujiangella beidoushanesea*

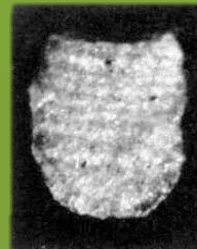




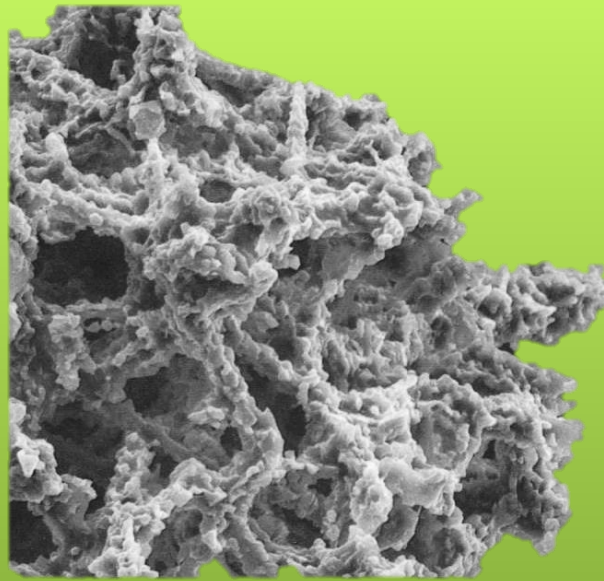
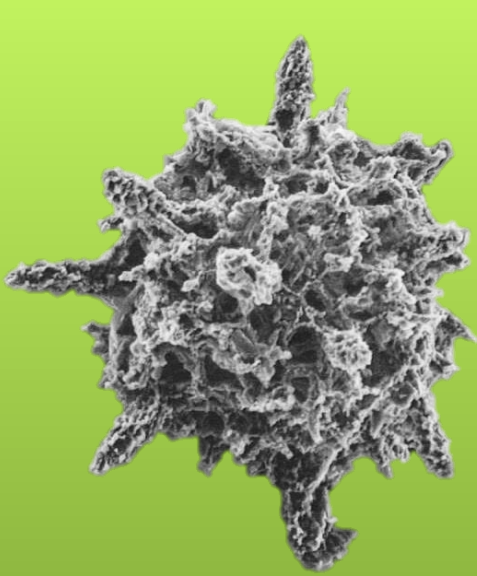
# Tintinnids: Cretaceous



Graneros Shale  
Wyoming,  
South Dakota,  
Colorado

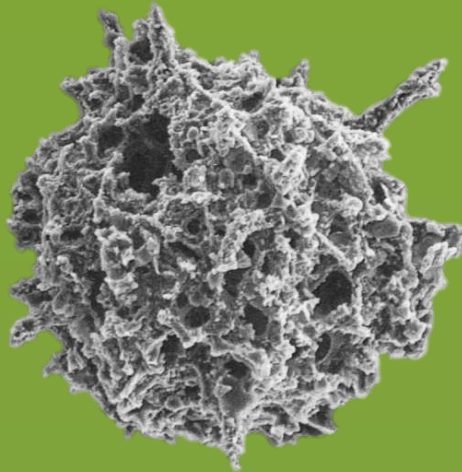
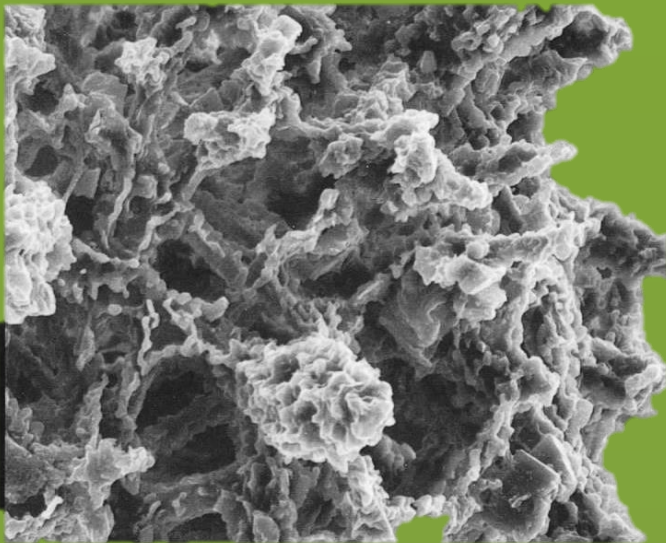


Eicher, 1965



# **Radiolaria: Cambrian**

**Hunan, China**



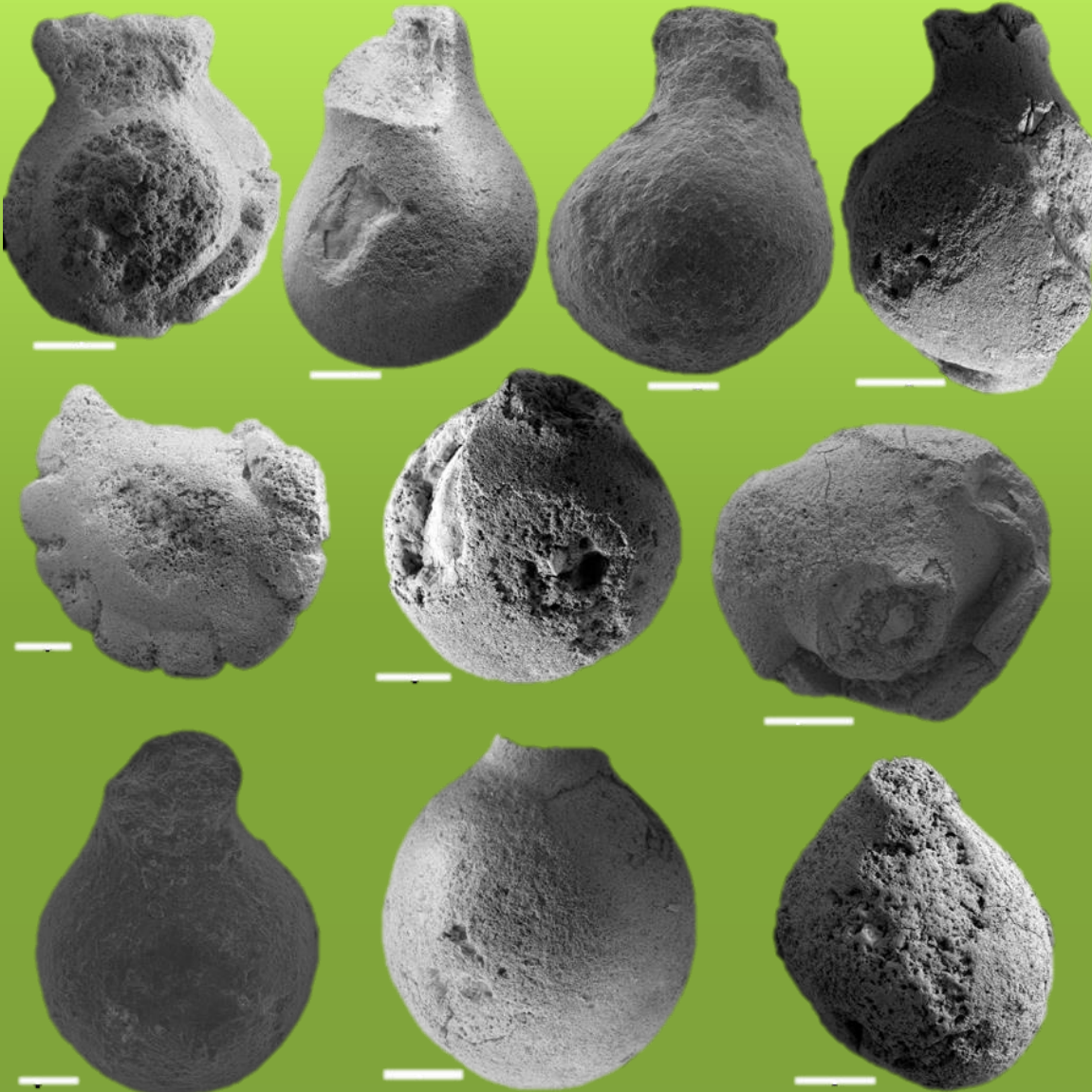
**Dong, Knoll & Lipps,  
1997**

# **Foraminifera = Thecamoebians**

**~550 mya**

**Late Ediacaran  
Dengying Formation  
(China)**

**Hua , Chen, Yuan,  
Xiao & Cai, 2010**



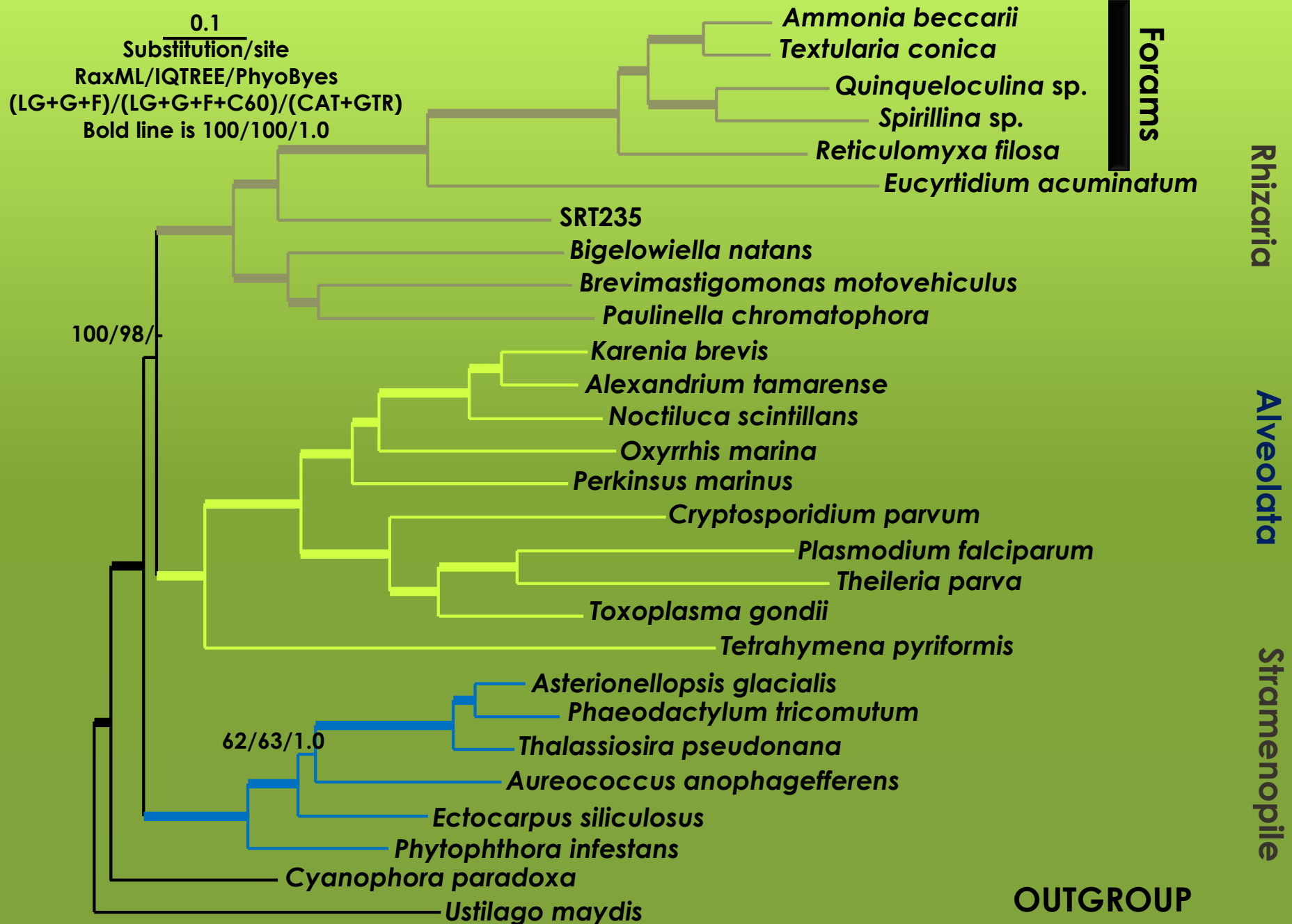


# Foraminifera: *Platysolenites*



**Lower Cambrian: Newfoundland**  
**Lipps & Rozanov, 1996**

# Molecular phylogeny (157 genes)



# Molecular clock (Forams)

BEAST v. 1.8.4

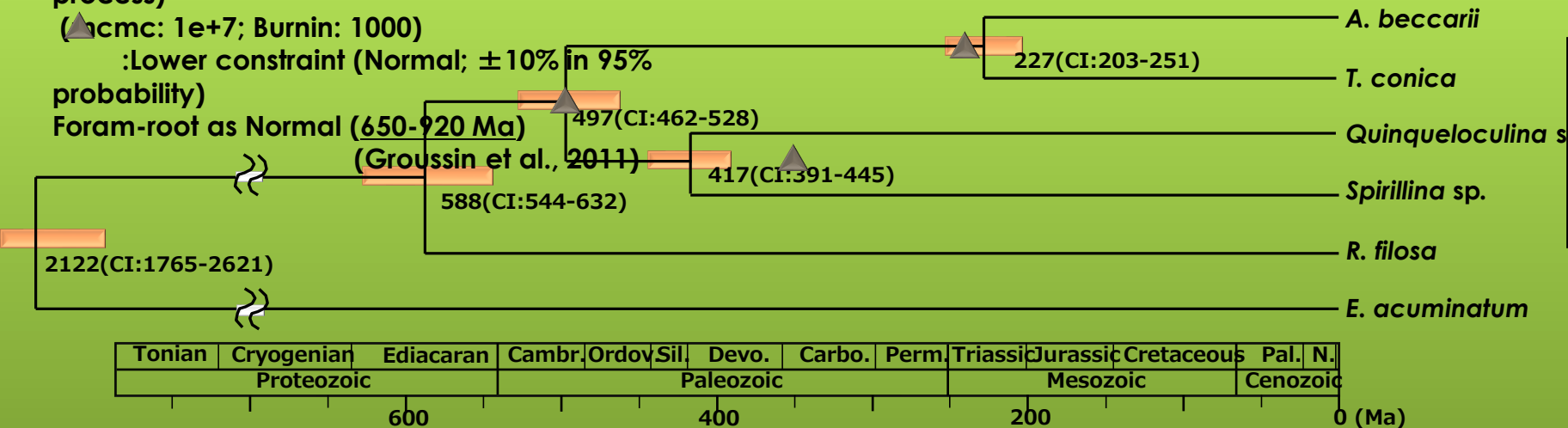
Uncorrelated relaxed clock (Birth-Death process)

( $\mu$ cmc:  $1e+7$ ; Burnin: 1000)

:Lower constraint (Normal;  $\pm 10\%$  in 95% probability)

Foram-root as Normal (650-920 Ma)

(Groussin et al., 2011)



Forams

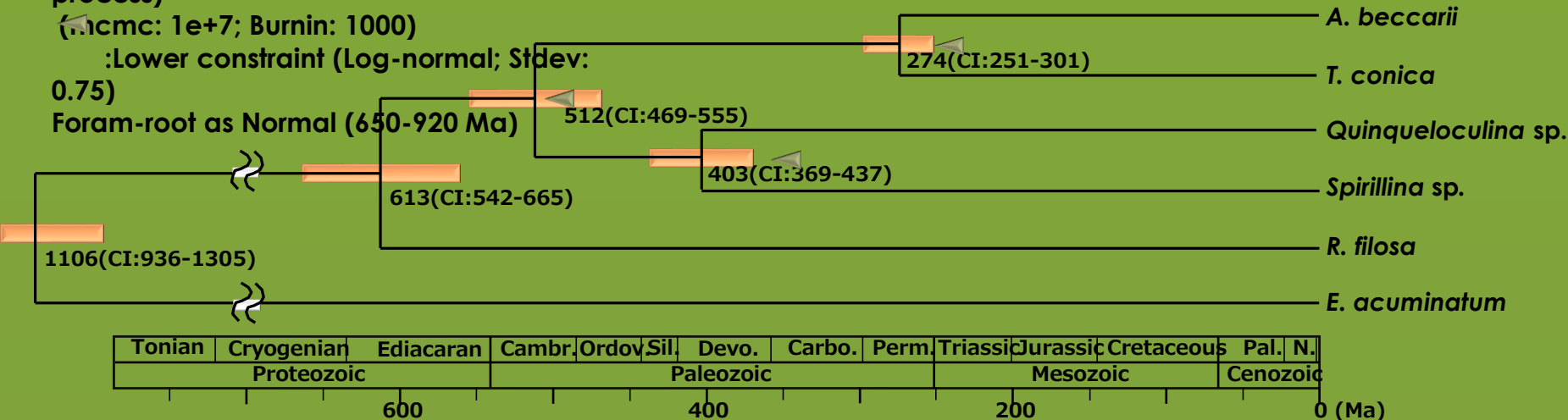
BEAST v. 1.8.4

Uncorrelated relaxed clock (Birth-Death process)

( $\mu$ cmc:  $1e+7$ ; Burnin: 1000)

:Lower constraint (Log-normal; Stdev: 0.75)

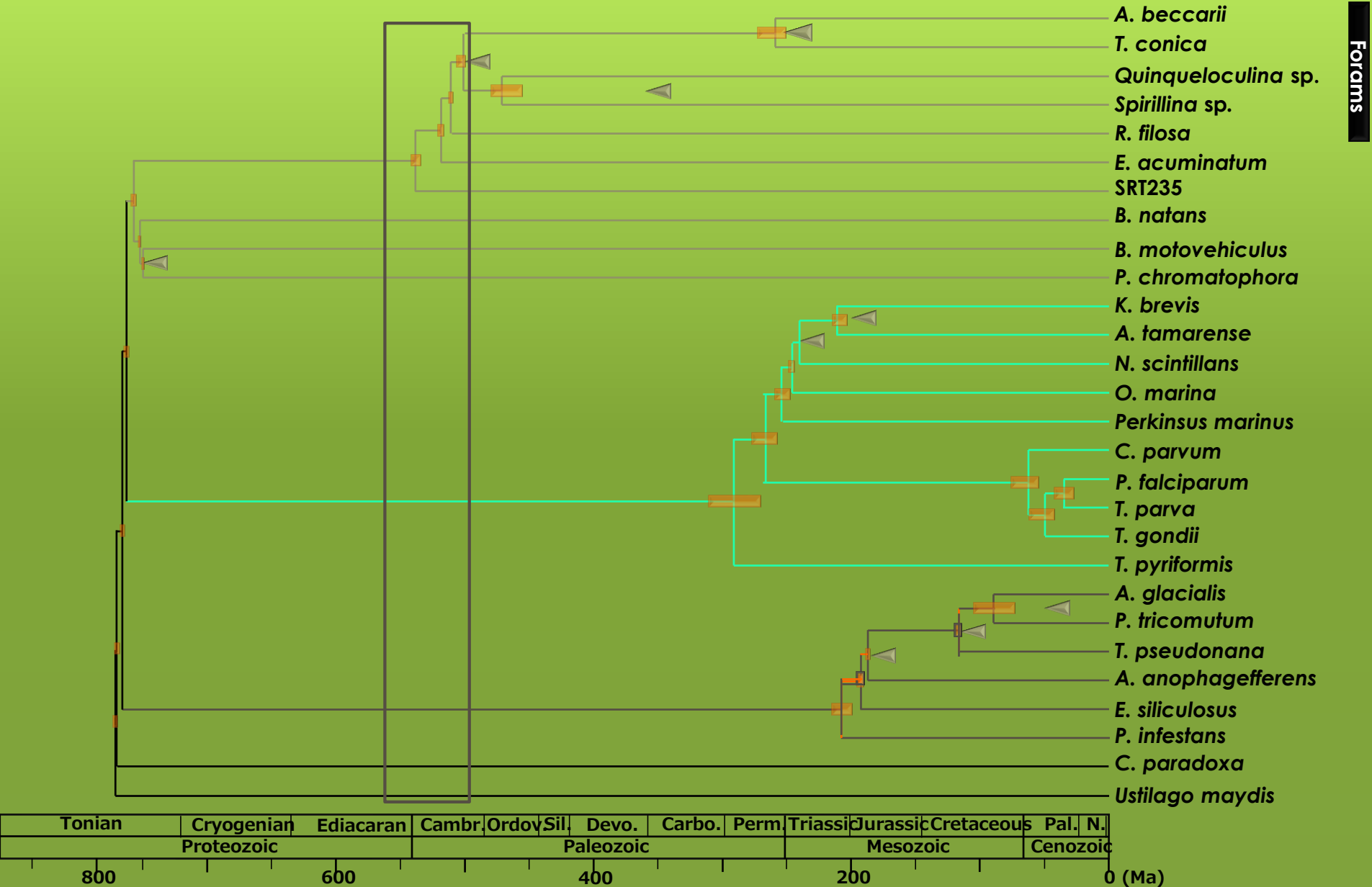
Foram-root as Normal (650-920 Ma)



Forams

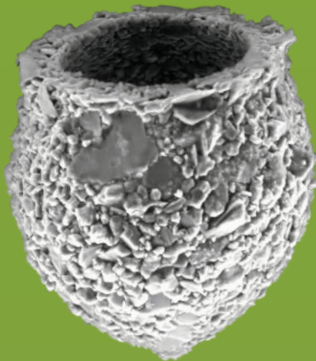
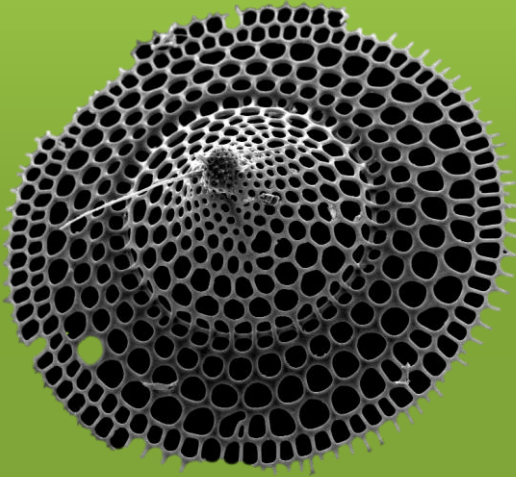


# Molecular clock (SAR+OUTGROUP)





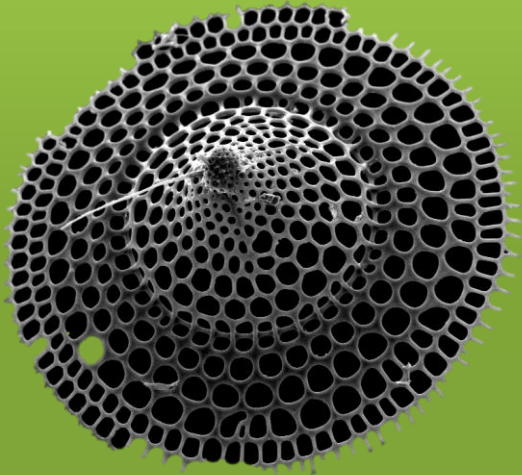
# ***First Fossils Millions of Years Ago***



|                            |                    |
|----------------------------|--------------------|
| <b><i>Metazoans</i></b>    | <b><i>~600</i></b> |
| <b><i>Foraminifera</i></b> | <b><i>544</i></b>  |
| <b><i>Radiolaria</i></b>   | <b><i>542</i></b>  |
| <b><i>Tintinnids</i></b>   | <b><i>180</i></b>  |



# **Molecular Clock Millions of Years Ago**



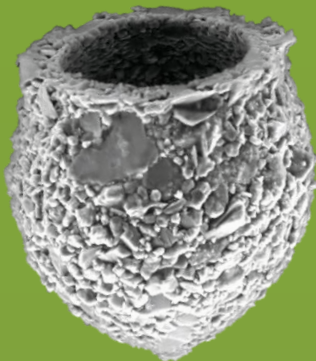
**Metazoans**  
**Foraminifera**  
**Radiolaria**  
**Tintinnids**

**~680**

**575-529**

**566-555**

**?**





**Molecular and fossil origination dates  
correspond more closely now near  
Precambrian/Cambrian boundary.**



***Thanks and  
be creative!***

**jlipps@berkeley.edu**