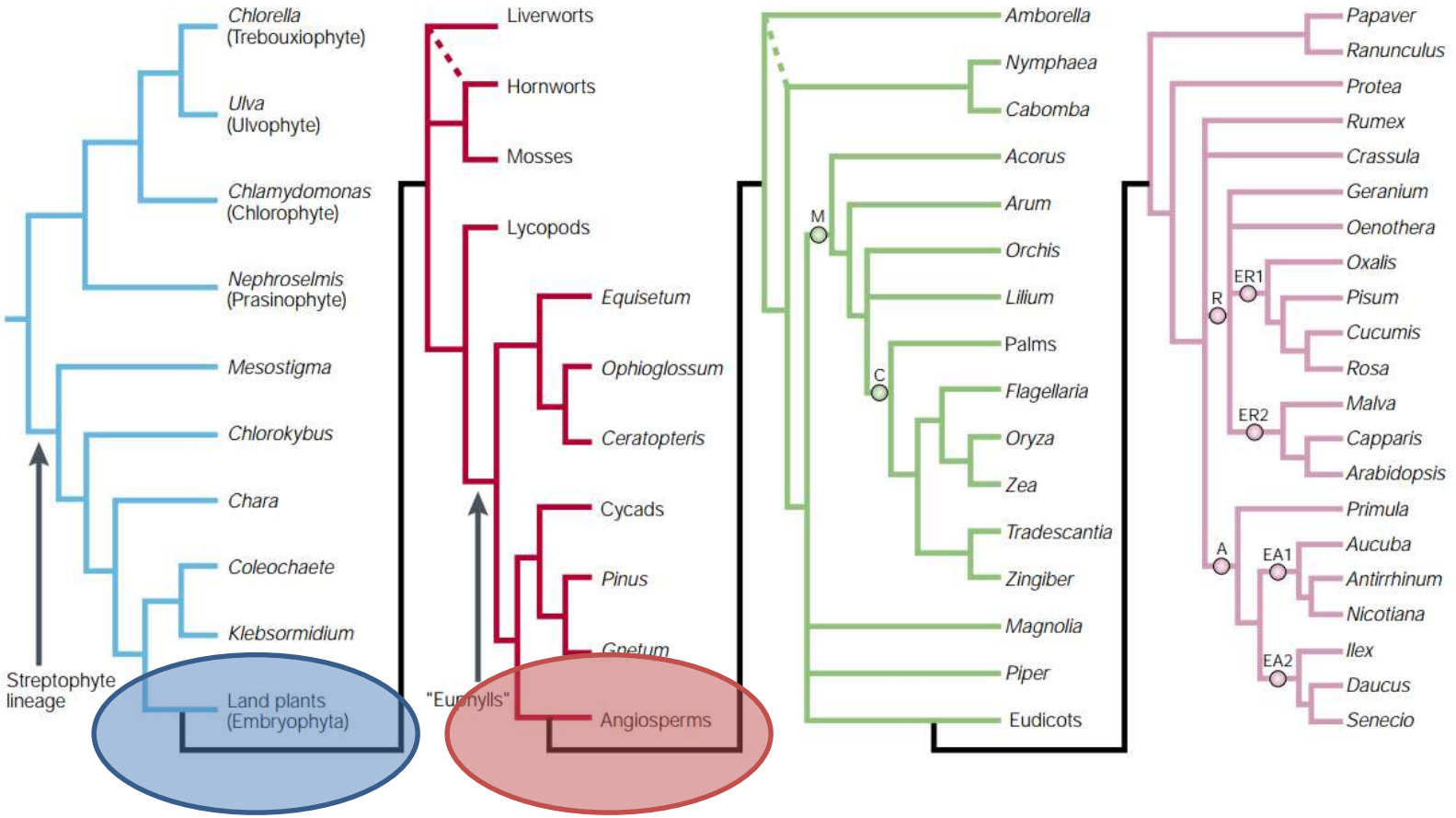
John Roddam Spencer Stanhope
(20 January 1829 — 2 August 1908)

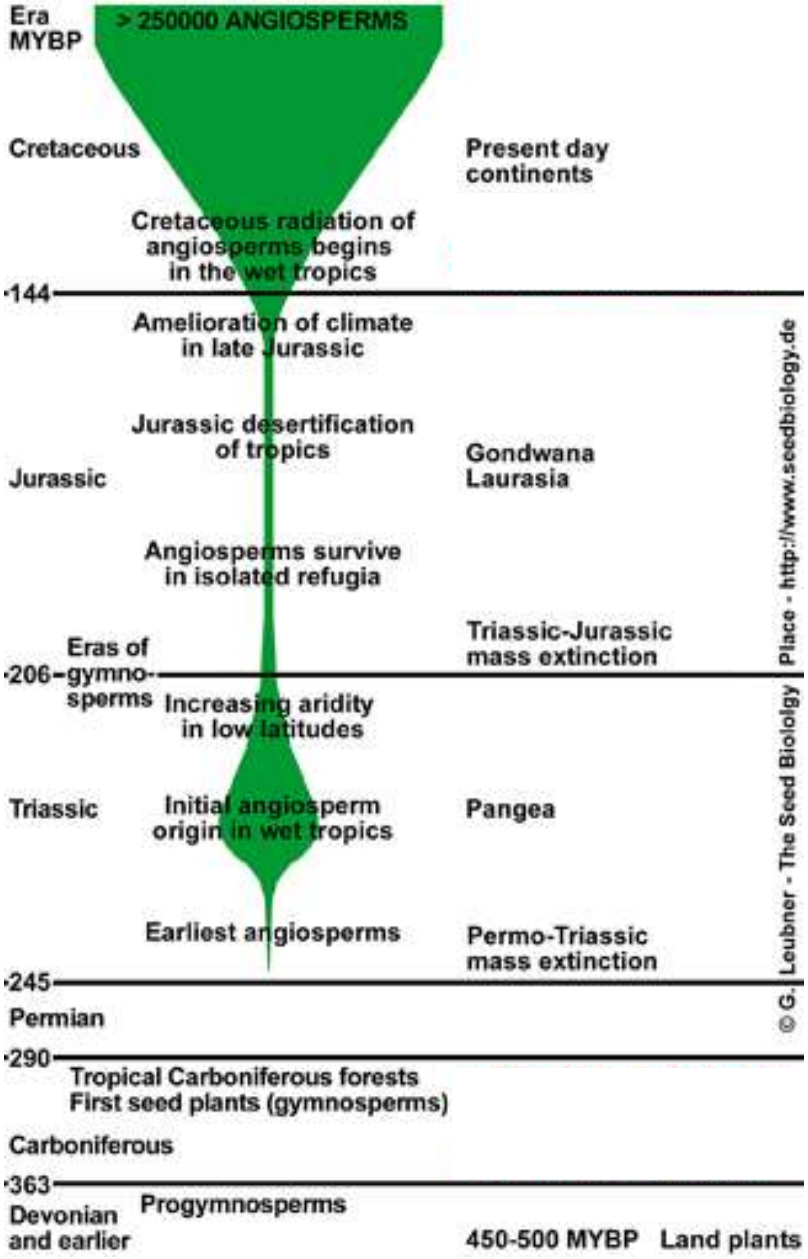
Functional Genomics of Plant Evolution

How EVE lead the flowering plants to dominate the world

Matias Kirst
School of Forest Resources and Conservation
Genetics Institute
University of Florida



Modified from Cronk, Q.C. 2001 Nat Rev Genet. 2:607-19.


Era
MYBP
> 250000 ANGIOSPERMS
Cretaceous
Present day
continents
Cretaceous radiation of
angiosperms begins
in the wet tropics
144
Amelioration of climate
in late Jurassic
Jurassic desertification
of tropics
Jurassic
Gondwana
Laurasia
Angiosperms survive
in isolated refugia
Triassic-Jurassic
mass extinction
Eras of
206
gymno-
sperms
Increasing aridity
in low latitudes
Triassic
Initial angiosperm
origin in wet tropics
Pangea
Earliest angiosperms
Permo-Triassic
mass extinction
245
Permian
290
Tropical Carboniferous forests
First seed plants (gymnosperms)
Carboniferous
363
Devonian
and earlier
Progymnosperms
450-500 MYBP
Land plants
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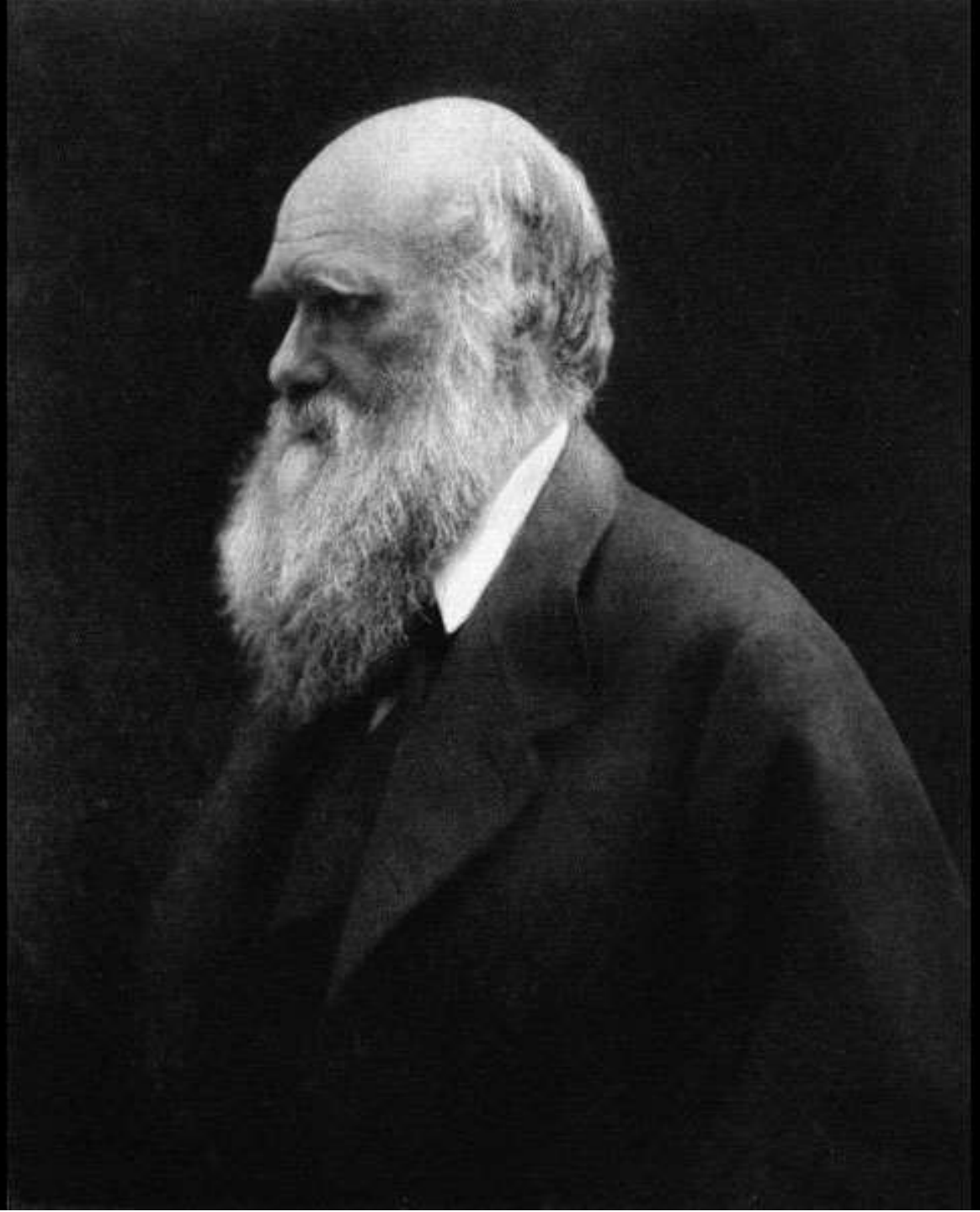
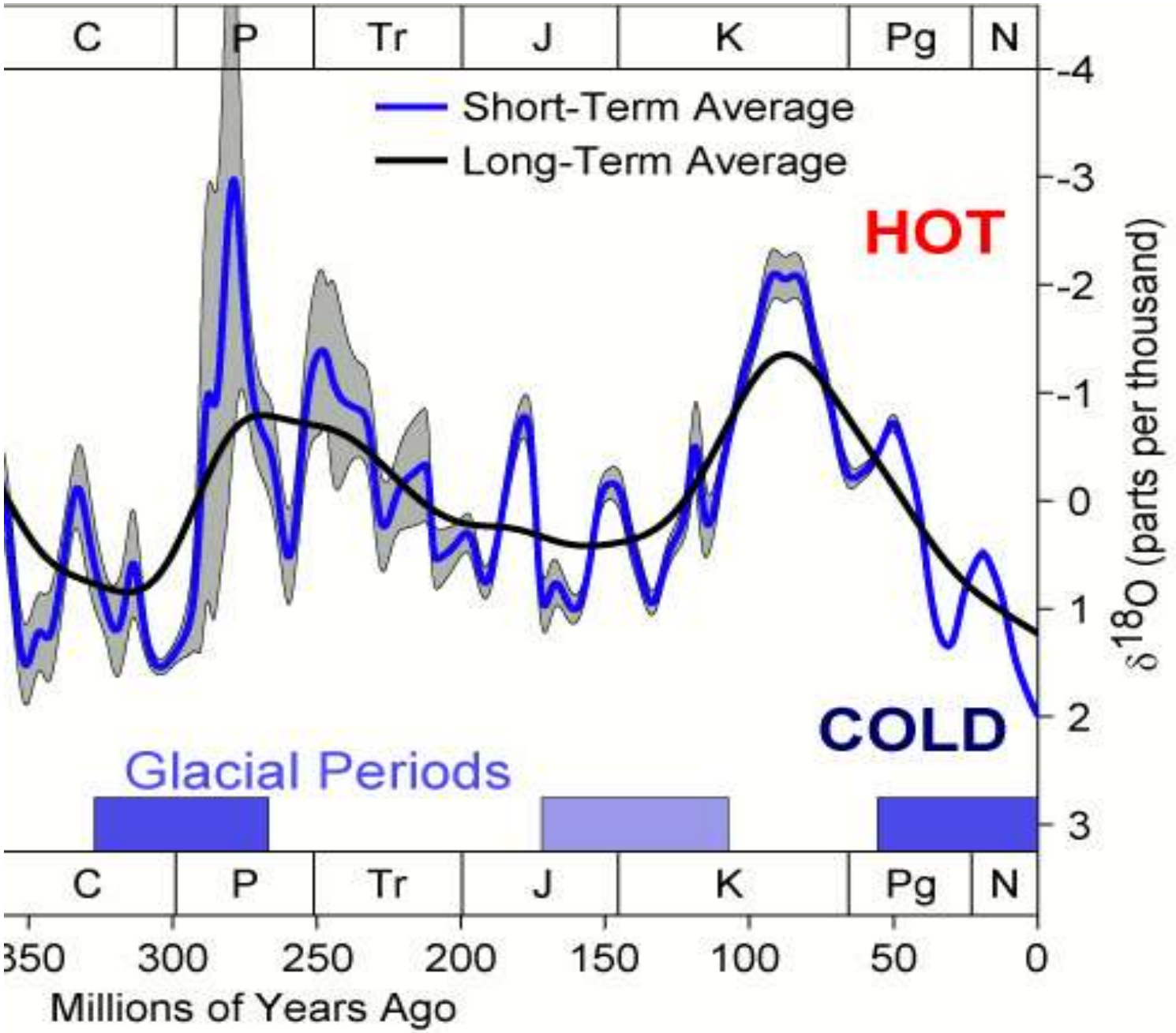
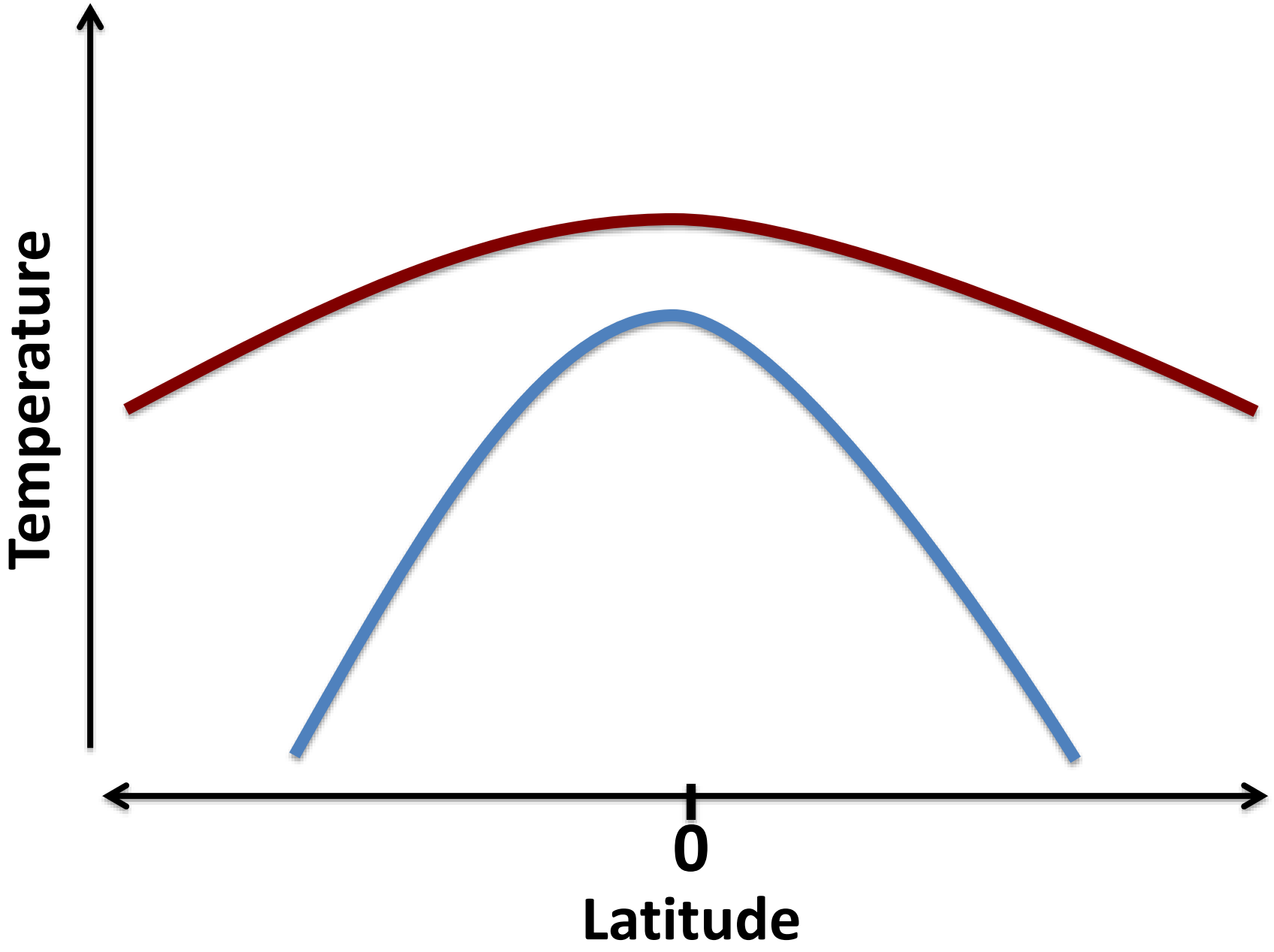
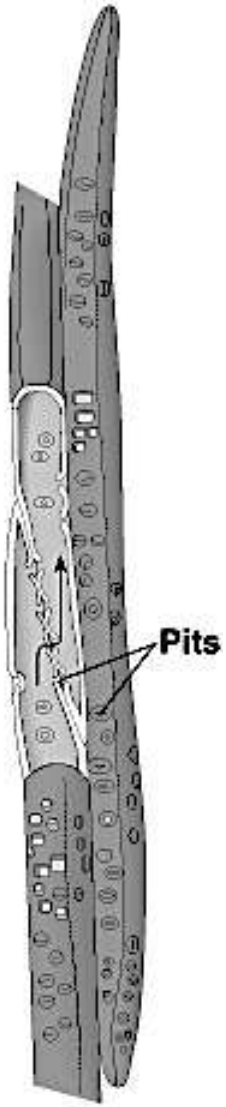



C
P
Tr
J
K
Pg
N
Short-Term Average
Long-Term Average
HOT
COLD
Glacial Periods
-4
-3
-2
-1
0
1
2
3
δ18O (parts per thousand)
350
300
250
200
150
100
50
0
Millions of Years Ago


Temperature
0
Latitude

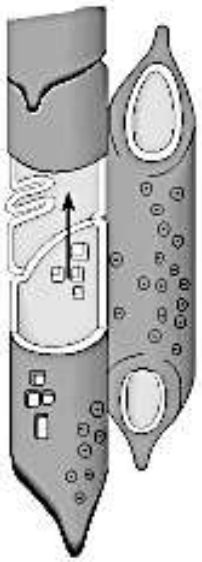
Gymnosperms

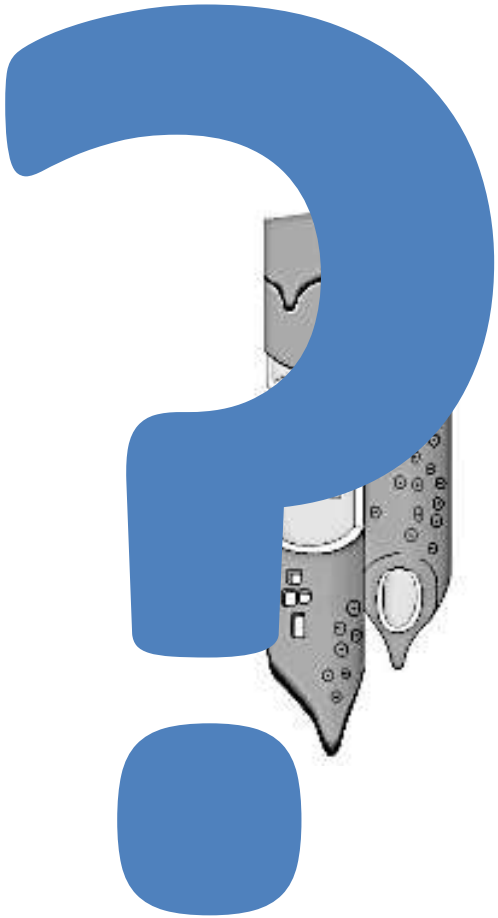
(Conifers)



Angiosperms

(Flowering plants)





John Roddam Spencer Stanhope
(1829-1908)

EVE

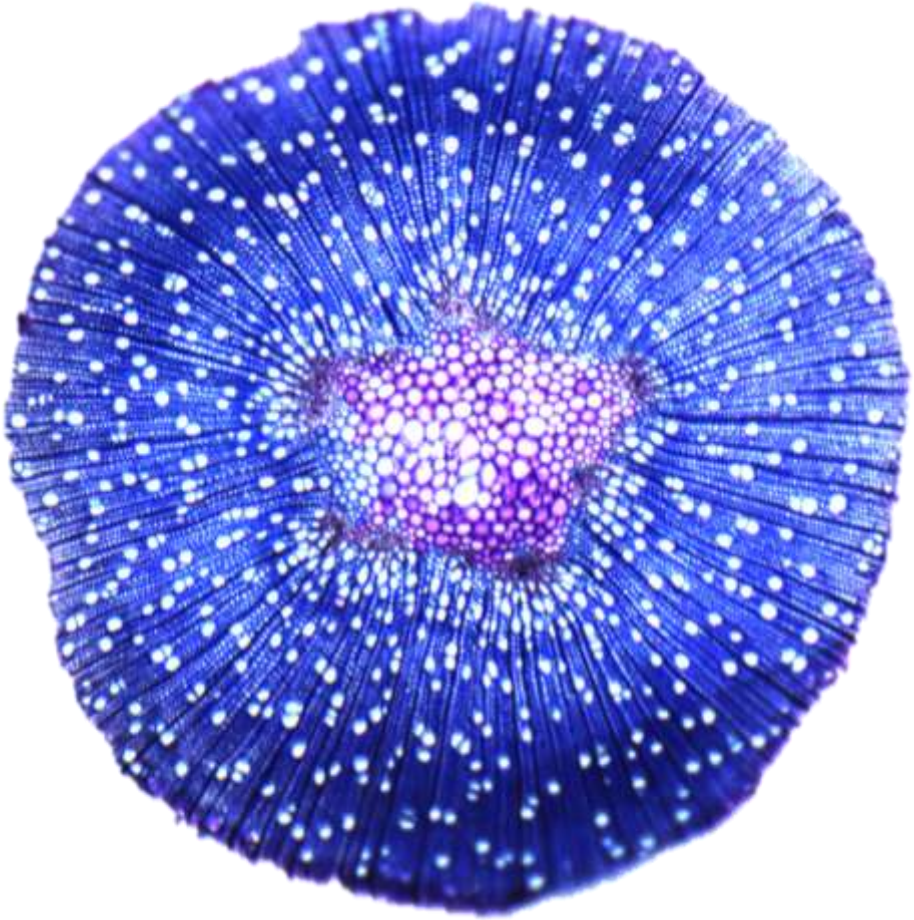
Enlarged vessel elements

Discovery

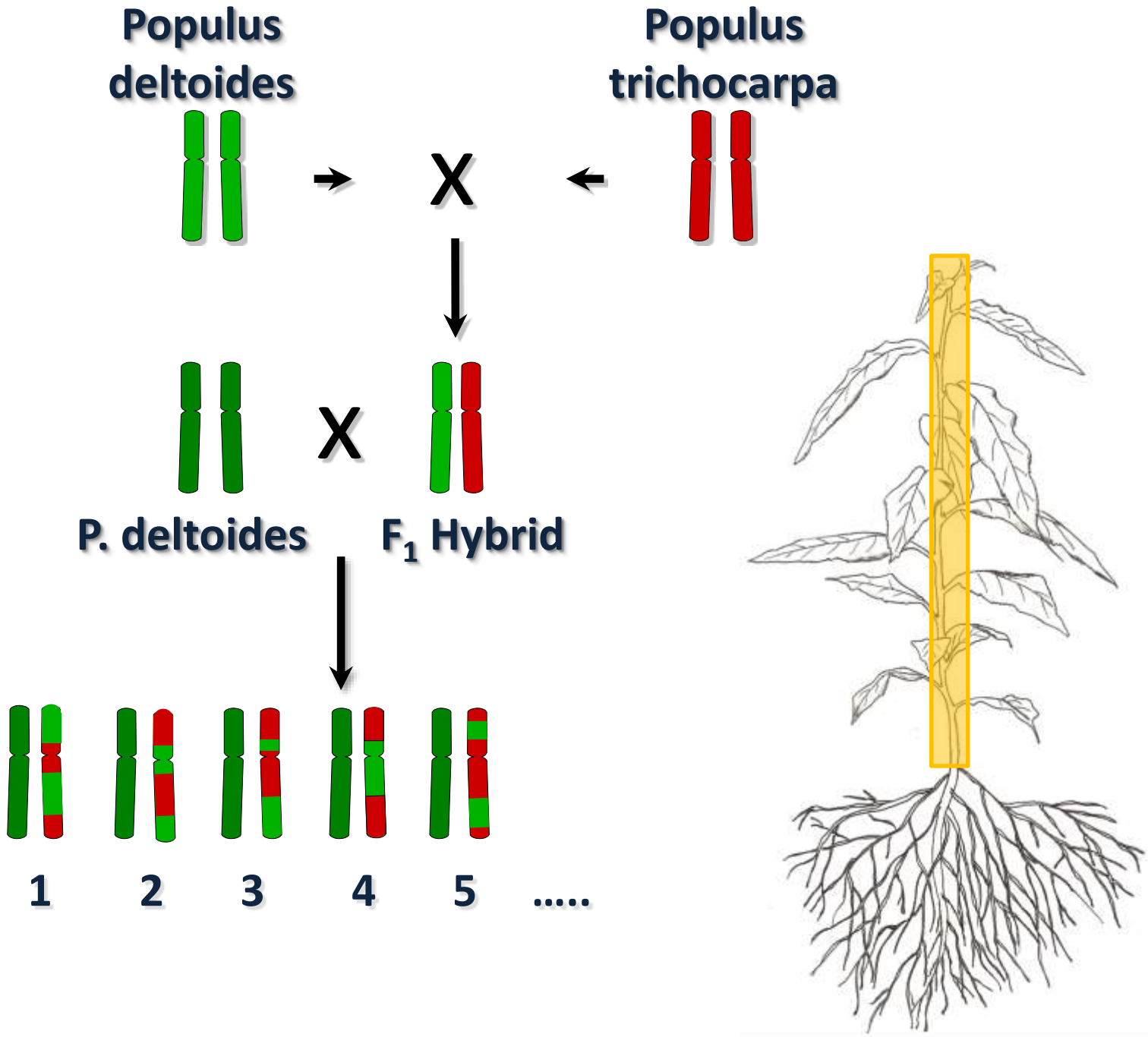
Function

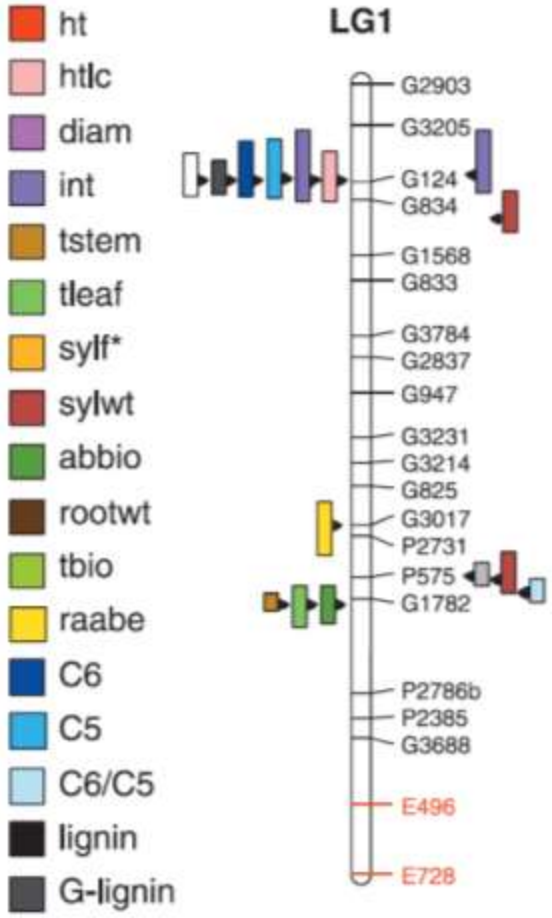
Evolutionary role

Origin

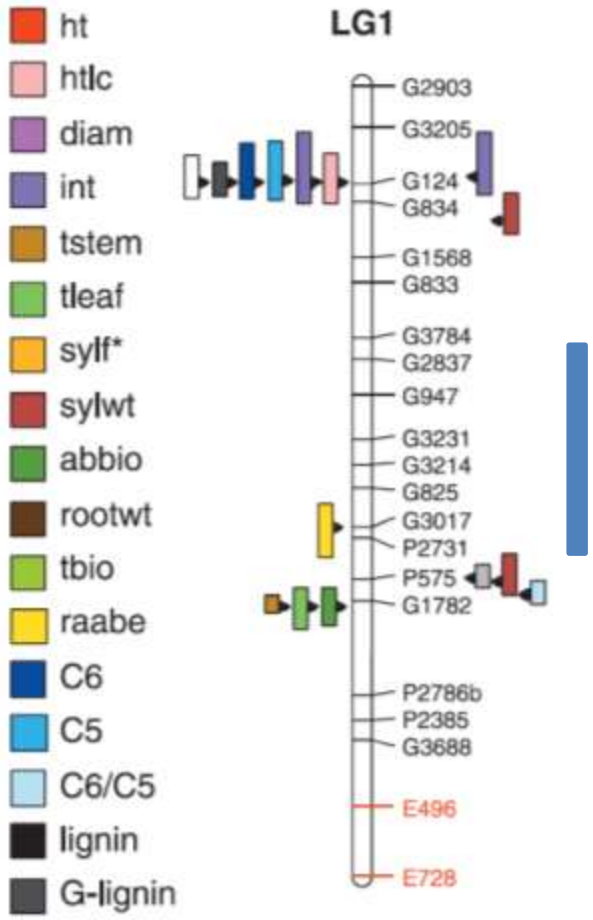


Brianna Miles, MSc

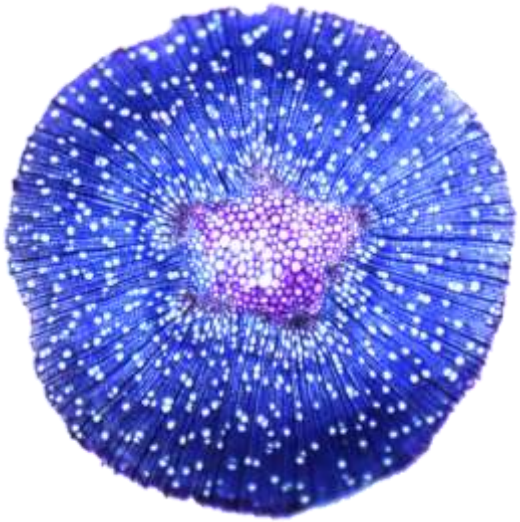

Populus deltoides
Populus trichocarpa
X
X
P. deltoides
F1 Hybrid
1
2
3
4
5
.....



Novaes et al. New Phytologist (2009) 182:878-890



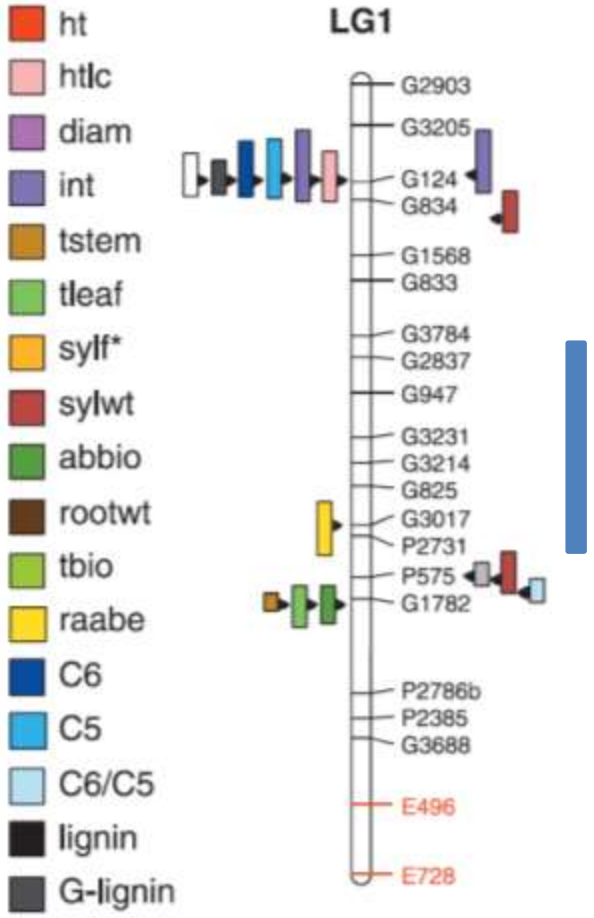
Vessel properties/hydraulic conductivity



Vessel area
Vessel number
Vessel element diameter
Hydraulic conductivity

$$K_h = \frac{r^4 p}{8h}$$

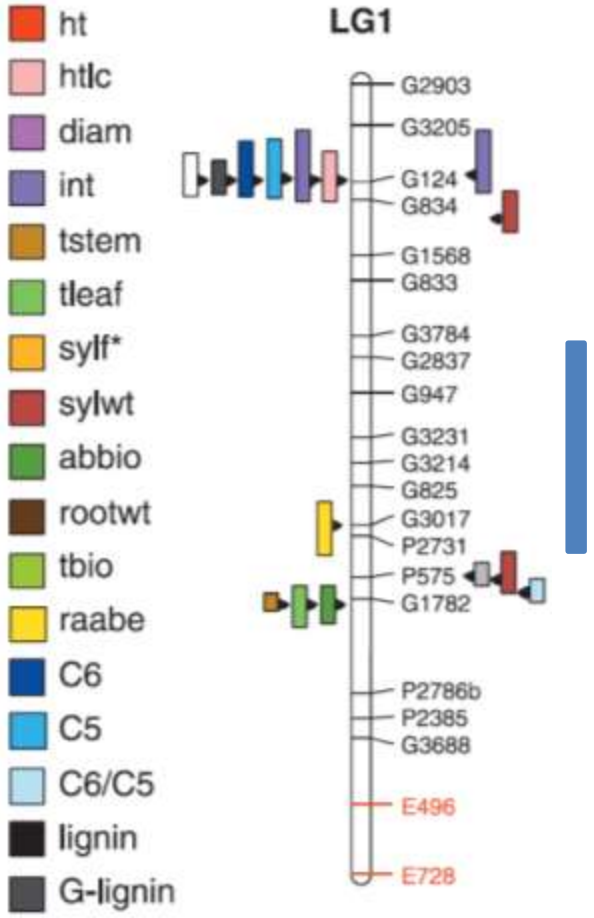
Novaes et al. New Phytologist (2009) 182:878-890
Miles B. (2007) MSc thesis



Vessel properties/hydraulic conductivity

~ 800 genes in the QTL interval

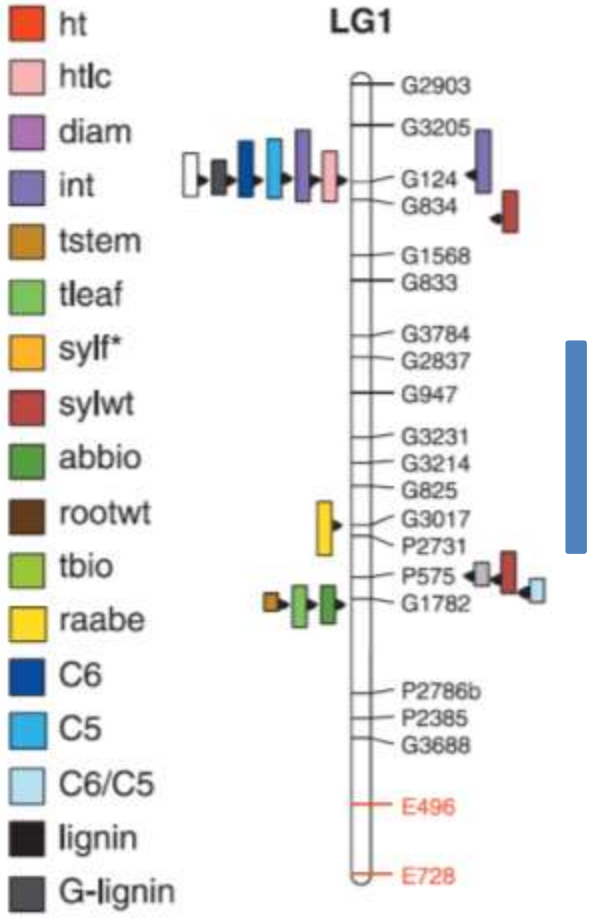
Novaes et al. New Phytologist (2009) 182:878-890
Miles B. (2007) MSc thesis
Tuskan et al. Science (2006) 313:1596-604.



Vessel properties/hydraulic conductivity

~ 800 genes in the QTL interval
53 expressed primarily in xylem

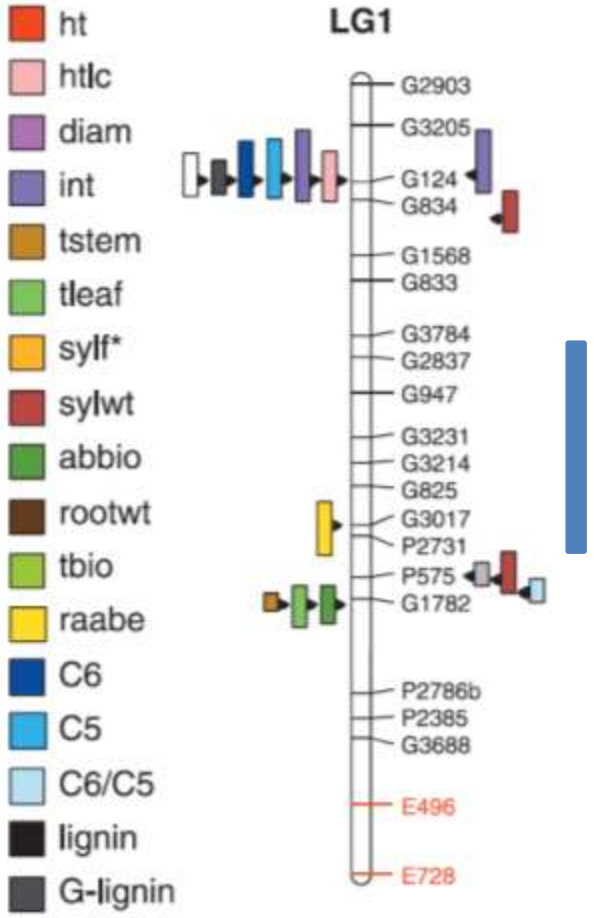
Novaes et al. New Phytologist (2009) 182:878-890
Miles B. (2007) MSc thesis
Tuskan et al. Science (2006) 313:1596-604.
Quesada et al. New Phytologist (2008) 180:408-420



Vessel properties/hydraulic conductivity

~ 800 genes in the QTL interval
53 expressed primarily in xylem
4 with gene expression QTL

Novaes et al. New Phytologist (2009) 182:878-890
Miles B. (2007) MSc thesis
Tuskan et al. Science (2006) 313:1596-604.
Quesada et al. New Phytologist (2008) 180:408-420
Drost et al. Proceeding of the National Academy of Sciences of the USA (2010) 107:8492-8497



Vessel properties/hydraulic conductivity

~ 800 genes in the QTL interval
53 expressed primarily in xylem
4 with gene expression QTL
1 gene was a DUF

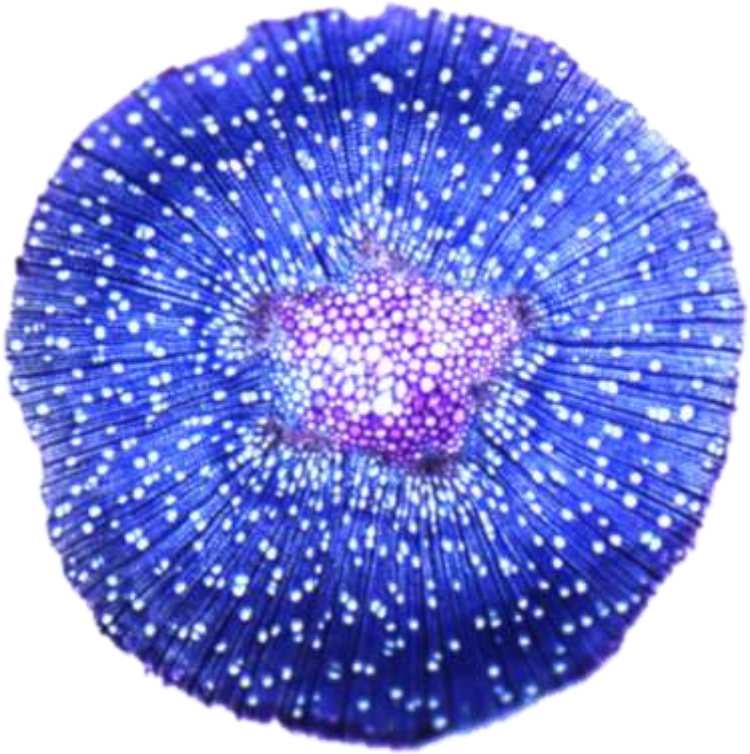
Novaes et al. New Phytologist (2009) 182:878-890
Miles B. (2007) MSc thesis
Tuskan et al. Science (2006) 313:1596-604.
Quesada et al. New Phytologist (2008) 180:408-420
Drost et al. Proceeding of the National Academy of Sciences of the USA (2010) 107:8492-8497

Downregulation: RNAi

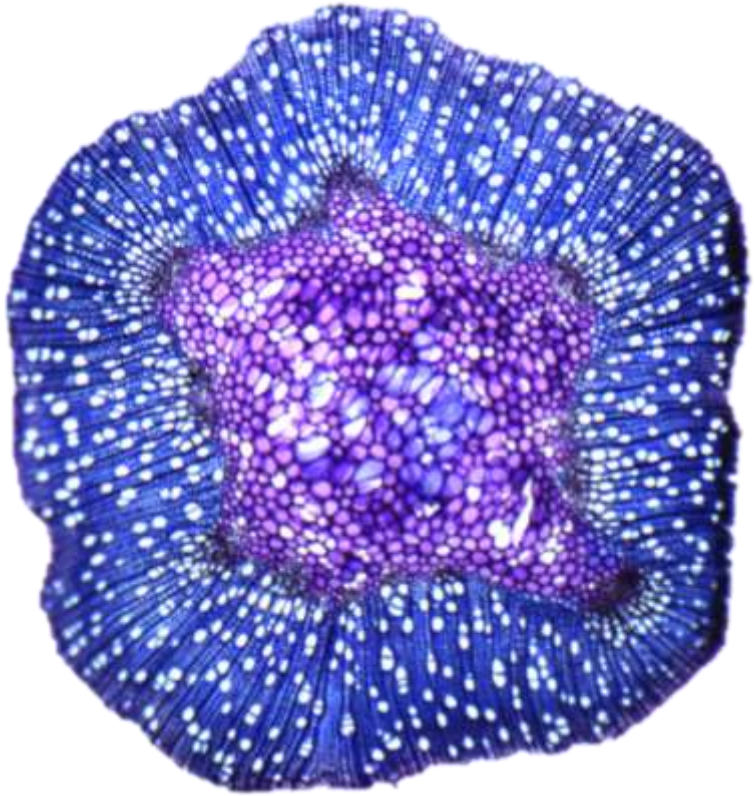
Cintia Ribeiro, PhD candidate

Downregulation: RNAi **(LETHAL)**

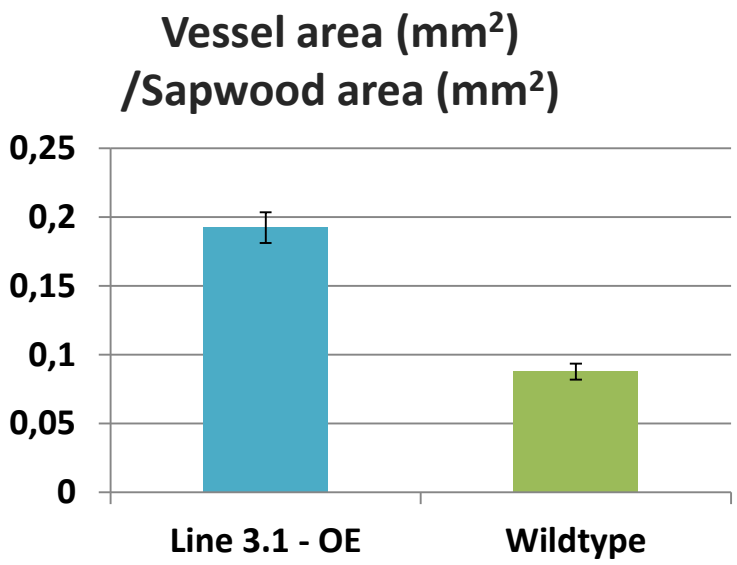
Overexpression: 35S promoter fusion

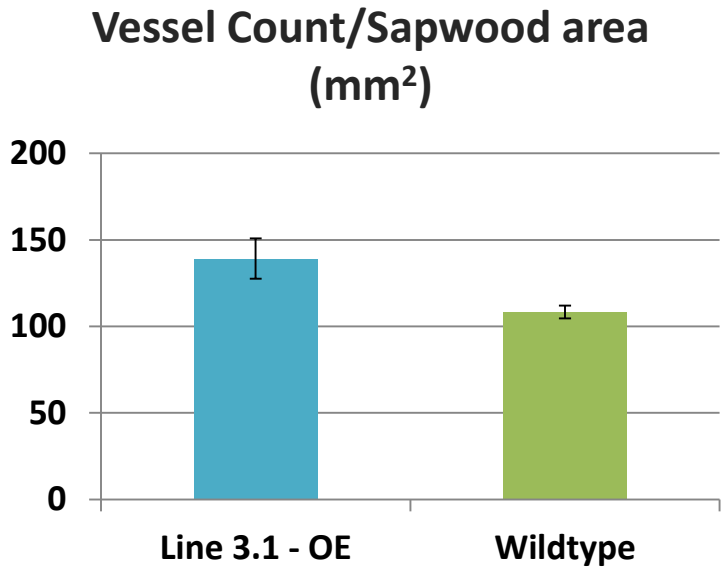


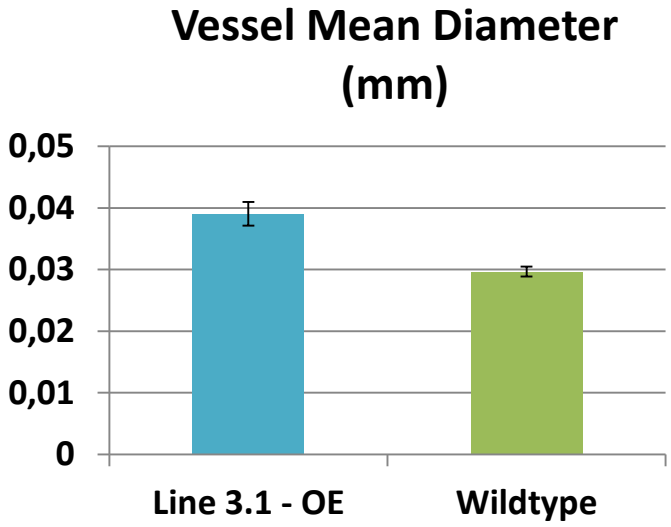
Wildtype



Line 3.1

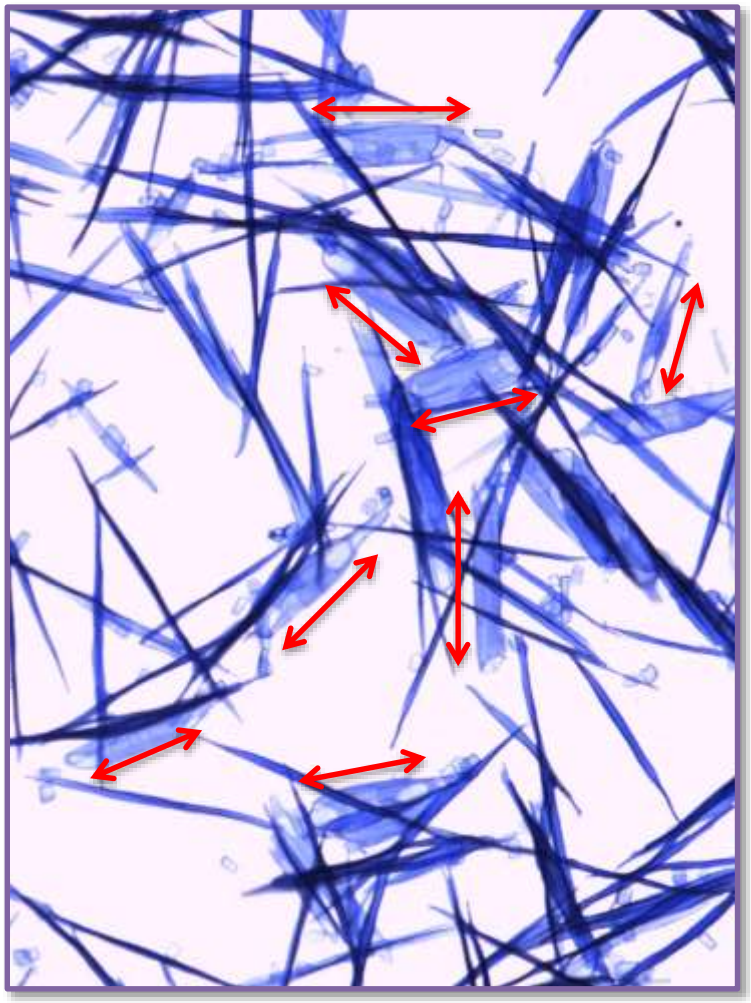




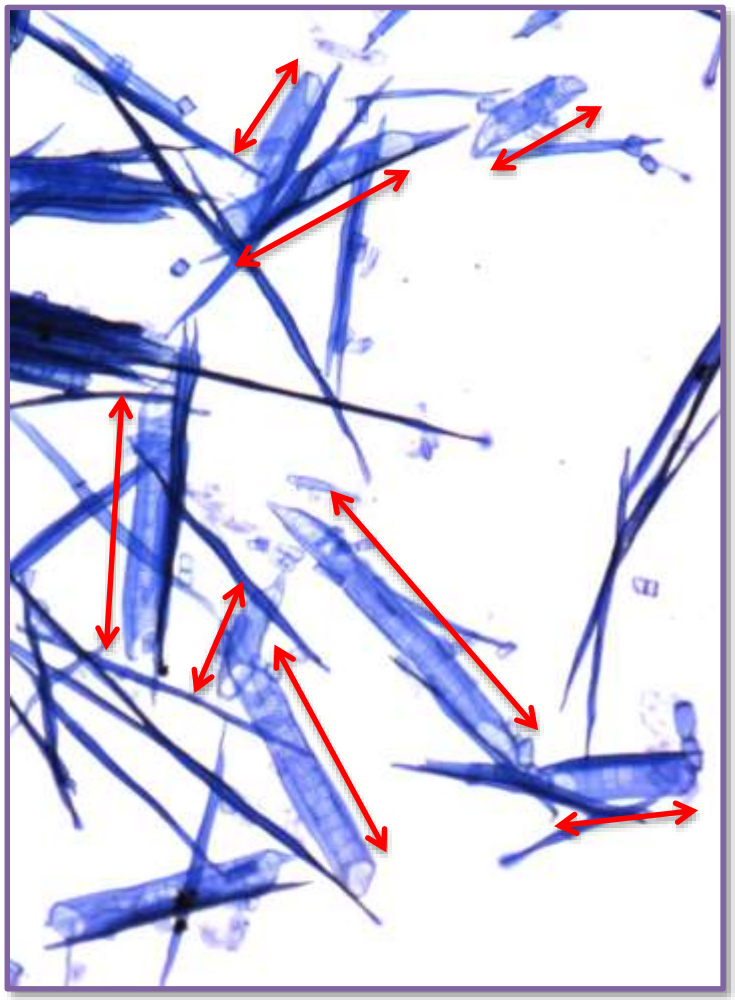


Hydraulic conductivity

$$K_h = \frac{r^4 p}{8h}$$

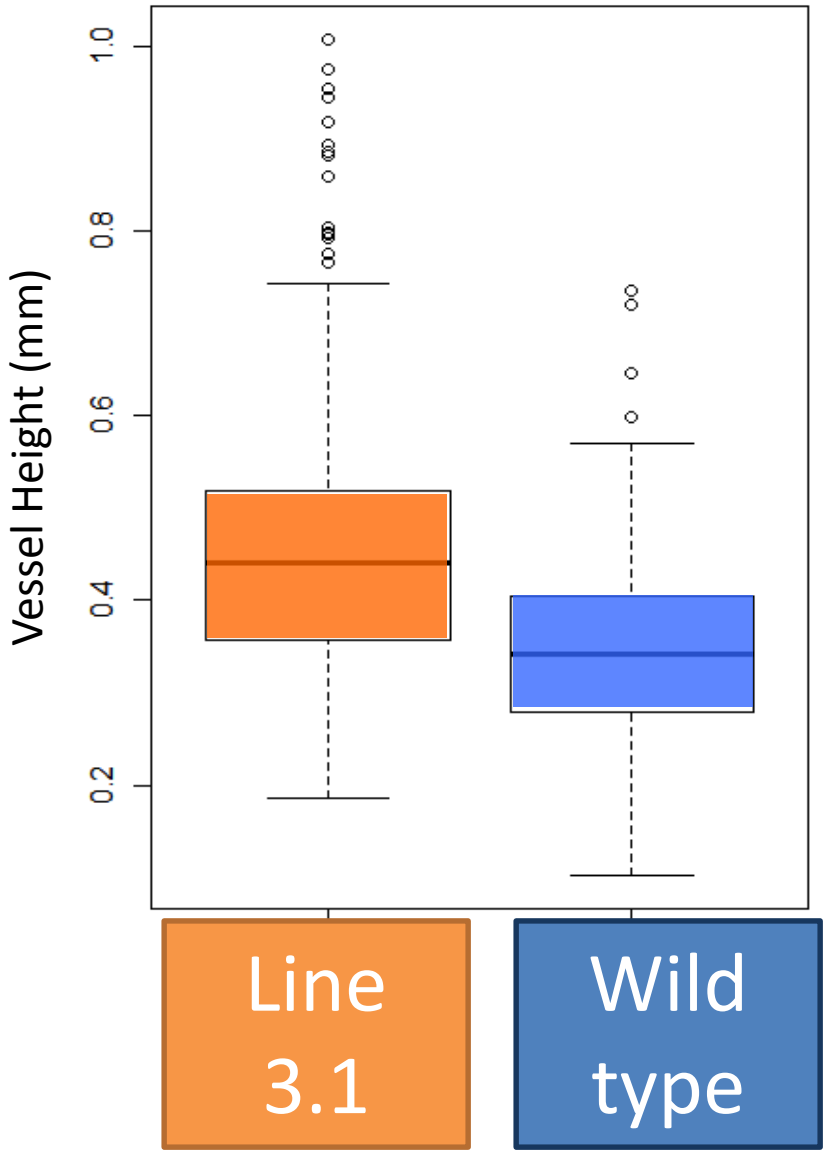


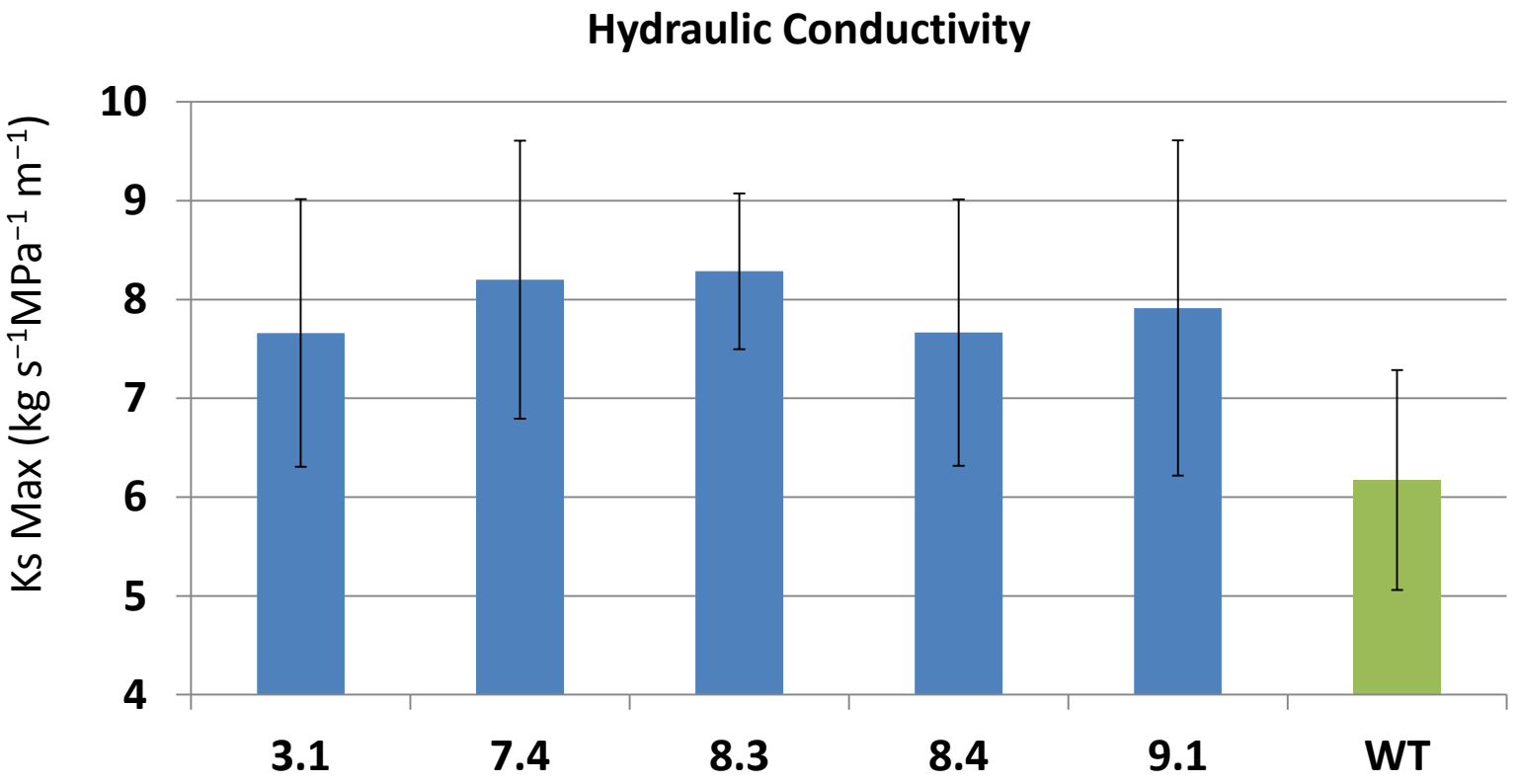
Wildtype



Line 3.1

Maceration with Acetic Acid and Hydrogen Peroxide


Vessel Height (mm)
0.2
0.4
0.6
0.8
1.0
Line 3.1
Wild type


Hydraulic Conductivity
Ks Max (kg s^{-1}MPa^{-1} m^{-1})
10
9
8
7
6
5
4
3.1
7.4
8.3
8.4
9.1
WT

John Roddam Spencer Stanhope
(1829-1908)

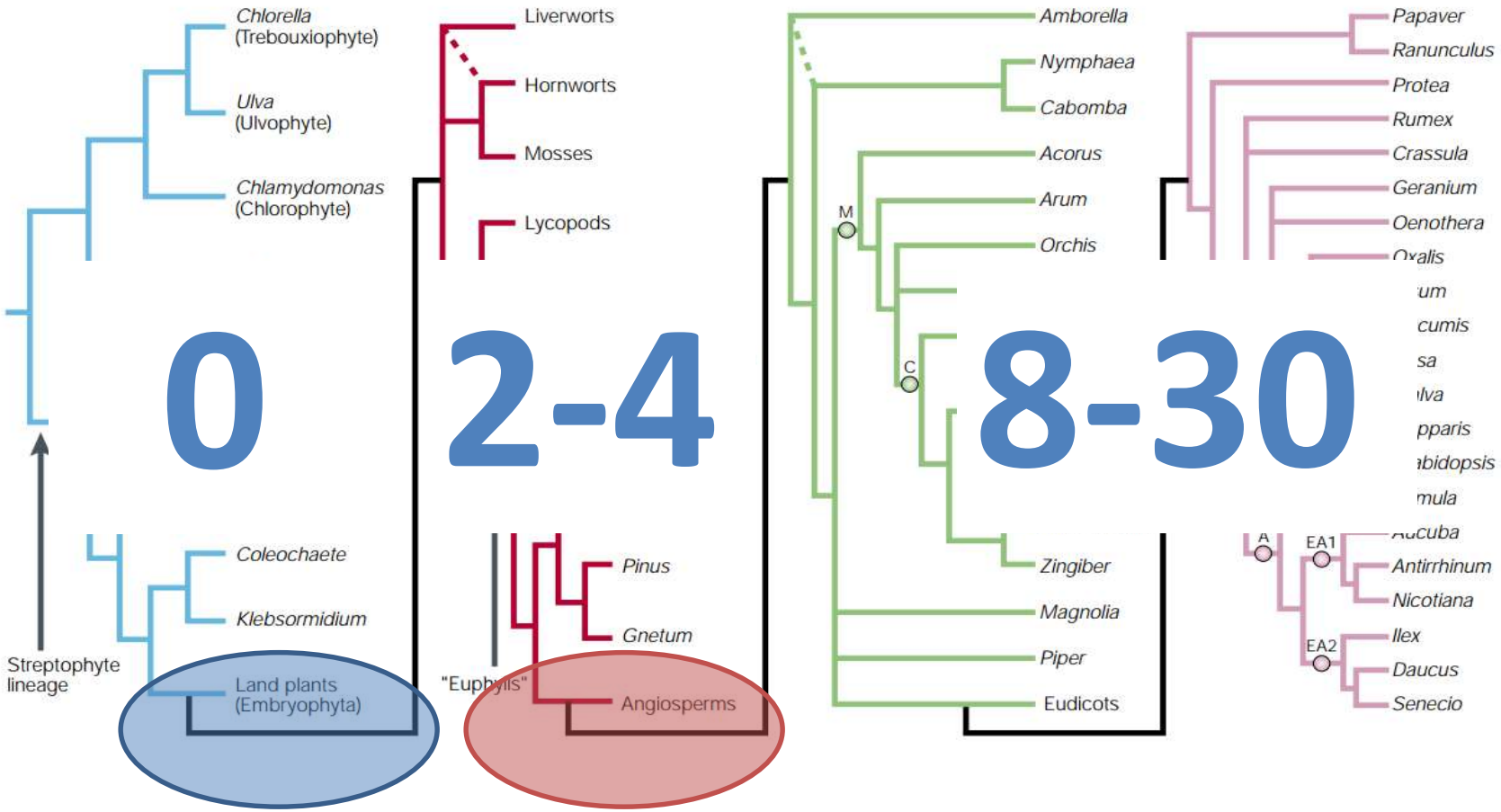
DUF

Domain of unknown function

EVE

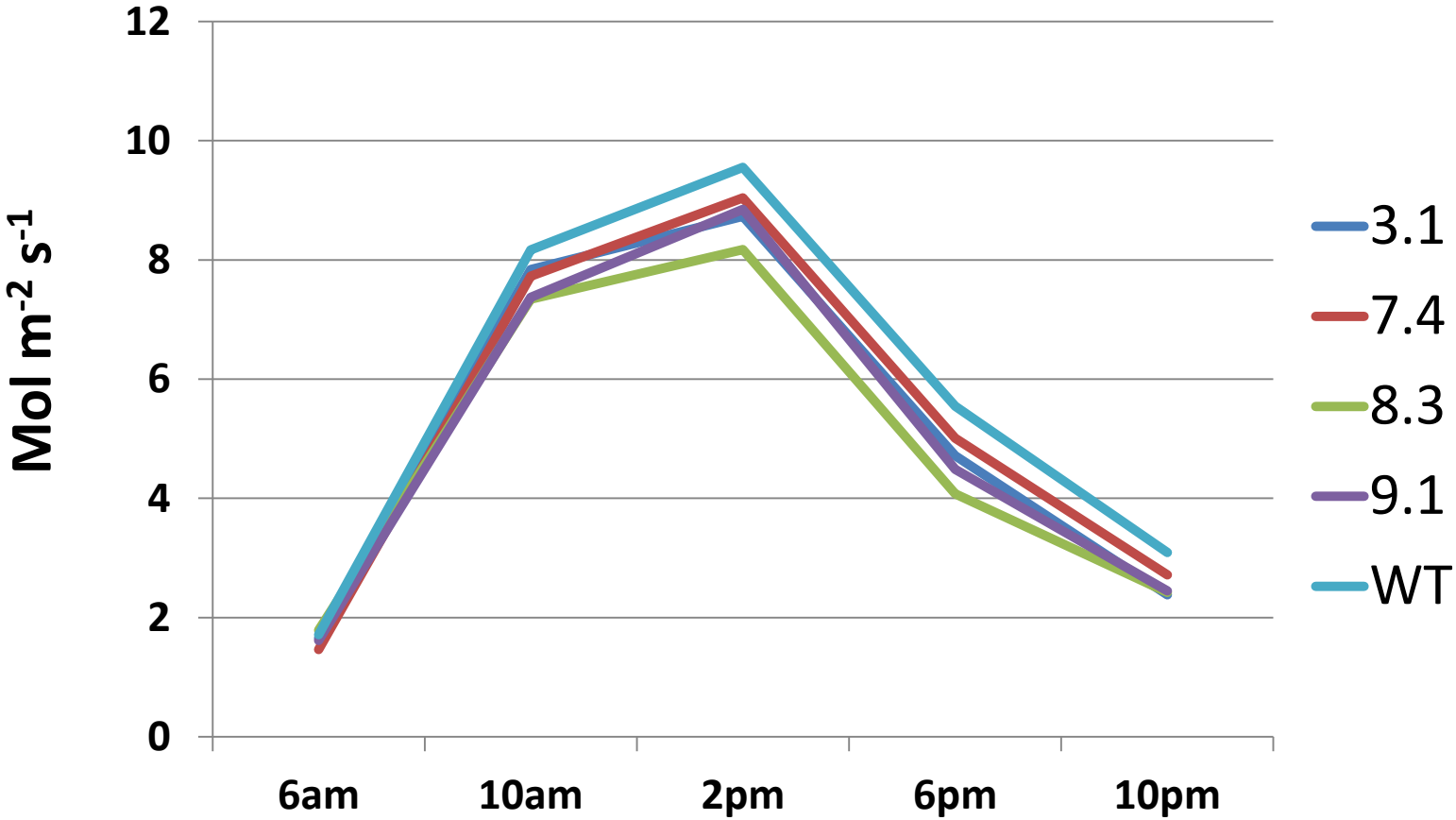
Enlarged vessel elements

Evolutionary role

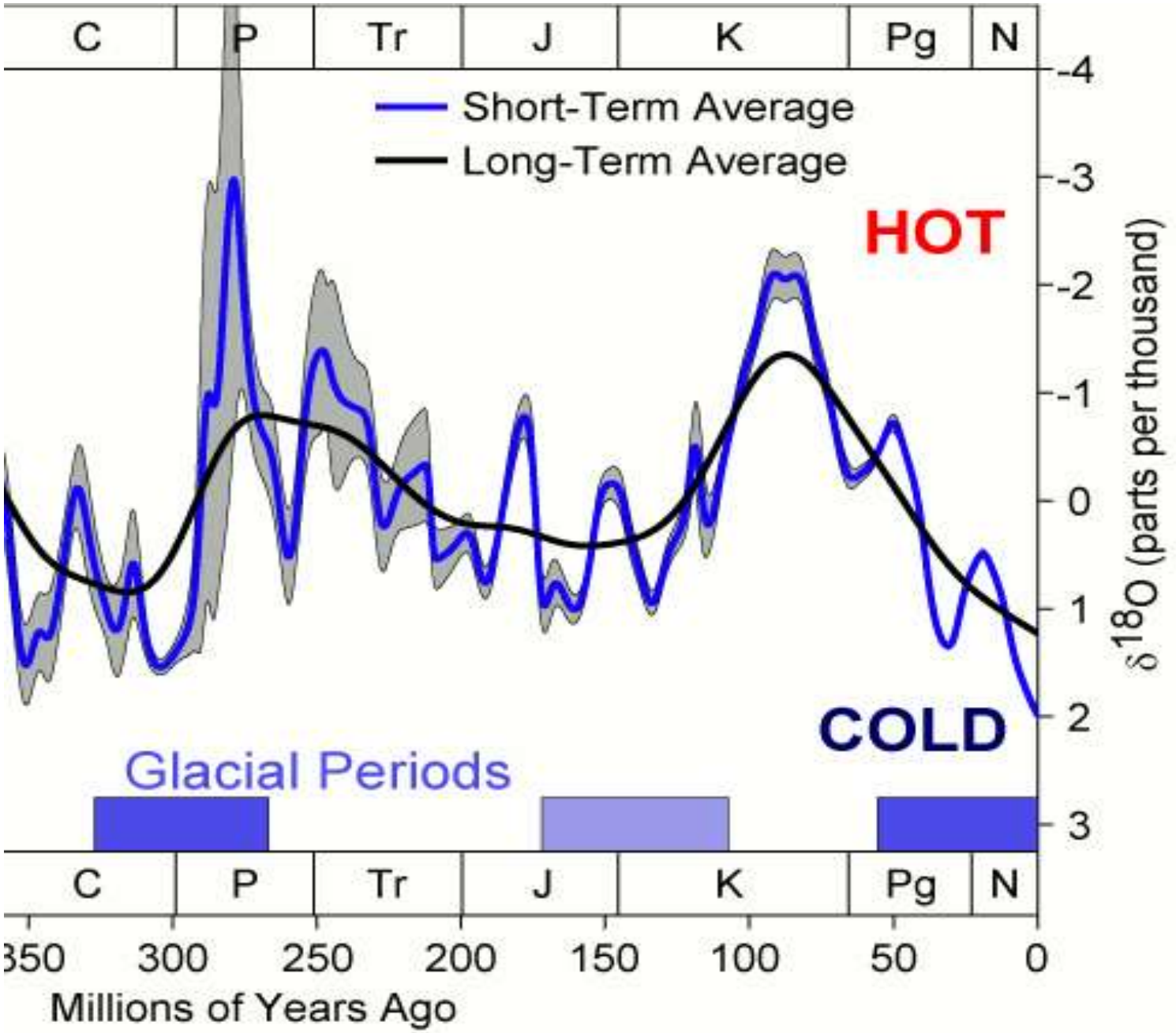


Does EVE provide a fitness advantage?

No difference in height growth, or photosynthesis.

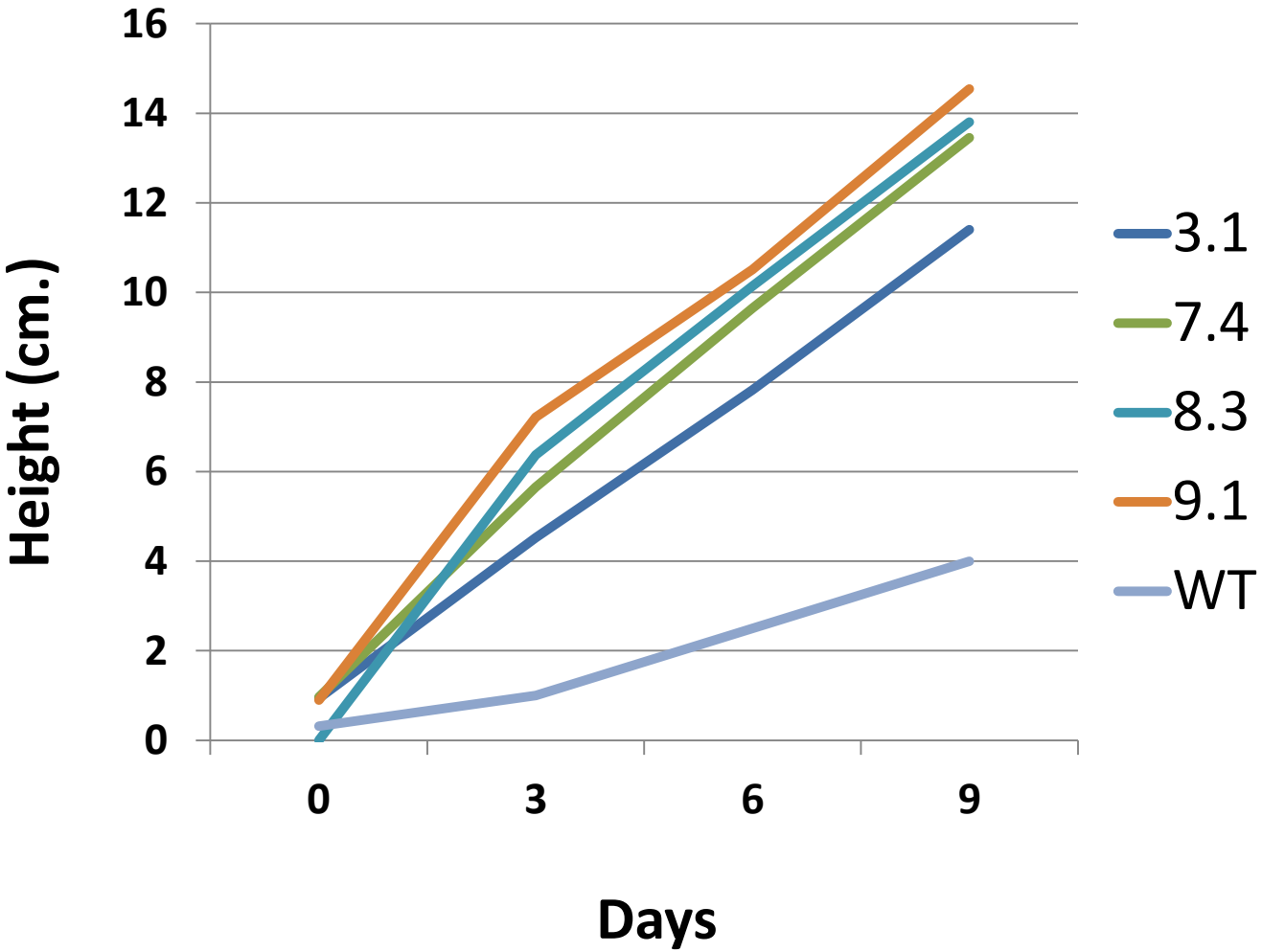


Evolutionary role


C
P
Tr
J
K
Pg
N
Short-Term Average
Long-Term Average
HOT
COLD
Glacial Periods
-4
-3
-2
-1
0
1
2
3
δ18O (parts per thousand)
350
300
250
200
150
100
50
0
Millions of Years Ago

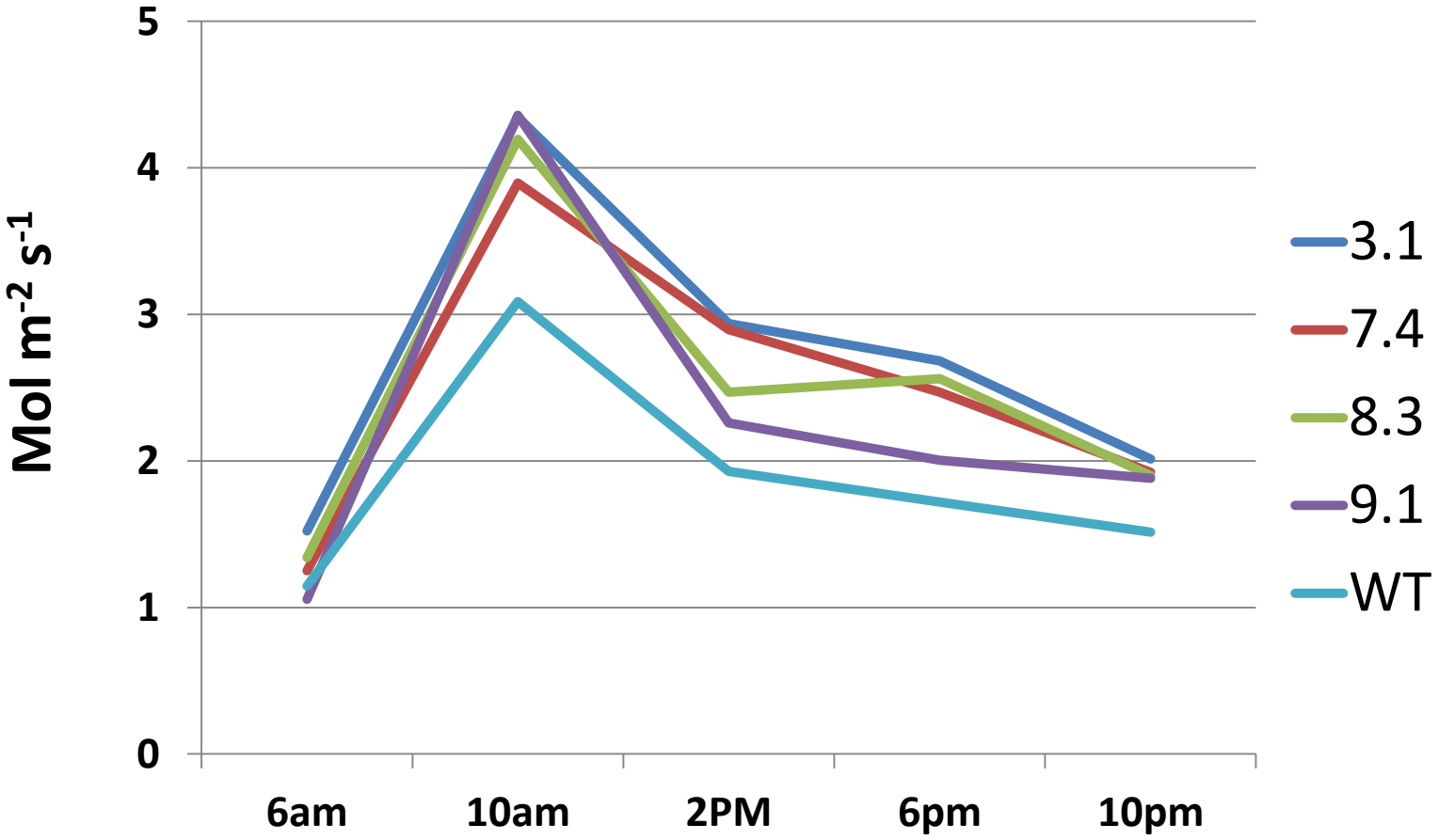
Does EVE provide a fitness advantage?

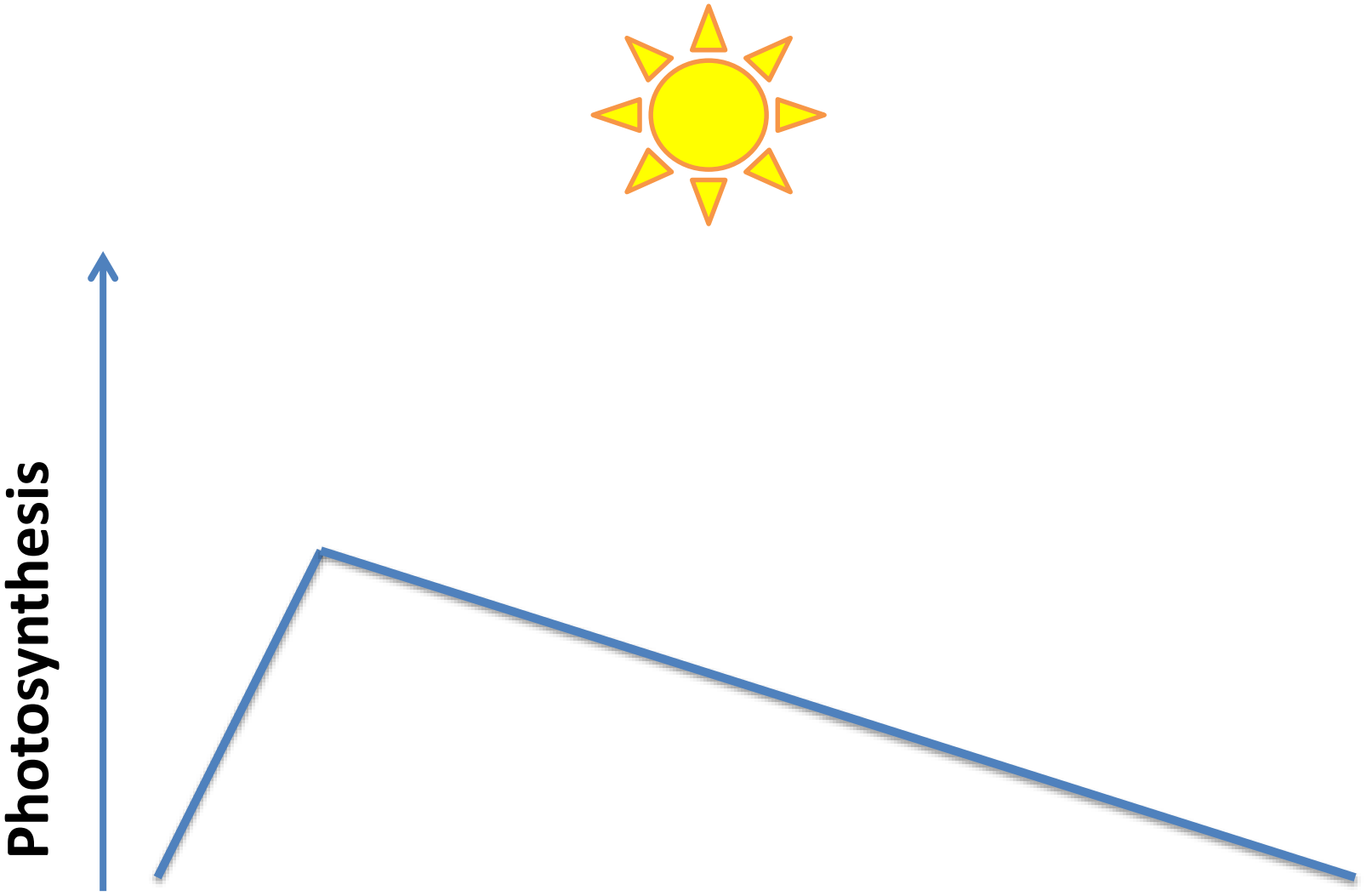
In hot and wet climate (a.k.a. the Cretaceous)!



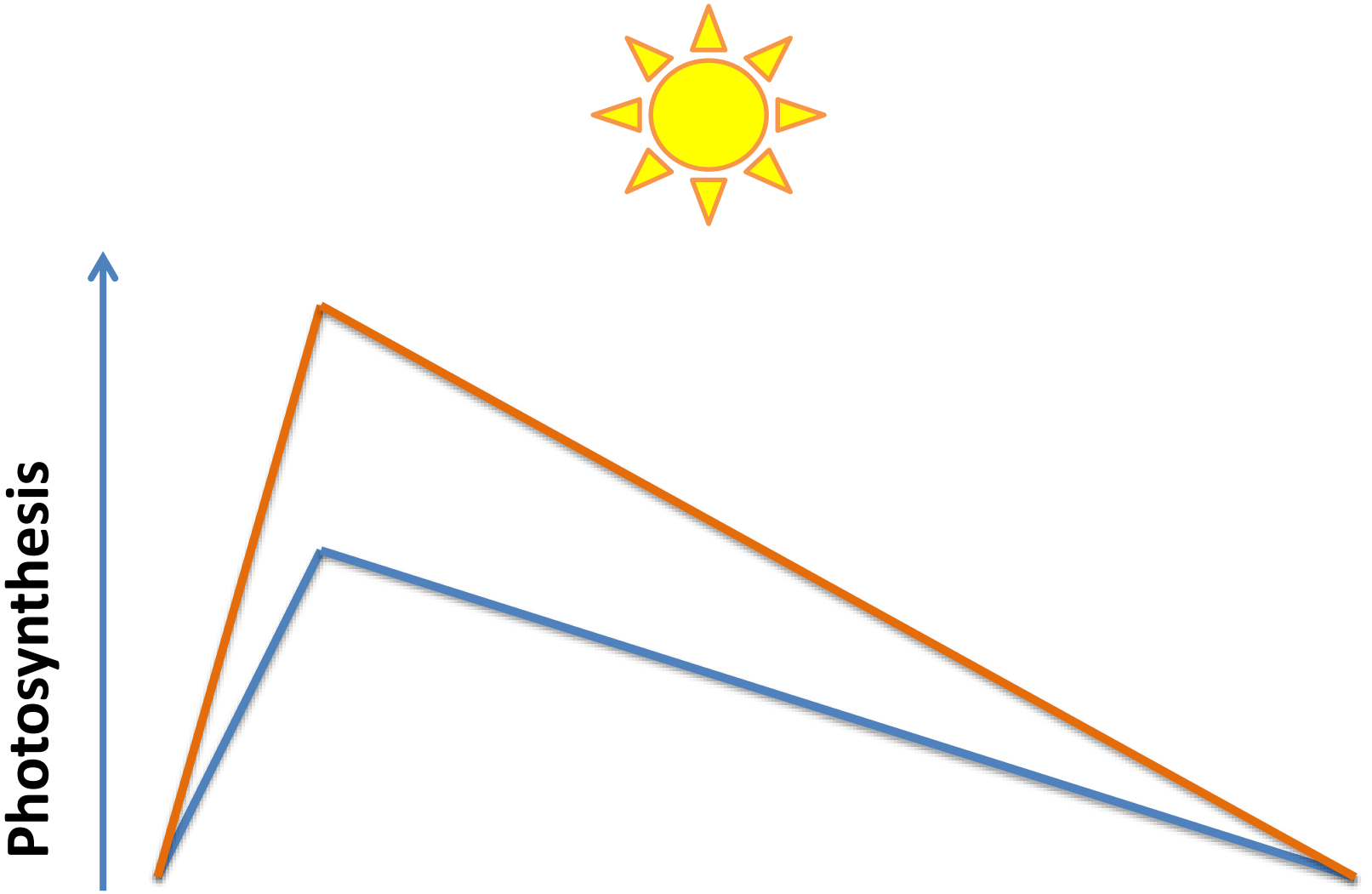
Does EVE provide a fitness advantage?

In hot and wet climate (a.k.a. the Cretaceous)!



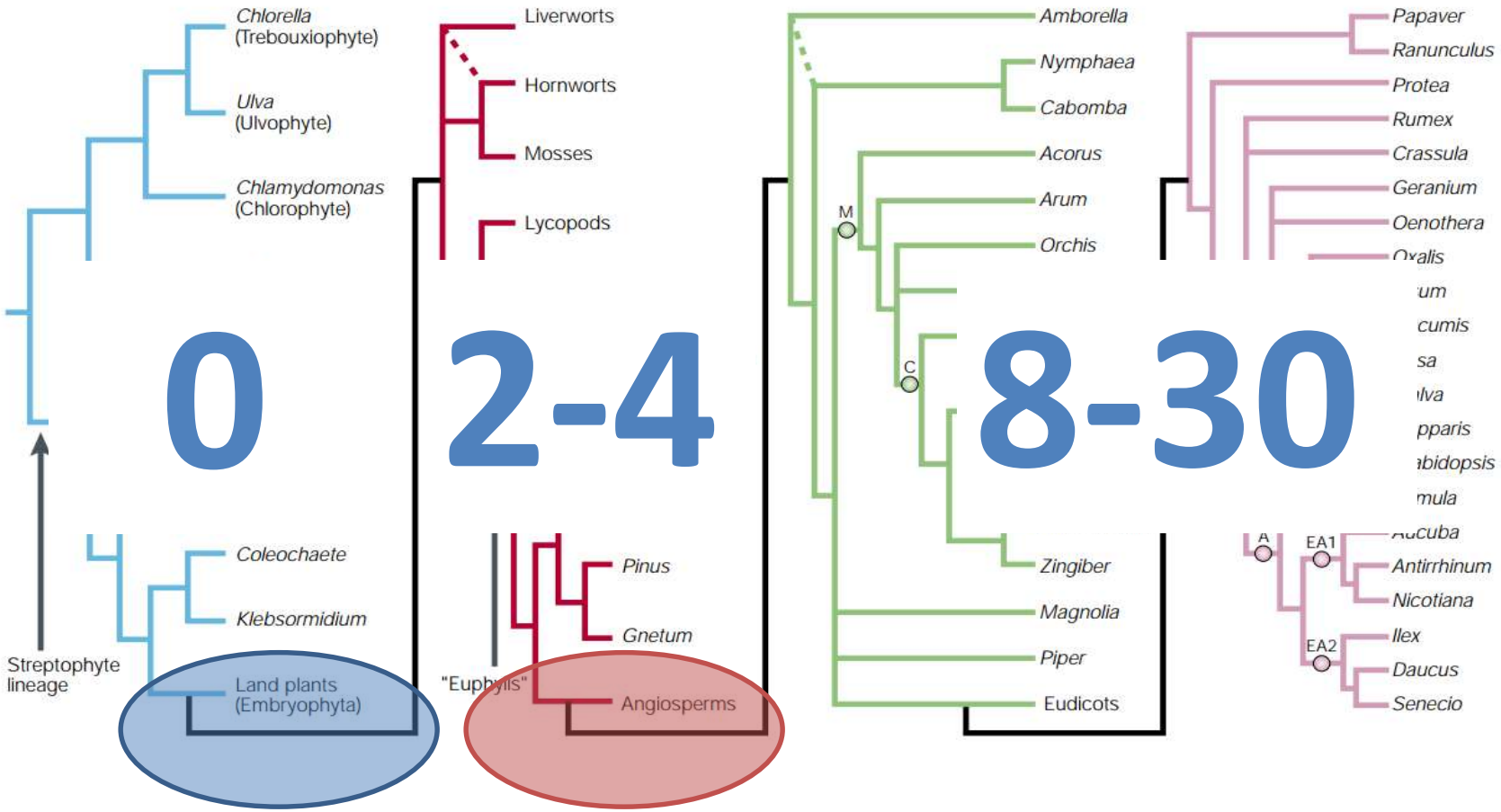


Evaporative demand is too high to sustain growth due to limited hydraulic conductivity – stomata closes and photosynthesis stops

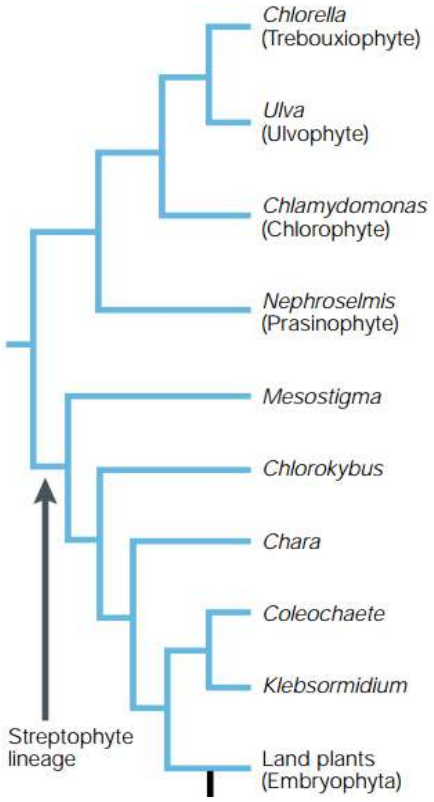


Evaporative demand is supported by the larger vessels and higher hydraulic conductivity – stomata remains open and photosynthesis continues

Who created EVE?

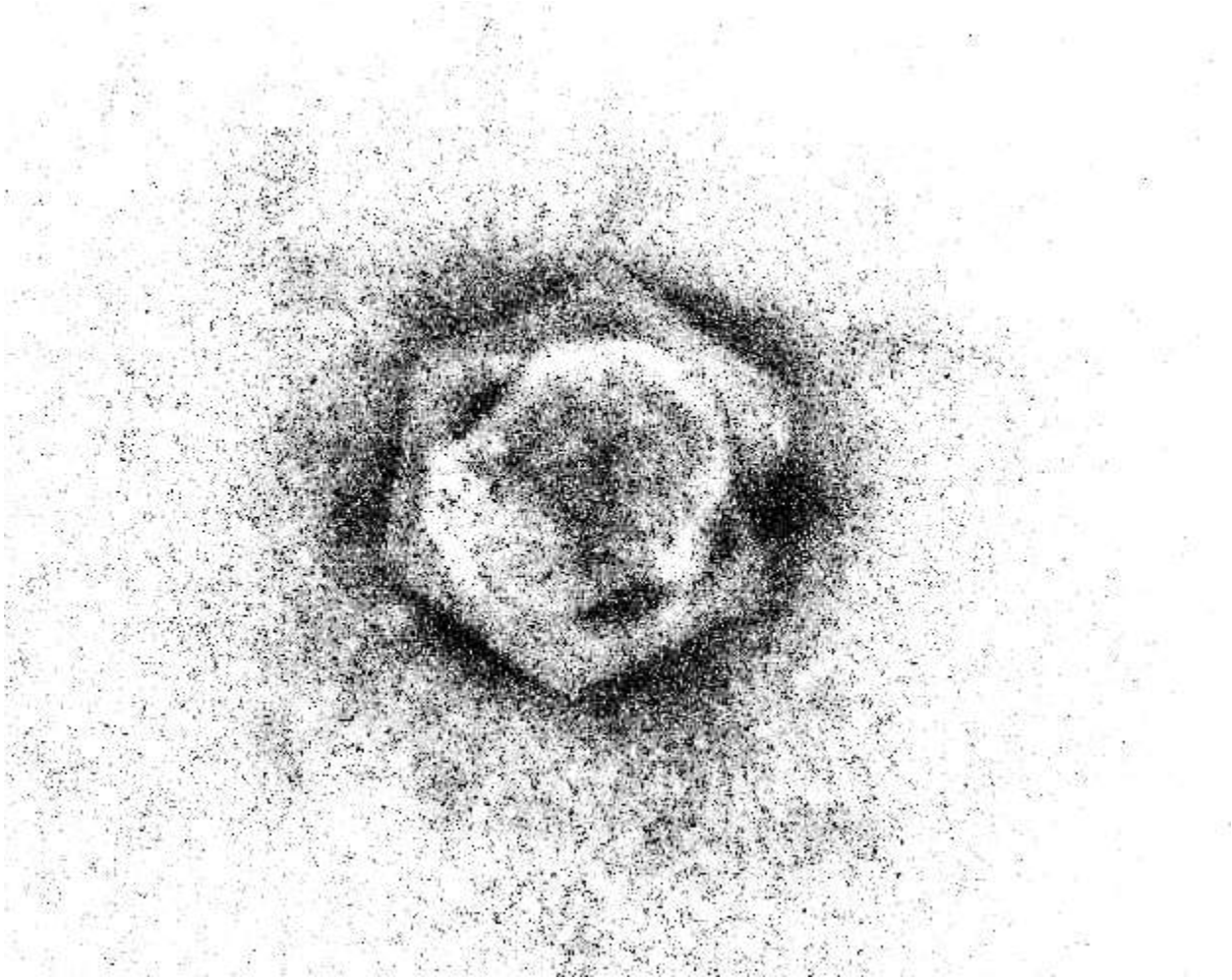


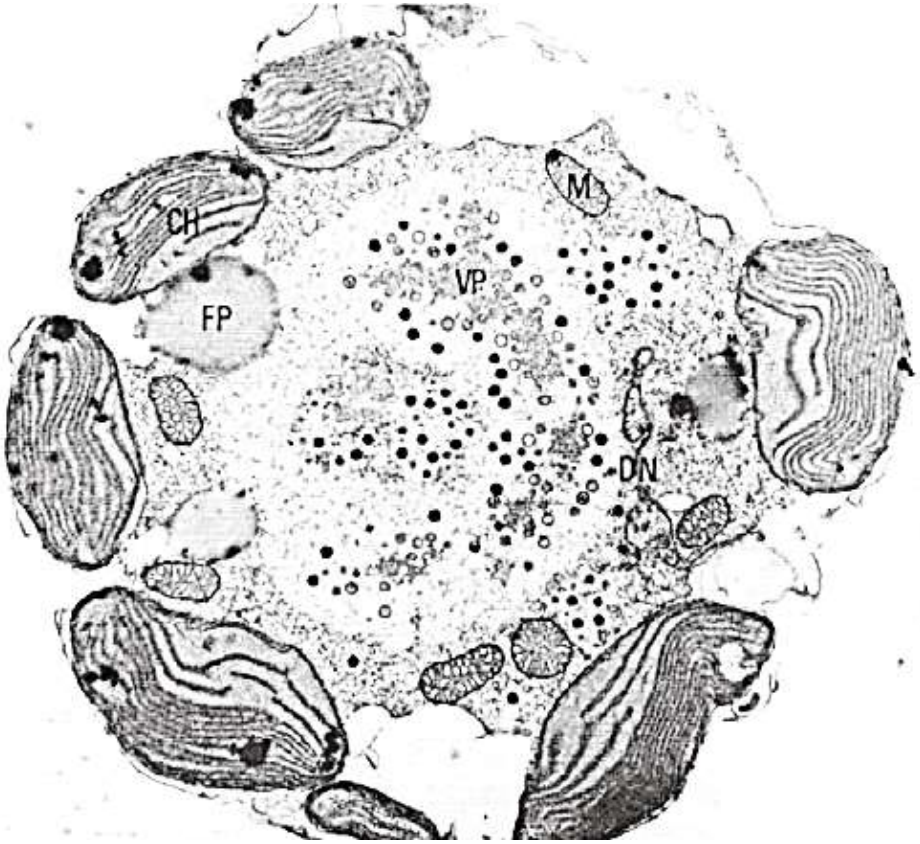
Who created EVE?



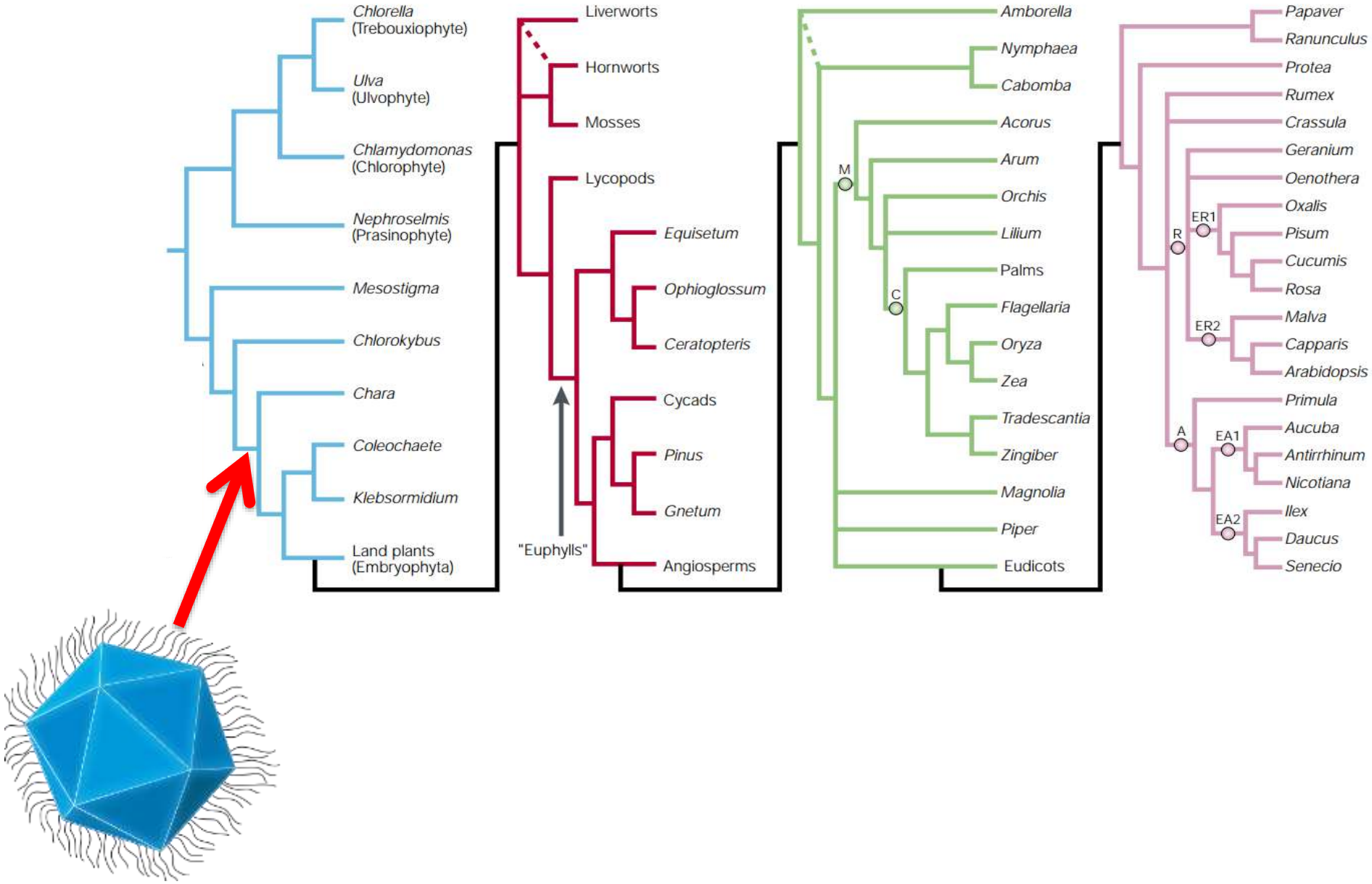
	Genomes	Transcriptomes (1 KP Project)
Chlorella (Trebouxiophyte)	NO	NO
Ulva (Ulvophyte)	NO	NO
Chlamydomonas (Chlorophyte)	NO	NO
Nephroselmis (Prasinophyte)	NO	NO
Mesostigma	NO	NO
Chlorokybus	NO	NO
Chara	?	YES
Coleochaete	?	YES
Klebsormidium	?	YES

Who created EVE?

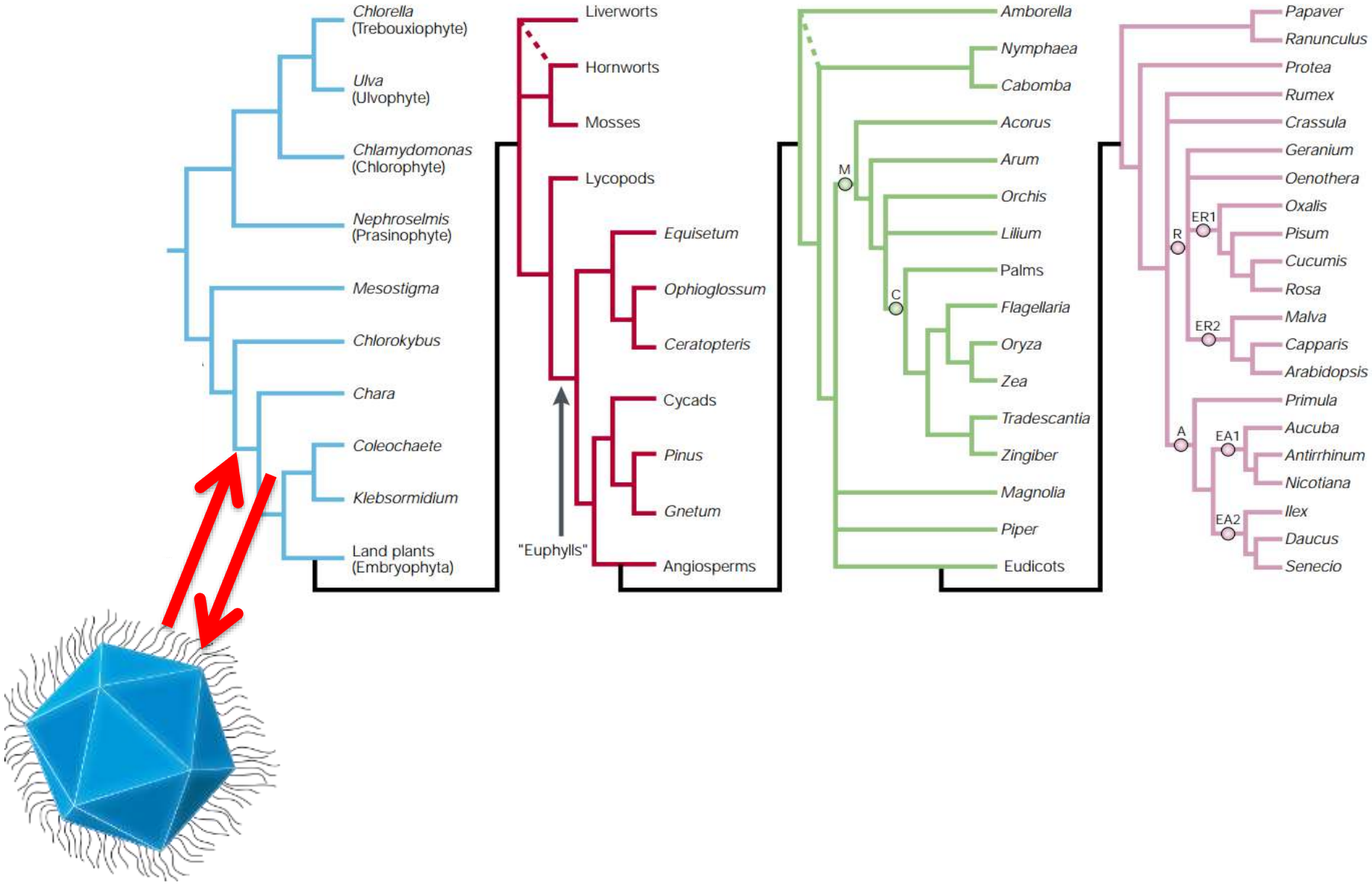




DOI: 10.1111/j.1444-2906.2008.01580.x



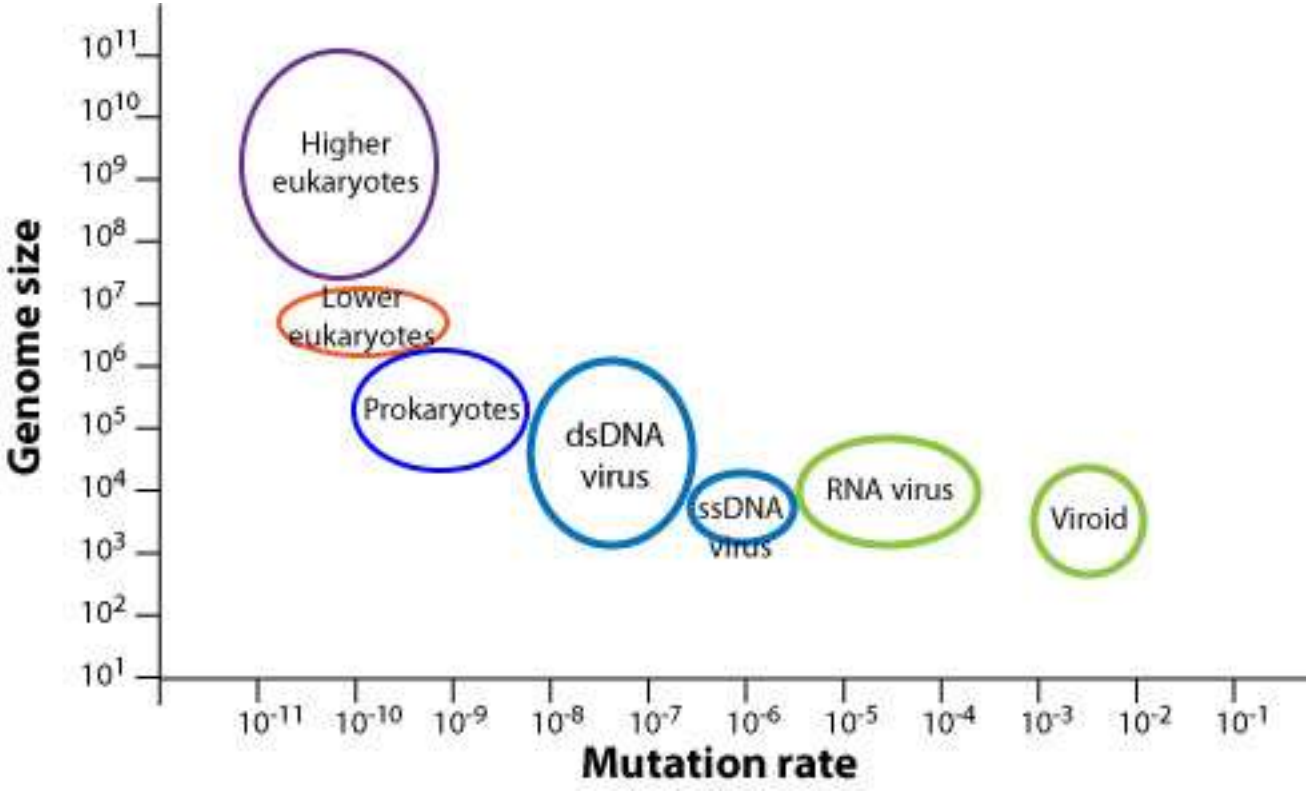
Modified from Cronk, Q.C. 2001 Nat Rev Genet. 2:607-19.



Modified from Cronk, Q.C. 2001 Nat Rev Genet. 2:607-19.

Phycodnaviruses create genomic novelty

- Phycodnaviruses are among the organisms with the highest mutation rate
- In three sequenced genomes, out of 1000 unique ORFs, only 14 in common
- Estimates are that over 10^{19} new phycodnaviruses are created each day



Drake JW. Ann N Y Acad Sci. 1999 May 18;870:100-7.

Phycodnaviruses are ~ 1B years older than green algae

EVE's architecture is more complex in viruses than it is in algae, and all land plants

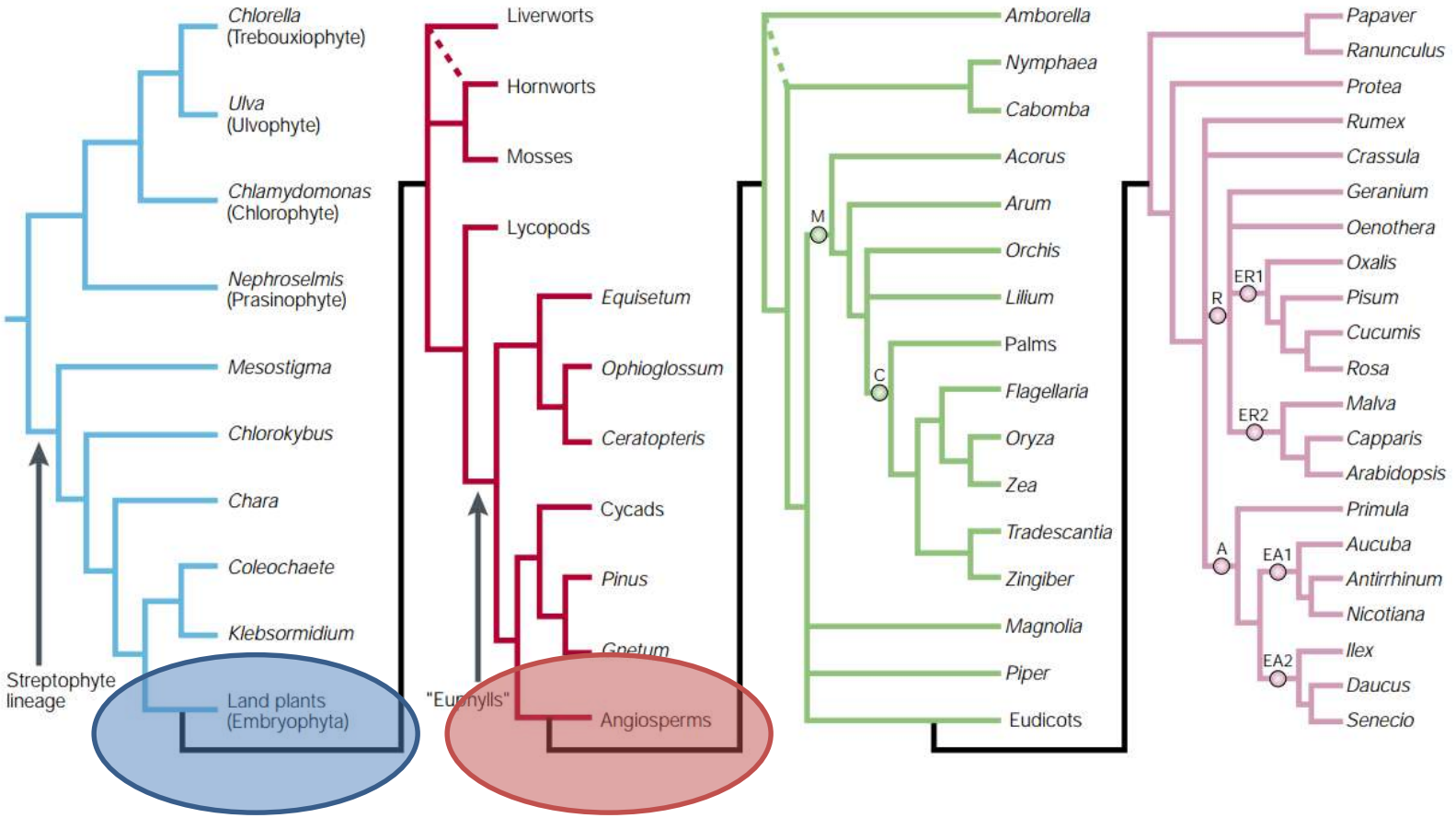
Drake JW. Ann N Y Acad Sci. 1999 May 18;870:100-7.

What does EVE do?

What would happen if we overexpress EVE in a gymnosperm?

Was EVE key to the colonization of land?

Summary


Chlorella
(Trebouxiophyte)
Ulva
(Ulvophyte)
Chlamydomonas
(Chlorophyte)
Nephroselmis
(Prasinophyte)
Mesostigma
Chlorokybus
Chara
Coleochaete
Klebsormidium
Land plants
(Embryophyta)
Streptophyte
lineage
Liverworts
Hornworts
Mosses
Lycopods
Equisetum
Ophioglossum
Ceratopteris
Cycads
Pinus
Gnetum
Angiosperms
"Eumyills"
Amborella
Nymphaea
Cabomba
Acorus
Arum
Orchis
Lilium
Palms
Flagellaria
Oryza
Zea
Tradescantia
Zingiber
Magnolia
Piper
Eudicots
M
C
Papaver
Ranunculus
Protea
Rumex
Crassula
Geranium
Oenothera
Oxalis
Pisum
Cucumis
Rosa
Malva
Capparis
Arabidopsis
Primula
Aucuba
Antirrhinum
Nicotiana
Ilex
Daucus
Senecio
R
ER1
ER2
A
EA1
EA2

Acknowledgements

University of Florida, Forest Genomics Laboratory

Juan J. Acosta
Chris Dervinis
Annette Fahrenkrog
Leandro G. Neves
Márcio Resende
Cintia L. Ribeiro

Alumni: Ryan Brown, Derek Drost, Patricio Munoz, Tania Quesada, Evandro Novaes, Carolina D. B. Novaes, Cynthia Silva

U British Columbia
Shawn Mansfield

U of Alberta
Onekp Project

United States Department of Agriculture
National Institute of Food and Agriculture