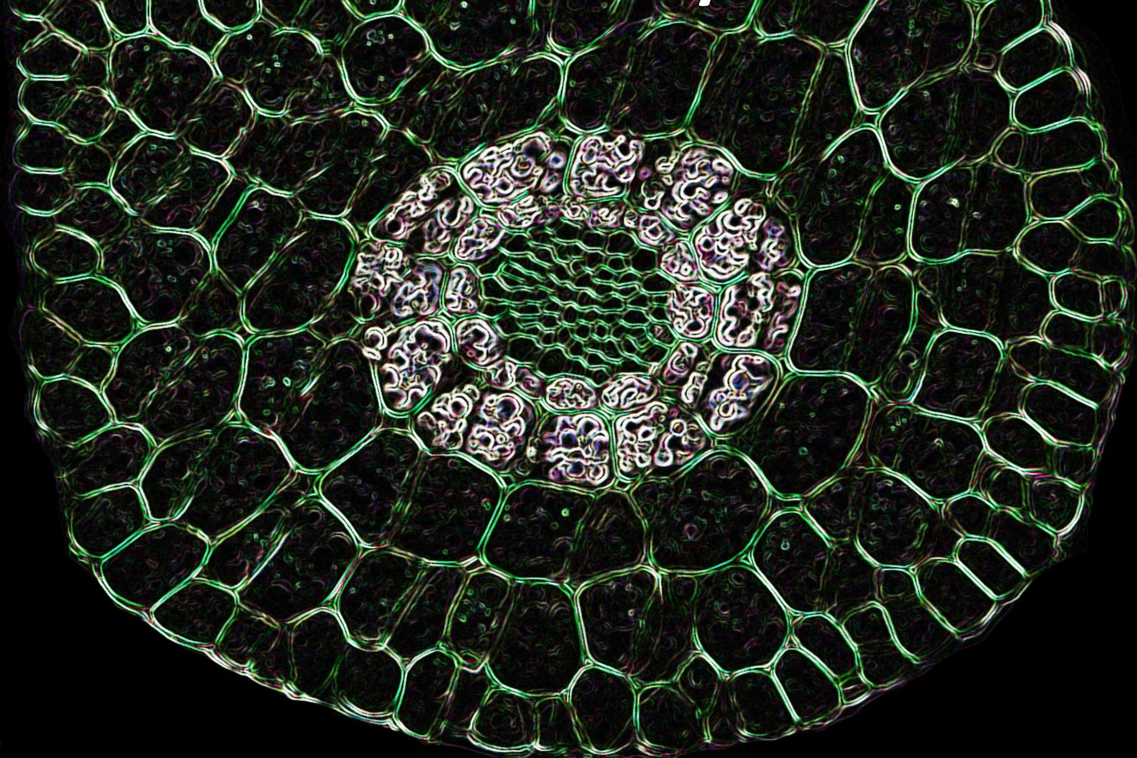
THE DIVERSE IRON DISTRIBUTION IN EUDICOTYLEDONEAE SEEDS: FROM ARABIDOPSIS TO QUINOA

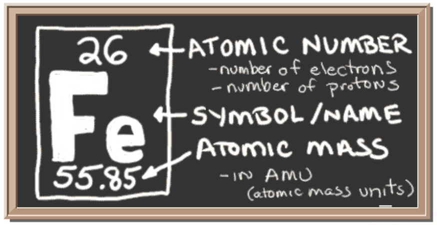
Using Plants as model to study iron distribution

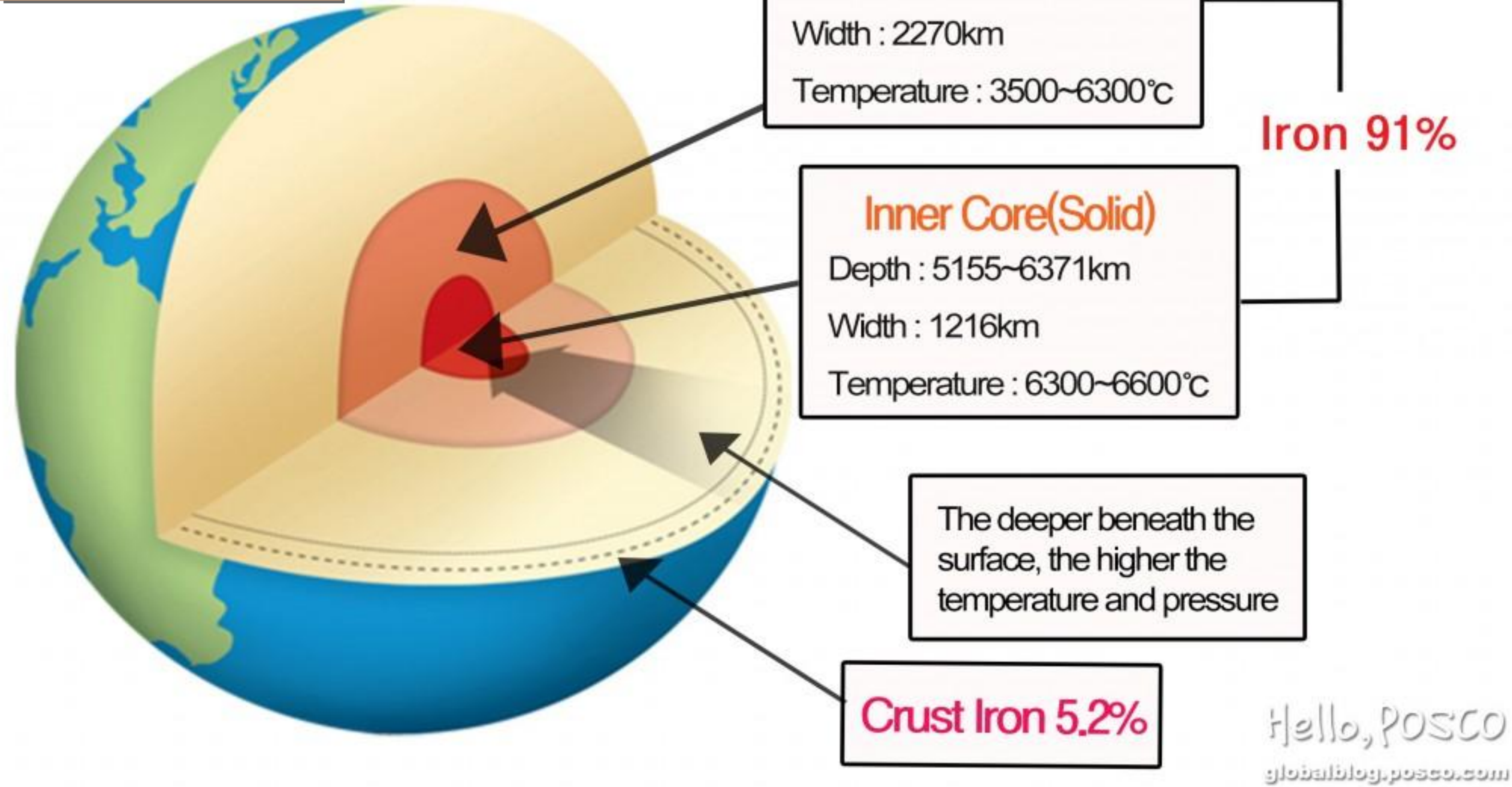


Hannetz Roschzttardtz

Assistant professor
Faculty of Biological Sciences
Iron Nutrition and Plant Development Laboratory
Pontificia Universidad Católica de Chile

How much iron is there in Earth?

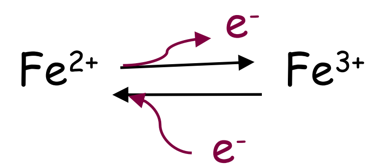




Iron is essential for life

Transition metal

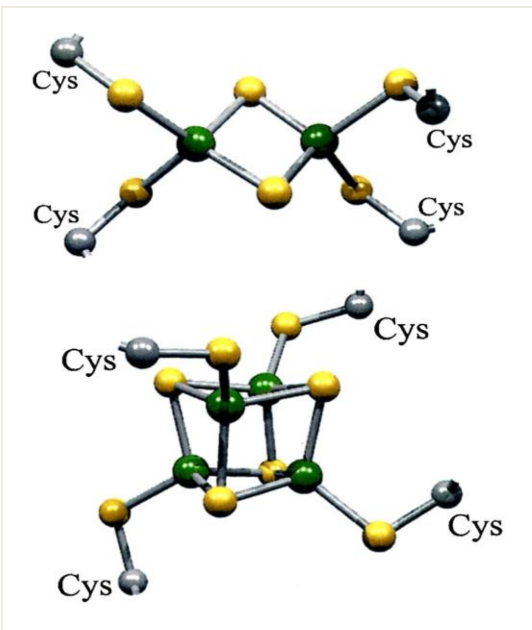
26	+2
Fe	+3
	55.85



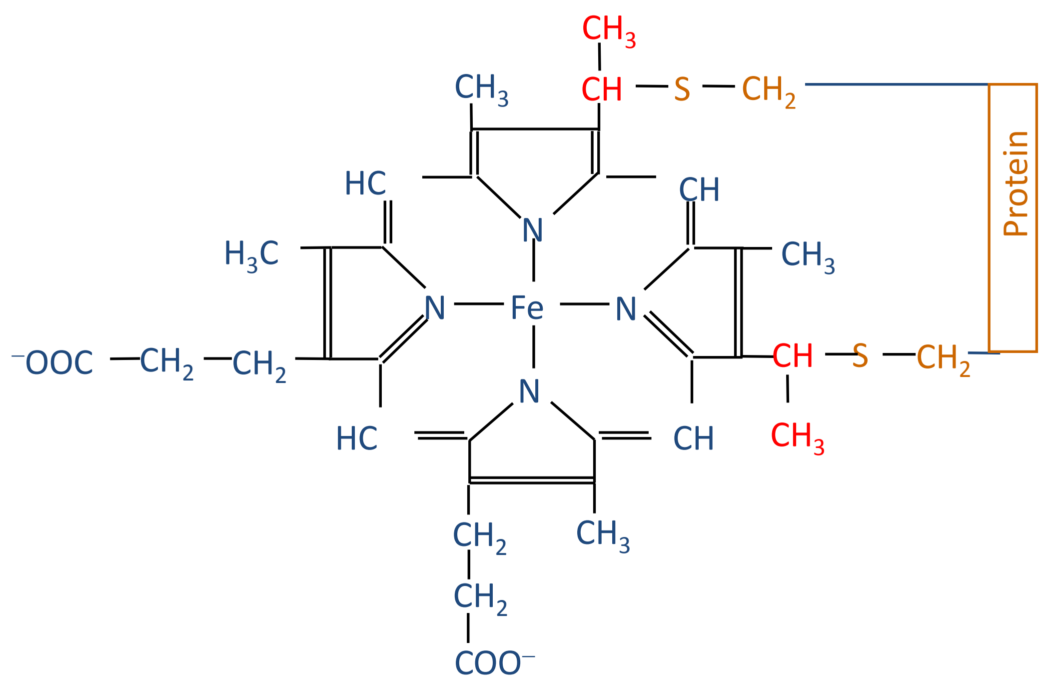
Iron sulfur clusters

$[Fe_2S_2]$

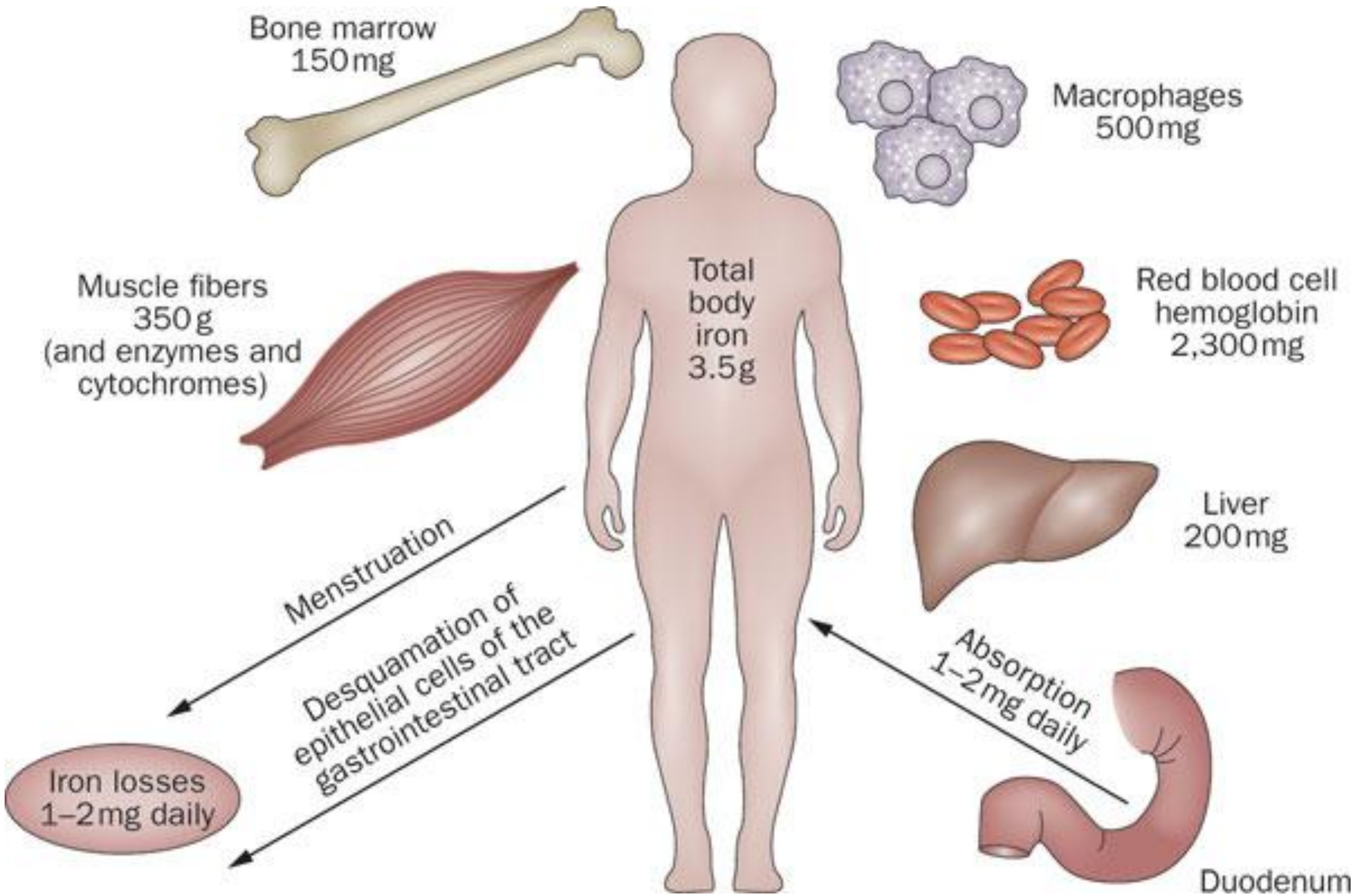
$[Fe_4S_4]$



Heme b



Iron Homeostasis in humans.



Nature Reviews Gastroenterology & Hepatology 7, 599-610 (November 2010)

Essential….but toxic!

Free radicals production by Fenton reaction

$$Fe^{2+} + O_2 \rightarrow Fe^{3+} + \mathbf{O_2^{\bullet -}}$$

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \mathbf{HO^{\bullet}} + HO^{-}$$

Iron excess

In plant: Rice bronzing
Animals: hereditary hemochromatosis.

Iron excess response:

Storage (Ferritins)

Compartmentalization

Inhibition of root uptake

Rice Bronzing

Essential....but toxic!

Free radicals production by Fenton reaction

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Iron excess

In plant: Rice bronzing
Animals: hereditary hemochromatosis.

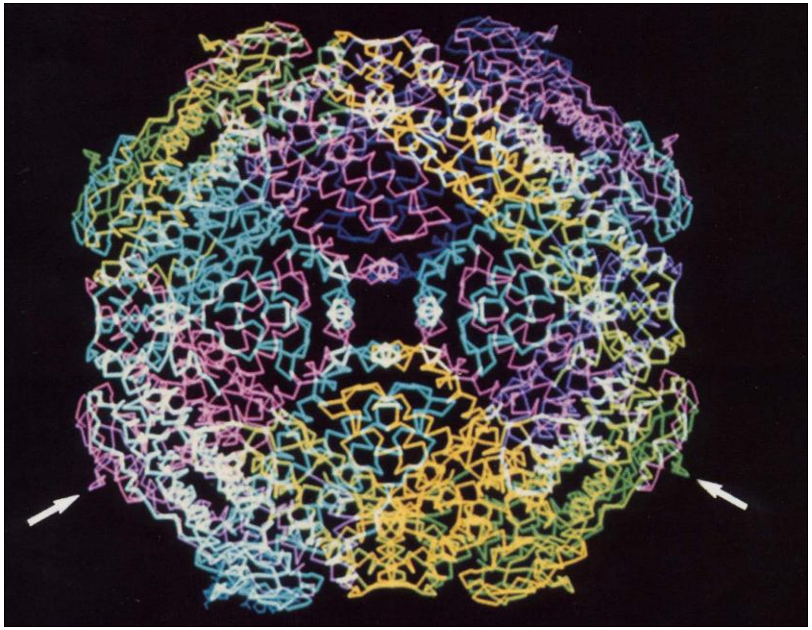
Iron excess response:

Storage (Ferritins)

Compartmentalization

Inhibition of root uptake

Plant ferritin

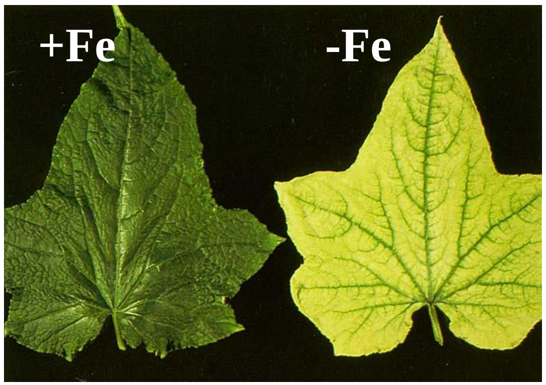


-24 subunits
-Plastid
-4500 atoms of Iron

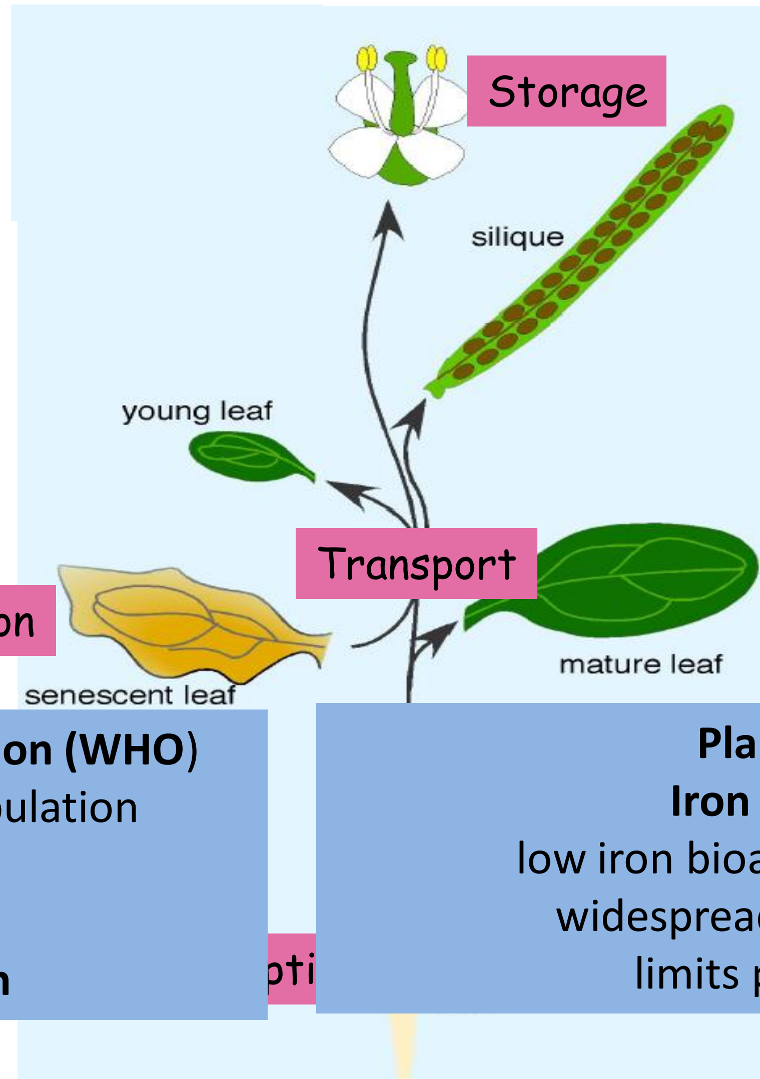
Iron in plant

$$Fe^{2+} \underset{e^-}{\overset{e^-}{\rightleftharpoons}} Fe^{3+}$$

Iron is essential.



Interveinal chlorosis



Remobilization

…but toxic!

World Health Organization (WHO)
30% of the world population
is anemic

Biofortification

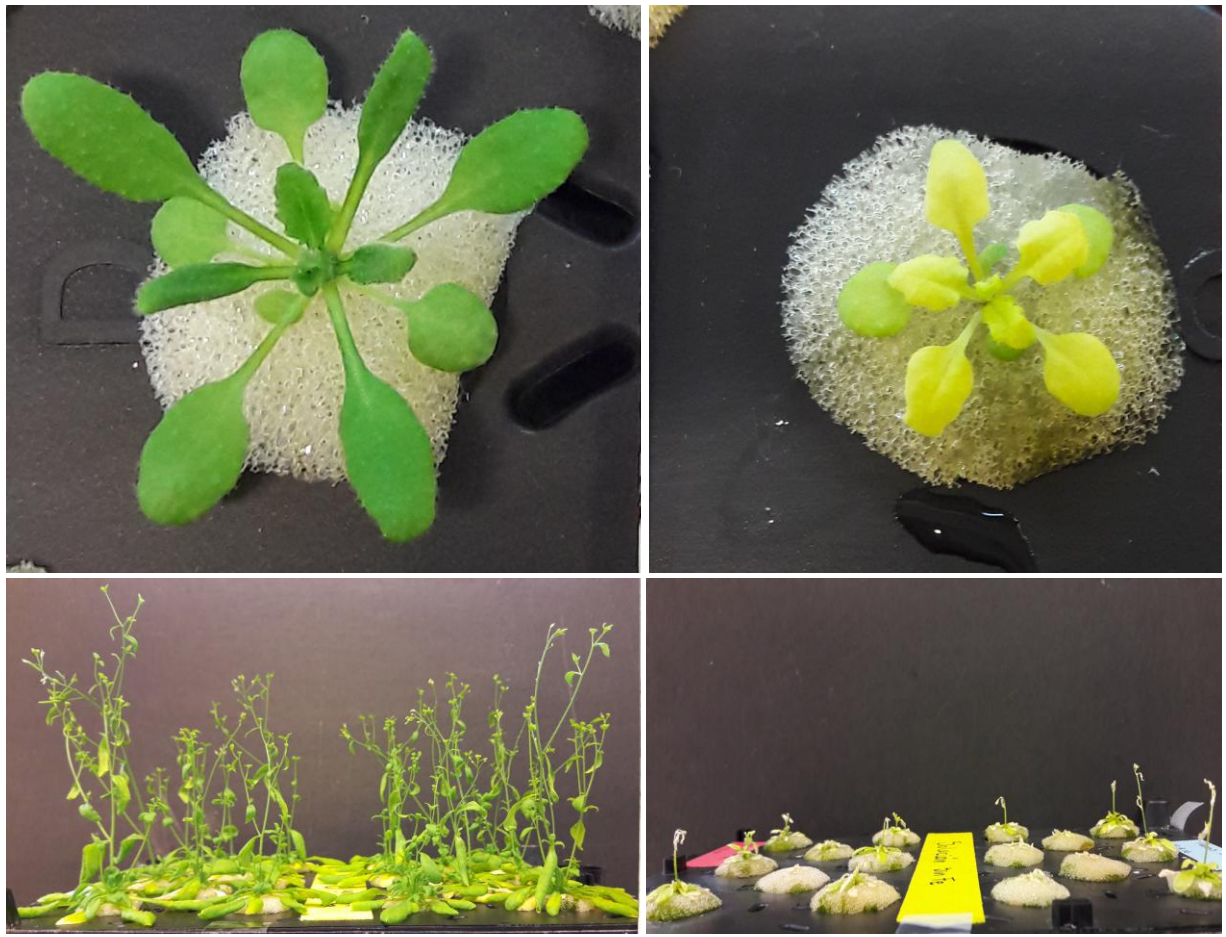
Plant Stress
Iron Deficiency
low iron bioavailability in soils,
widespread in arable soils,
limits plant growth

Hydroponic to evaluate Iron deficiency on *Arabidopsis thaliana*.

+Fe -Fe

4 weeks

6 weeks



Nathalia Navarro

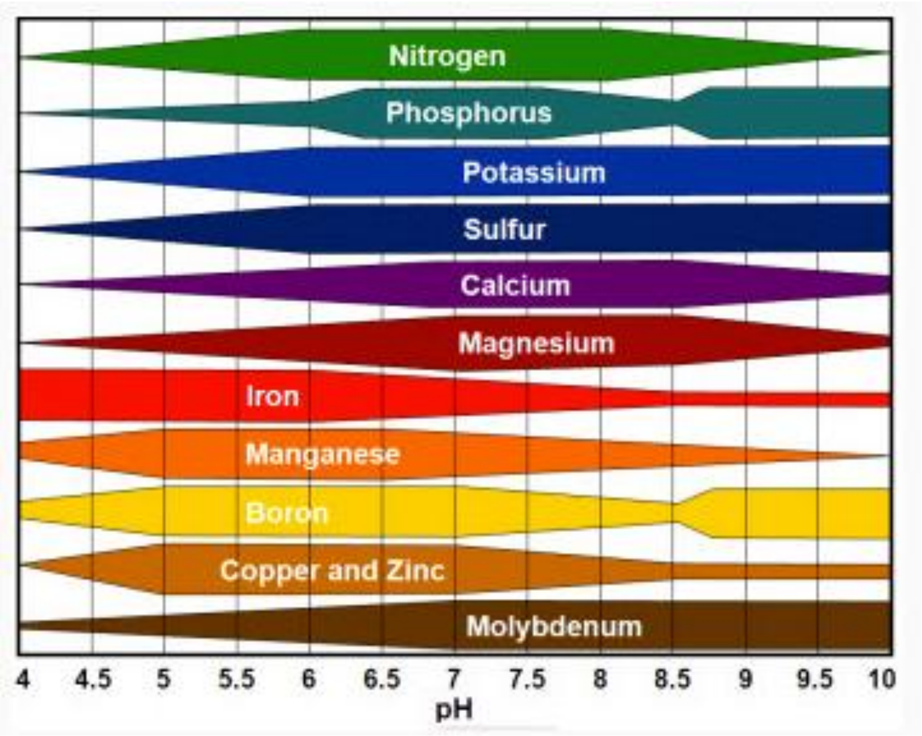
Iron chlorosis and plant growth

Pin oak with severe iron chlorosis

The same pin oak 6 weeks later after injection with ferric ammonium citrate.

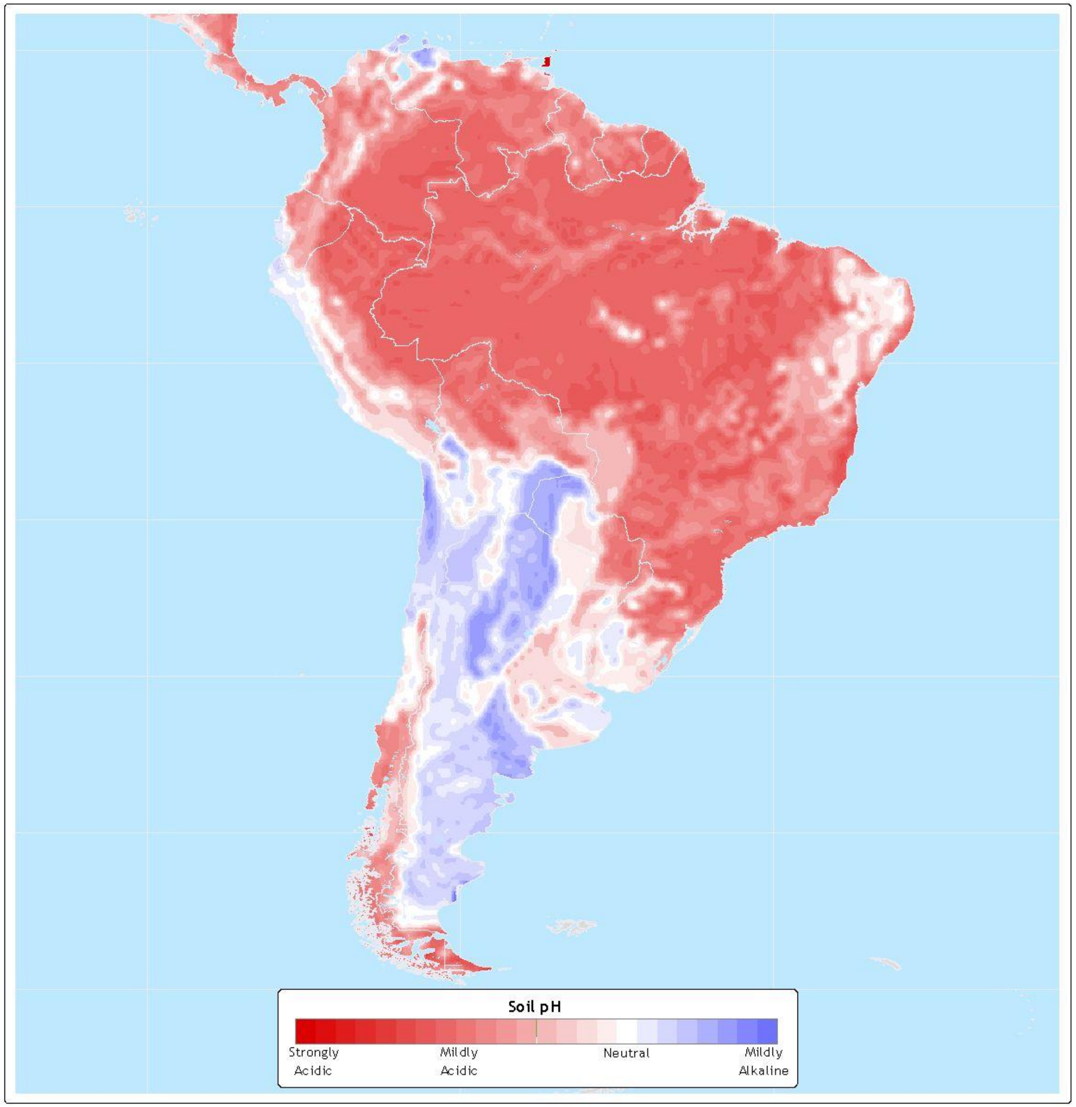
(http://forestry.usu.edu/)

pH and iron in soil



Soil pH

South America



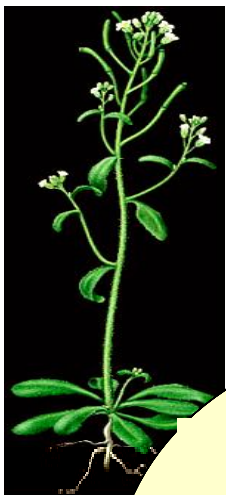
Data taken from: IGBP-DIS Global Soils Dataset (1998)

Atlas of the Biosphere

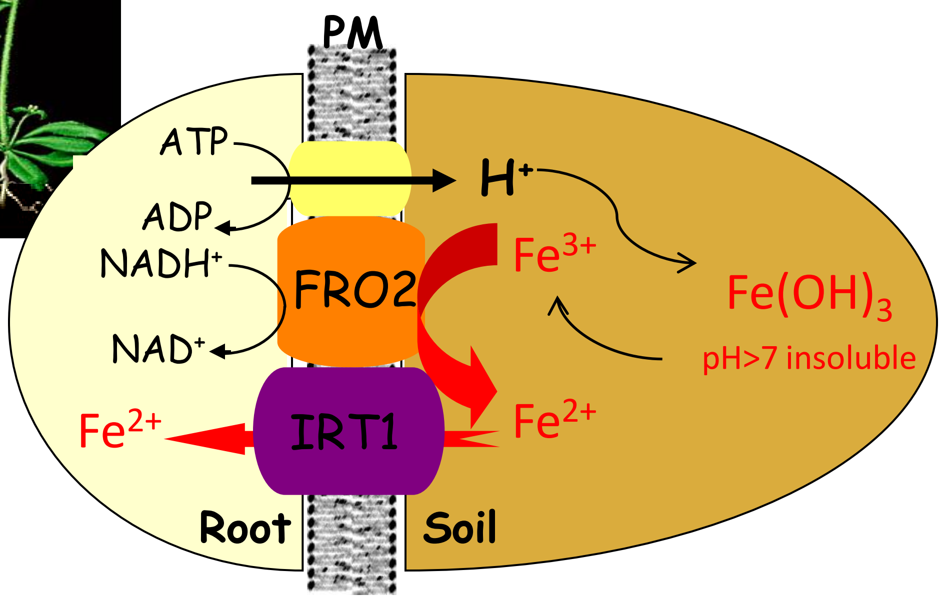
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

Iron from the soil

Strategy I (non grasses)
Acidification/reduction
Fe^{2+} Transport

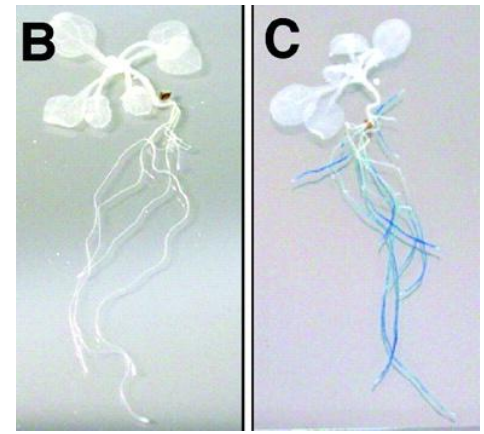


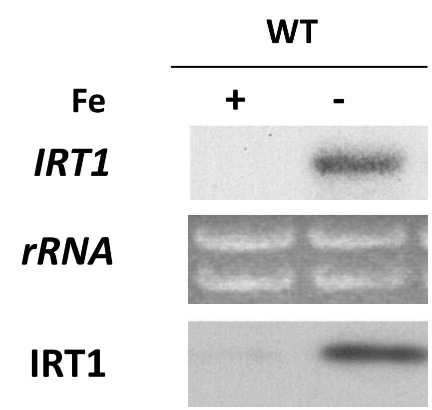
Arabidopsis
Tomato
Pea...



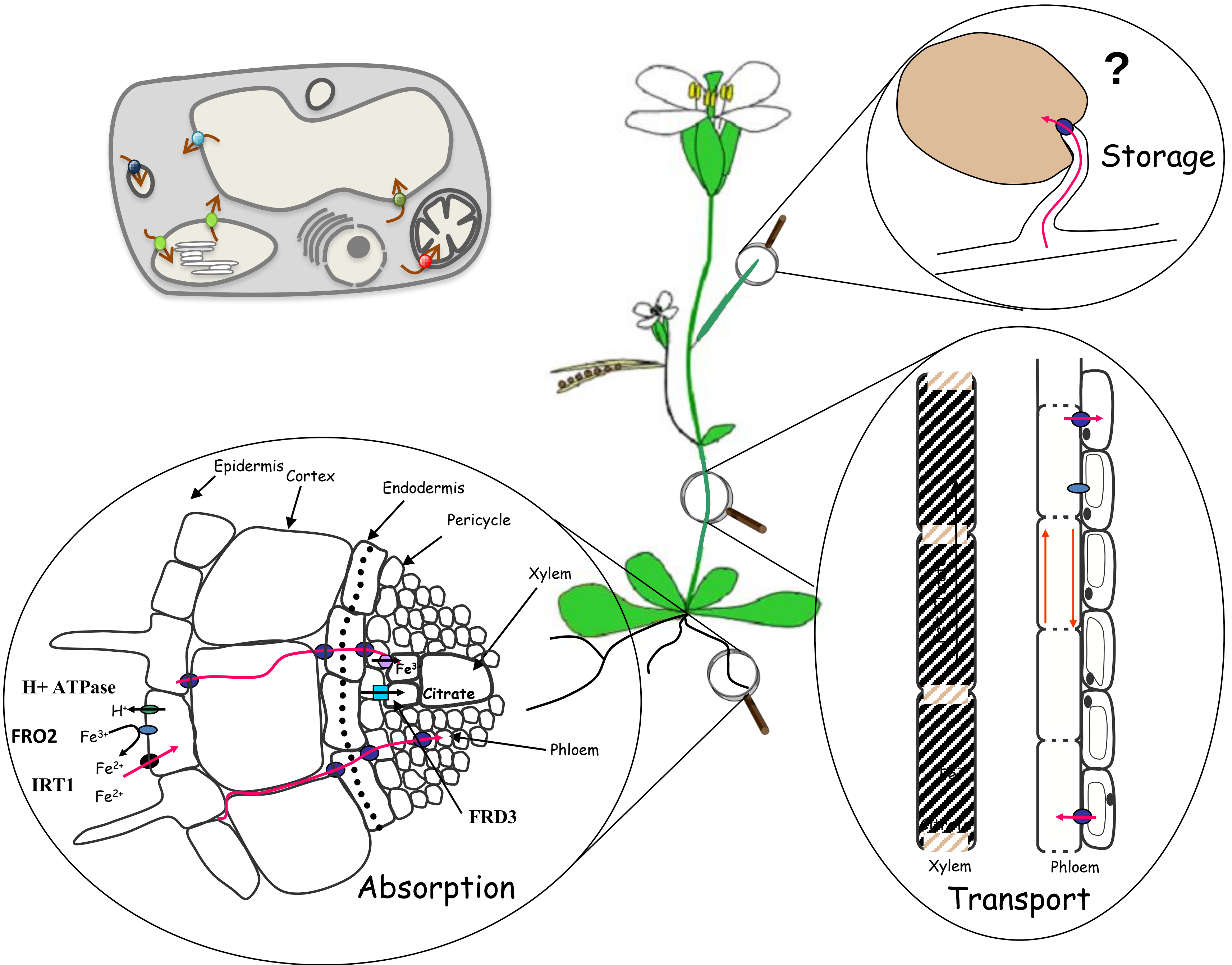
IRT1::GUS

+Fe -Fe





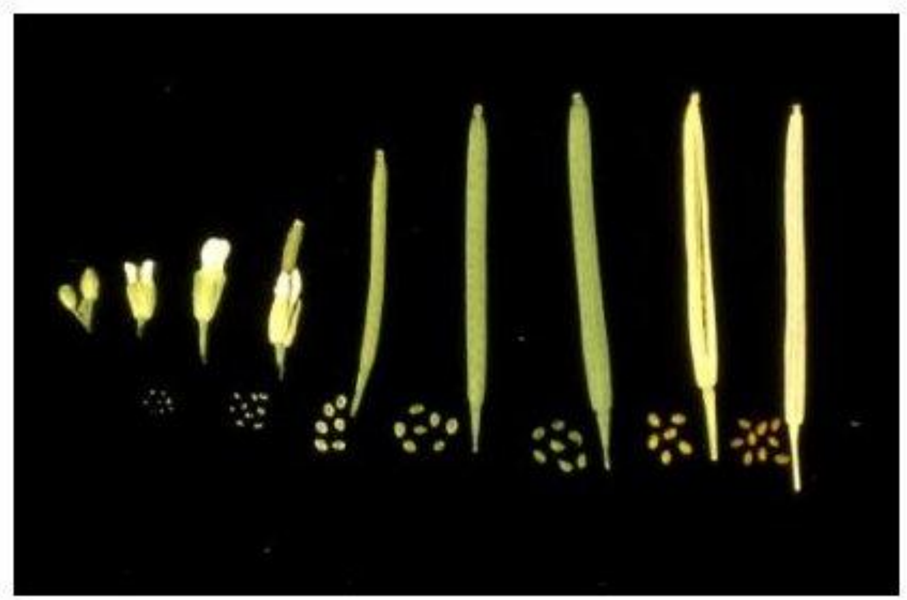
Iron in Arabidopsis



Seeds

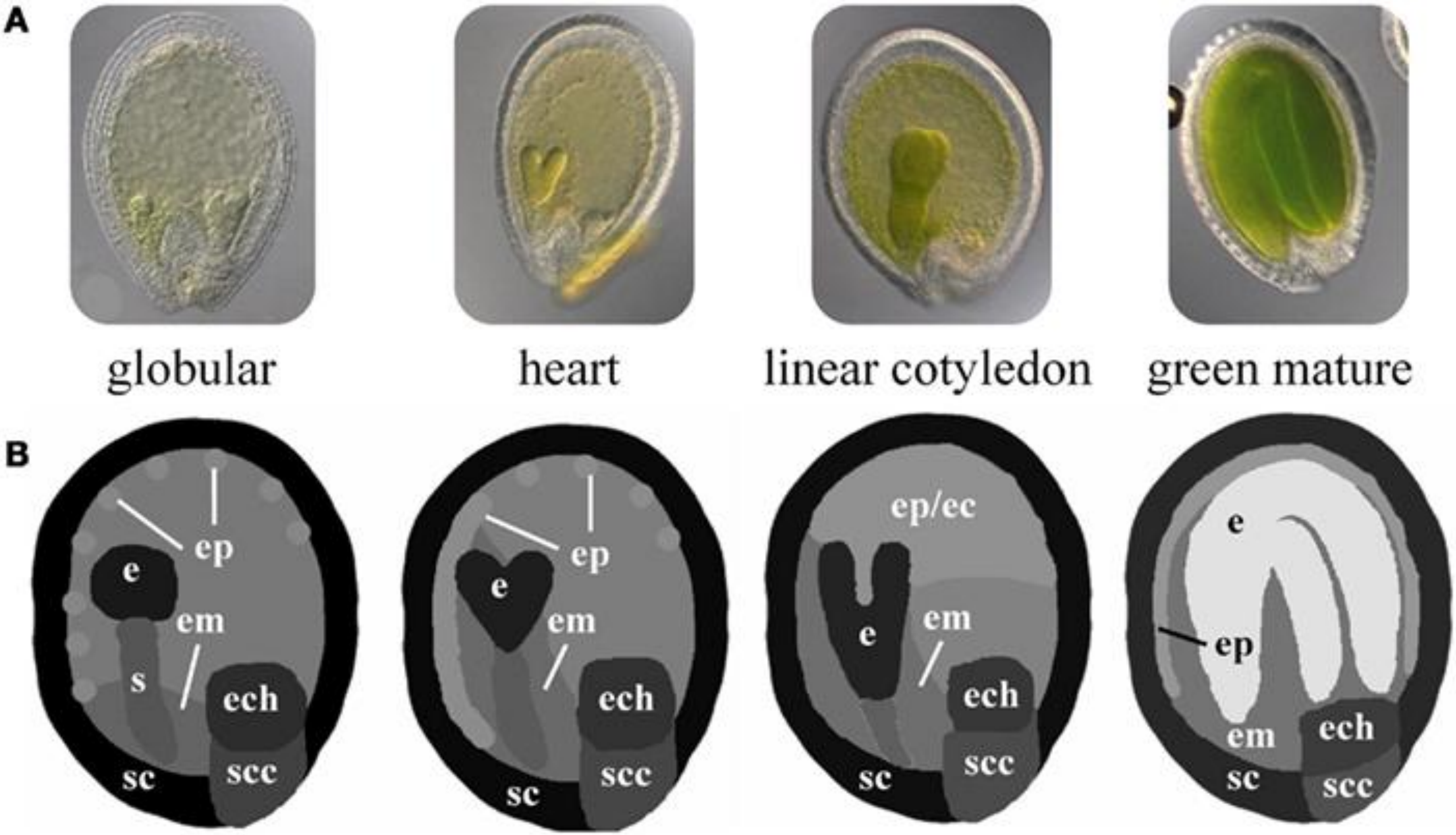
http://www.health.harvard.edu/

Arabidopsis thaliana
Model plant



http://seedgenes.org

Embryogenesis in Arabidopsis



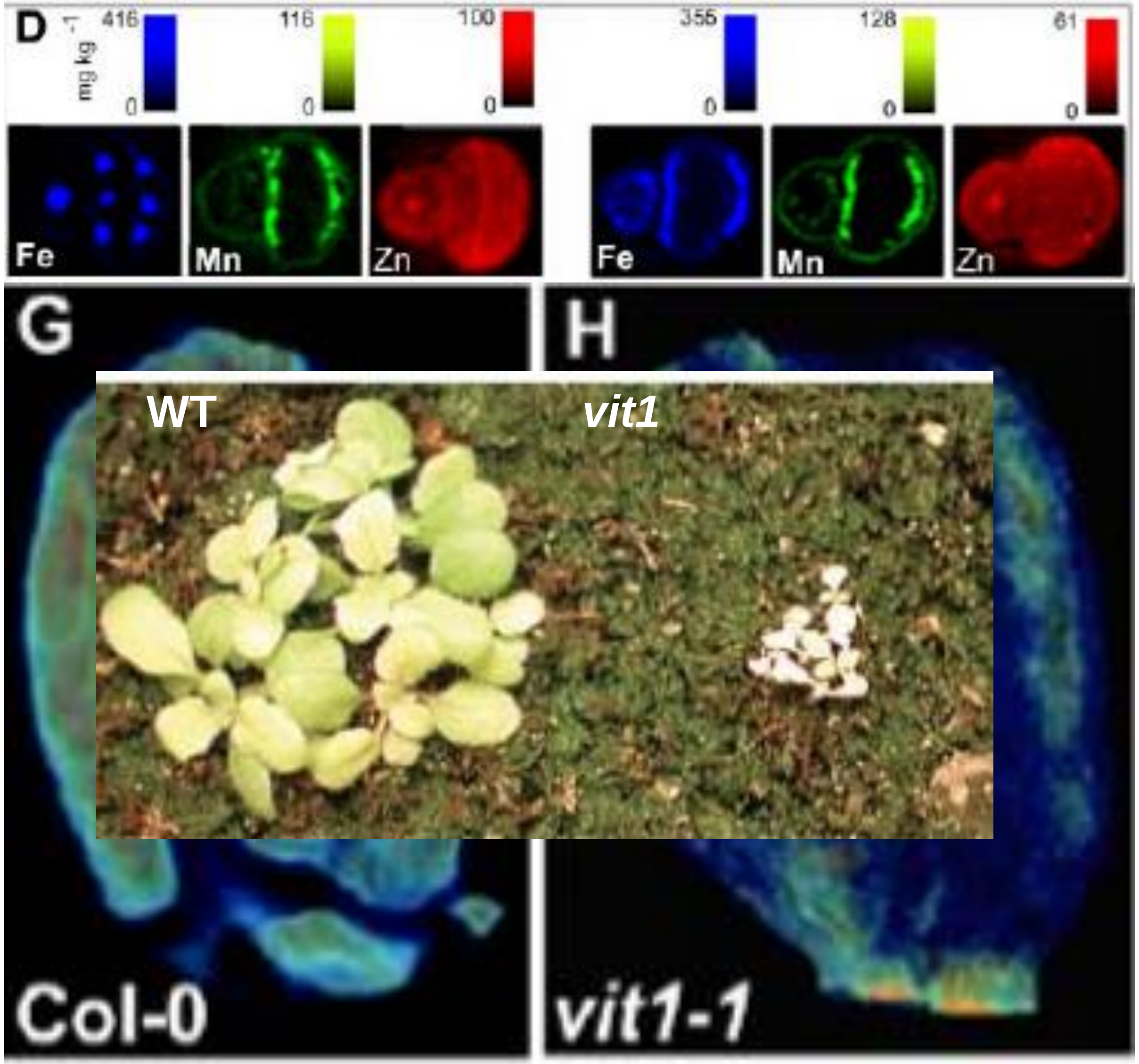
Junker et al., 2012

Iron in *Arabidopsis thaliana seeds*

Synchrotron-generated X-ray fluorescence (XRF)

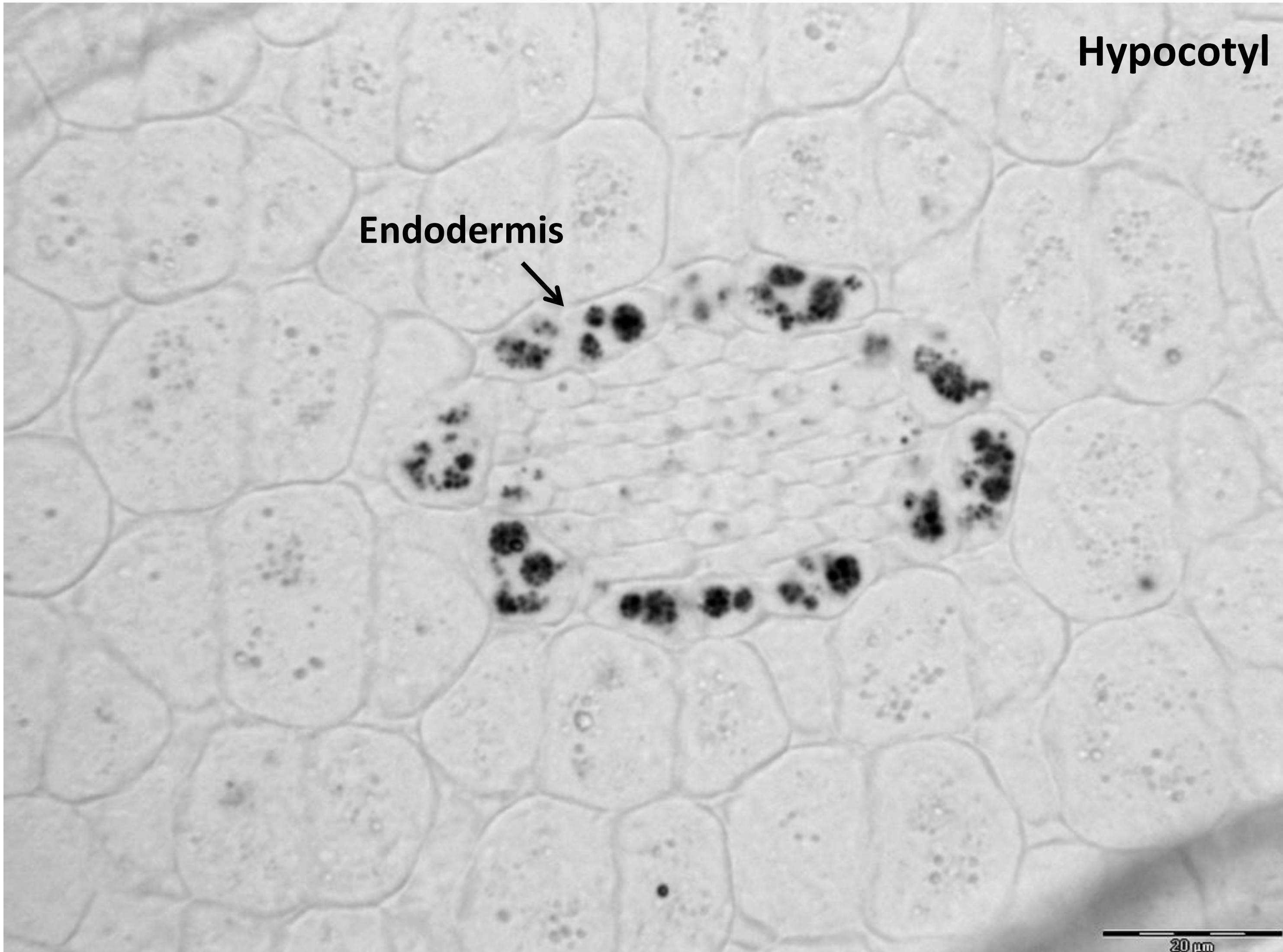
Iron in *Arabidopsis thaliana seeds*

Synchrotron-generated X-ray fluorescence (XRF)



(Kim et al., 2006)

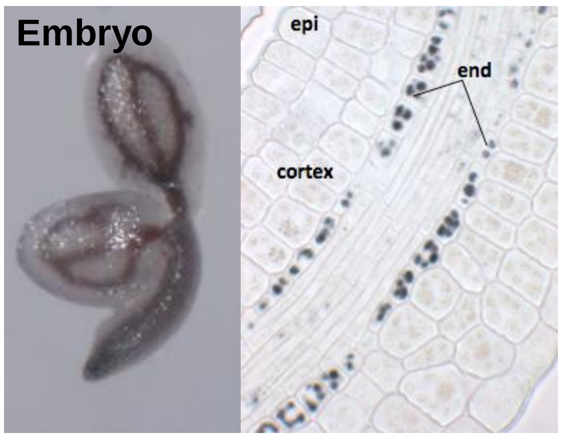
Iron is accumulated in embryonic endodermis



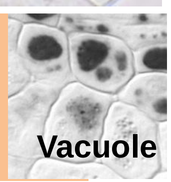
(Roschzttardtz et al., 2009)

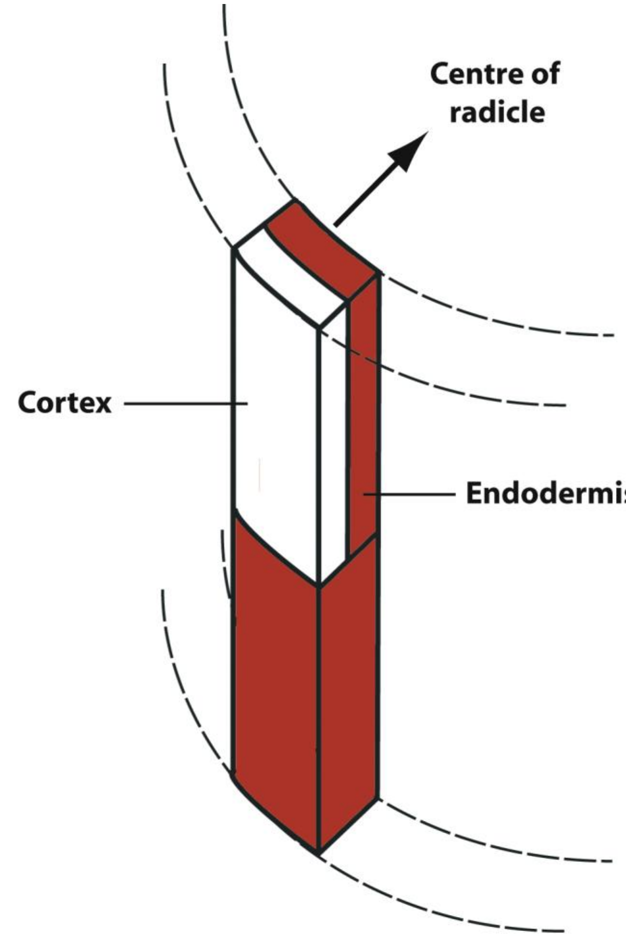
Iron localization in seeds…
A conserved character in plant evolution?

Perls/DAB staining



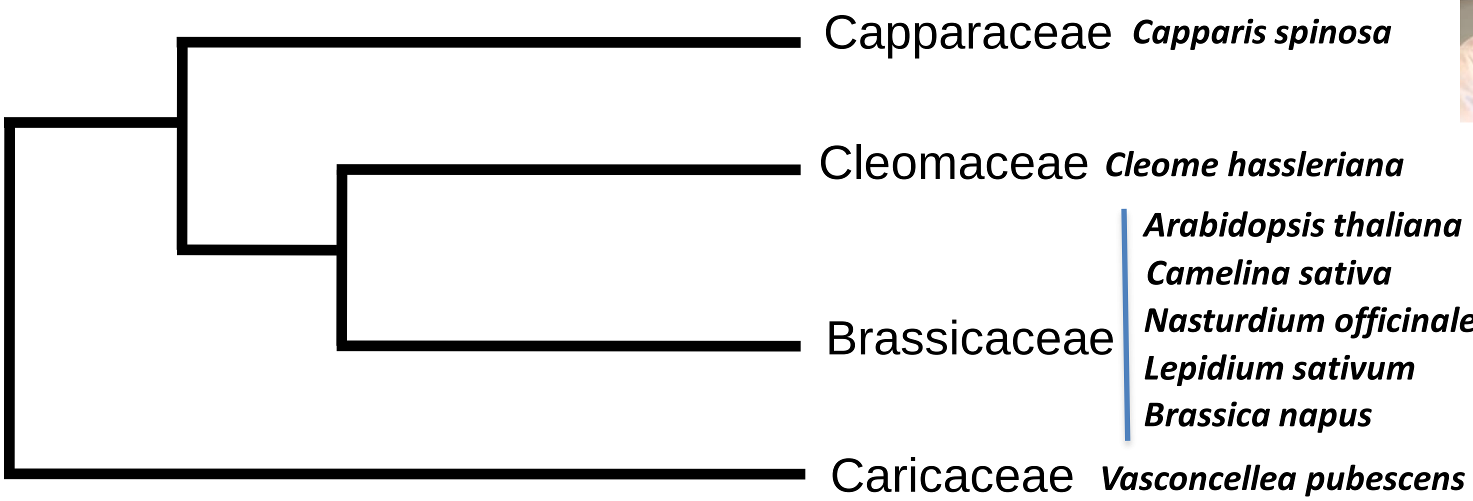
- -Easy to perform
- -Specific
- -Sensitive





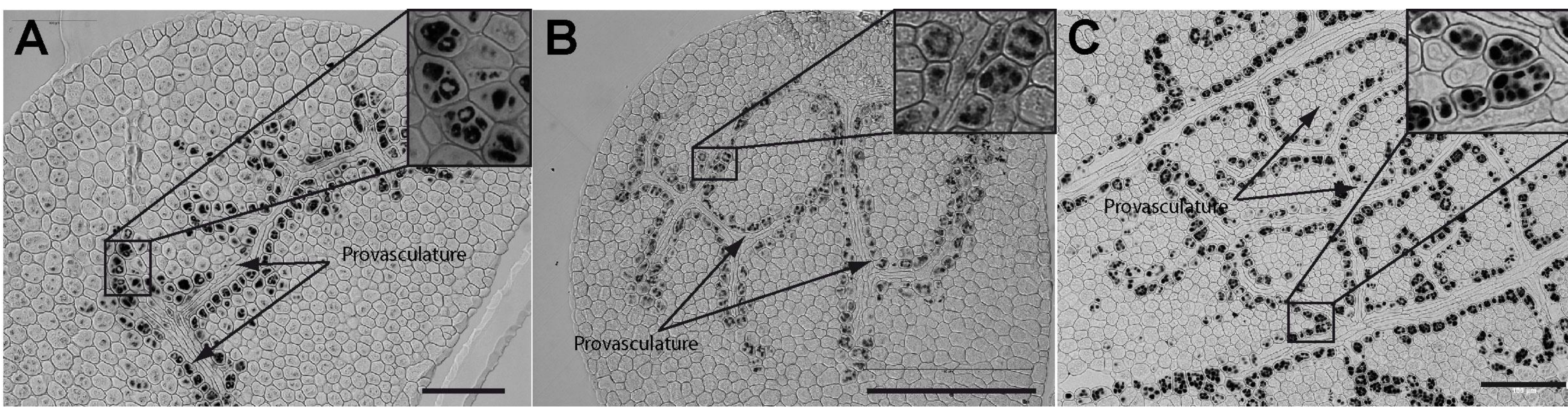
(Adapted from Leyser and Day, 2002)

Orden Brassicales



Family Brassicaceae

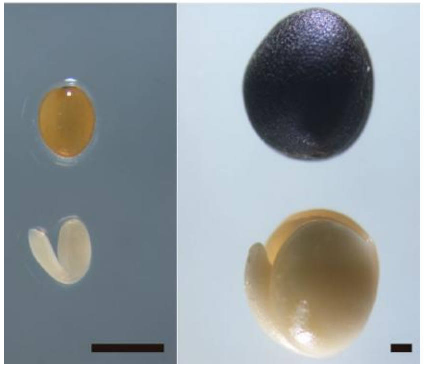
Nasturdium officinale | *Camelina sativa* | *Brassica napus*



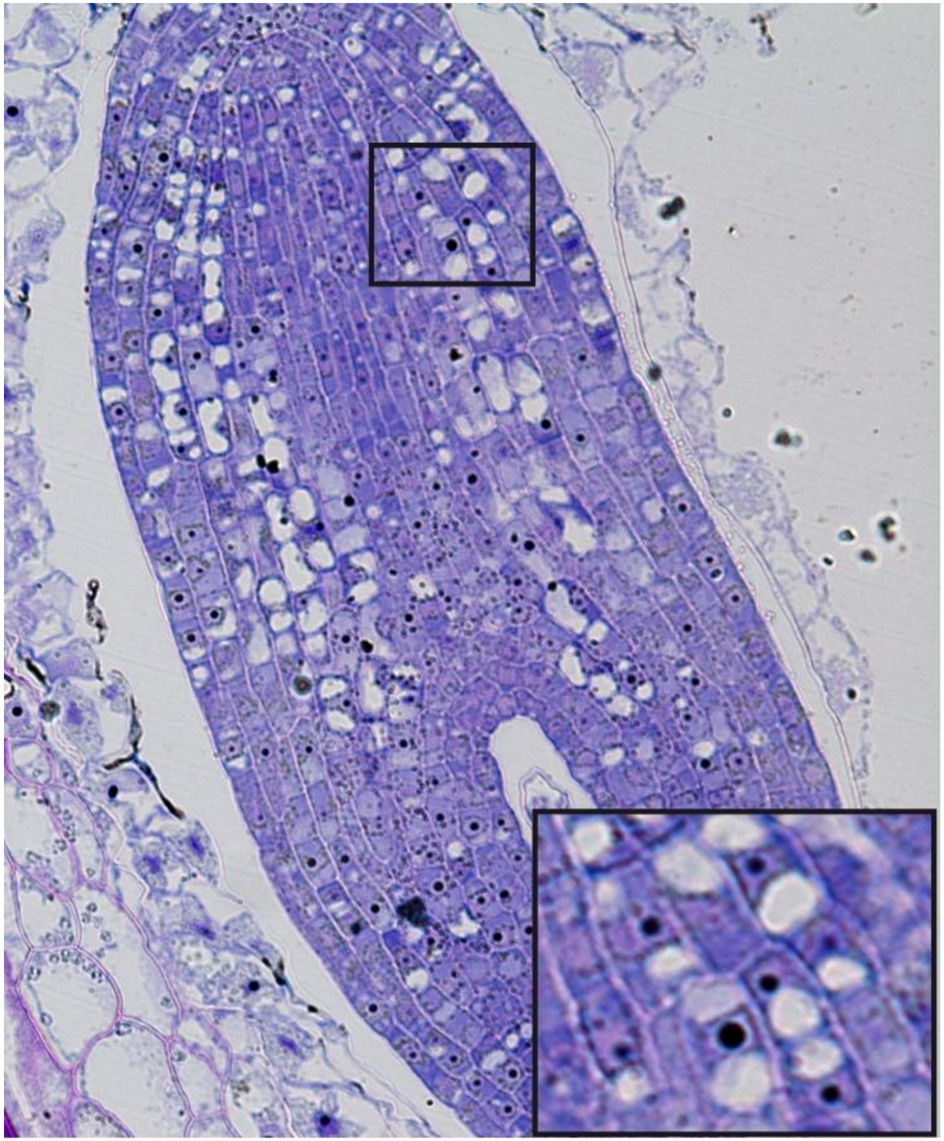
(Ibeas el al., 2017)

Dynamic of iron during seed development

A thaliana *B. napus*

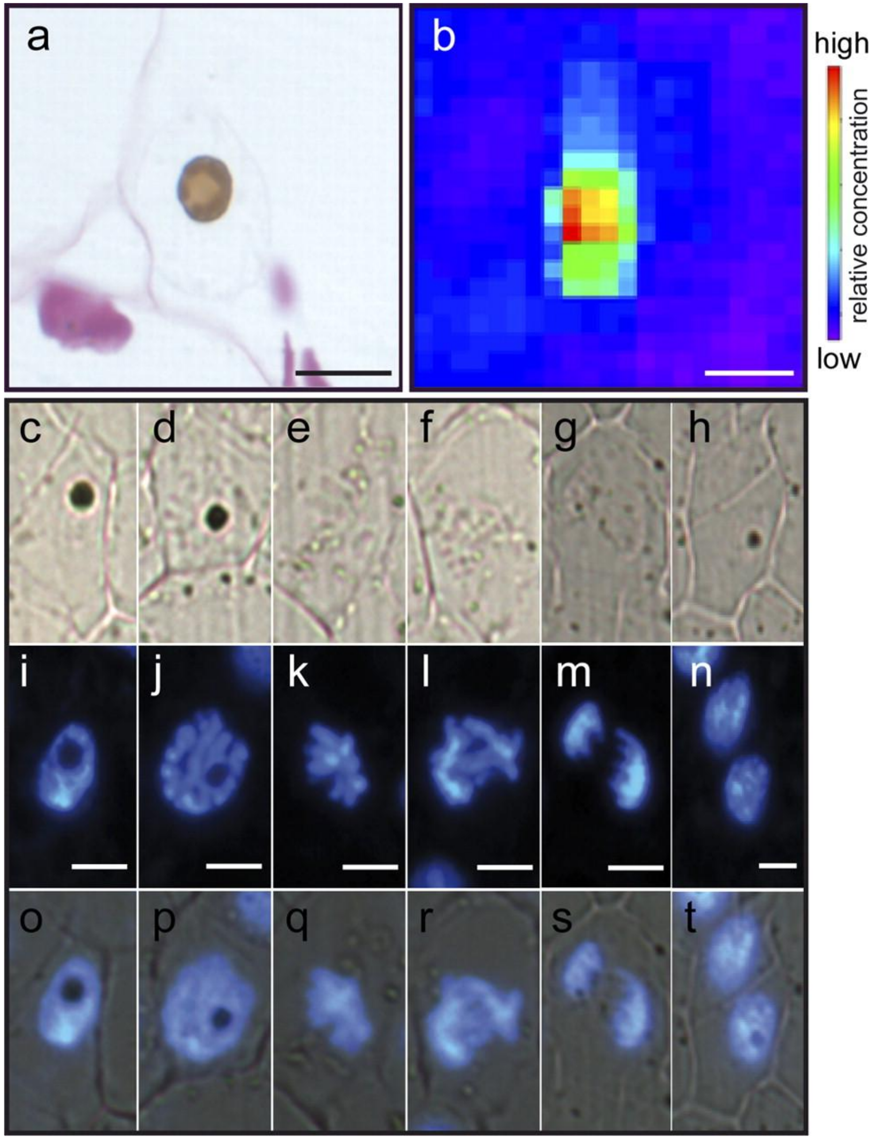


Brassica napus torpedo stage



(Ibeas el al., 2017)

Iron-specific accumulation in the nucleolus of plant cells



Synchrotron

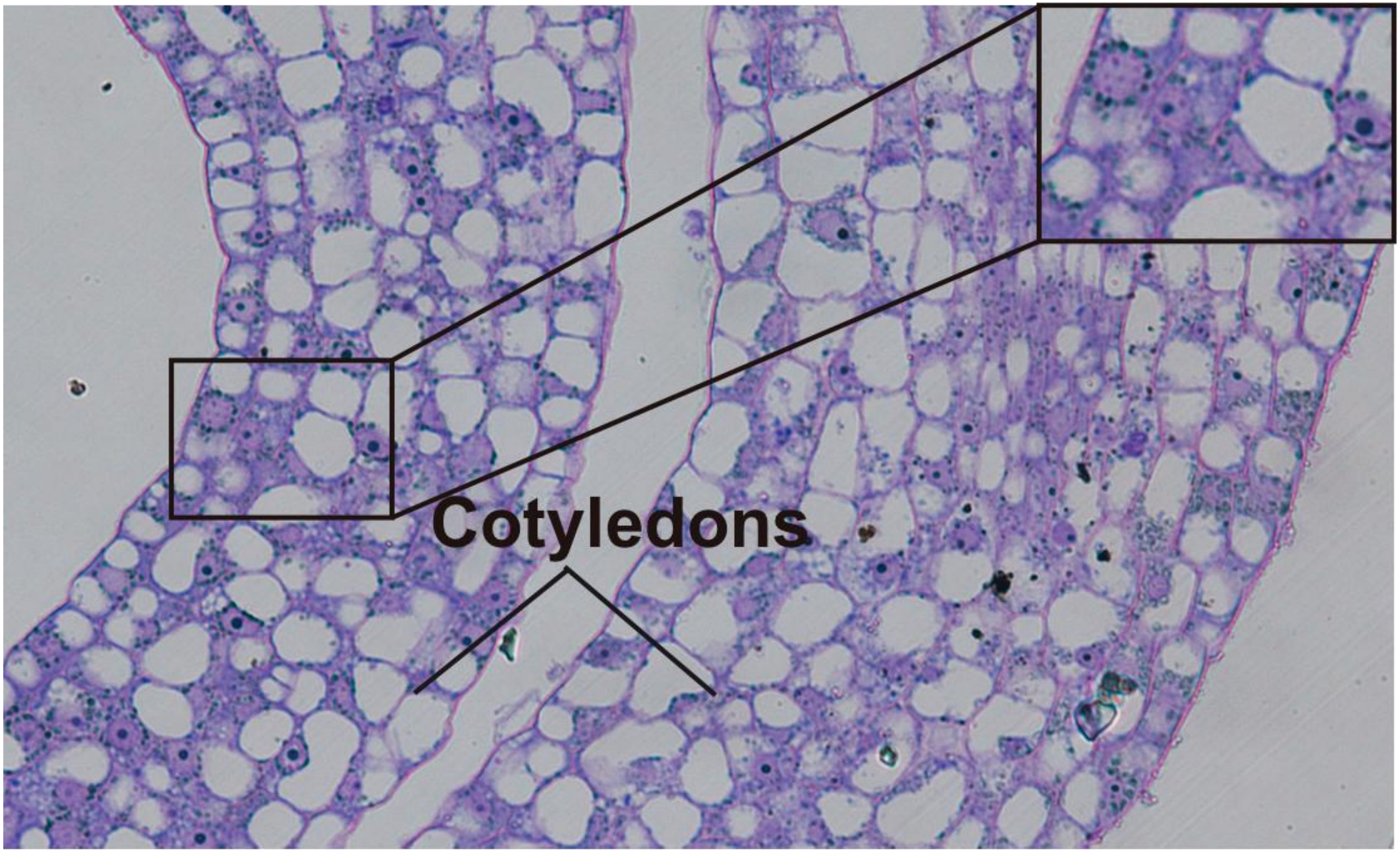
Perls/DAB

Perls/DAB/ DAPI

Roschzttardtz et el., 2011

Dynamic of iron during seed development

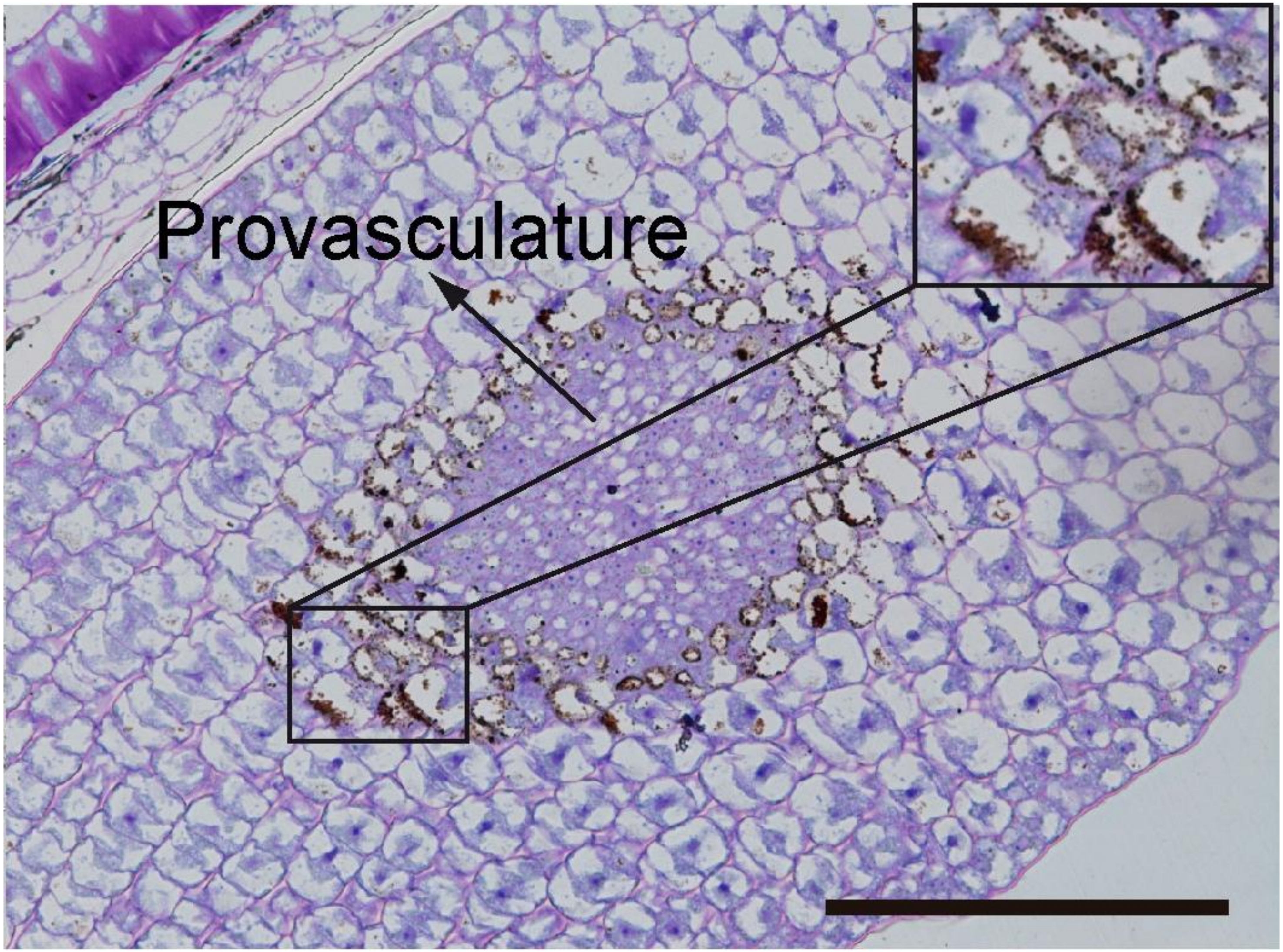
Brassica napus bend cotyledon stage



(Ibeas el al., 2017)

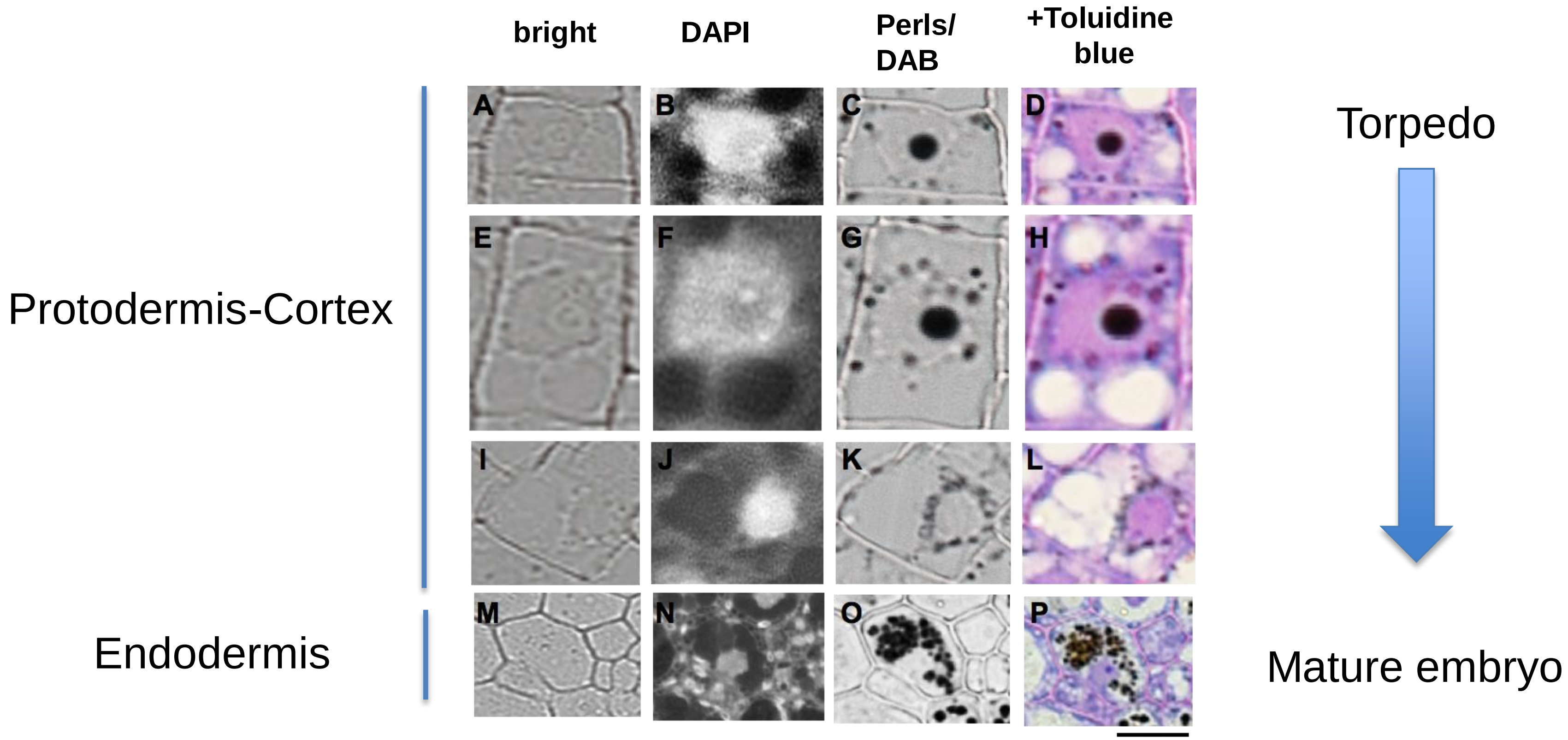
Dynamic of iron during seed development

Brassica napus mature green before desiccation stage



(Ibeas el al., 2017)

Nuclei may be a reservoir of iron during seed development



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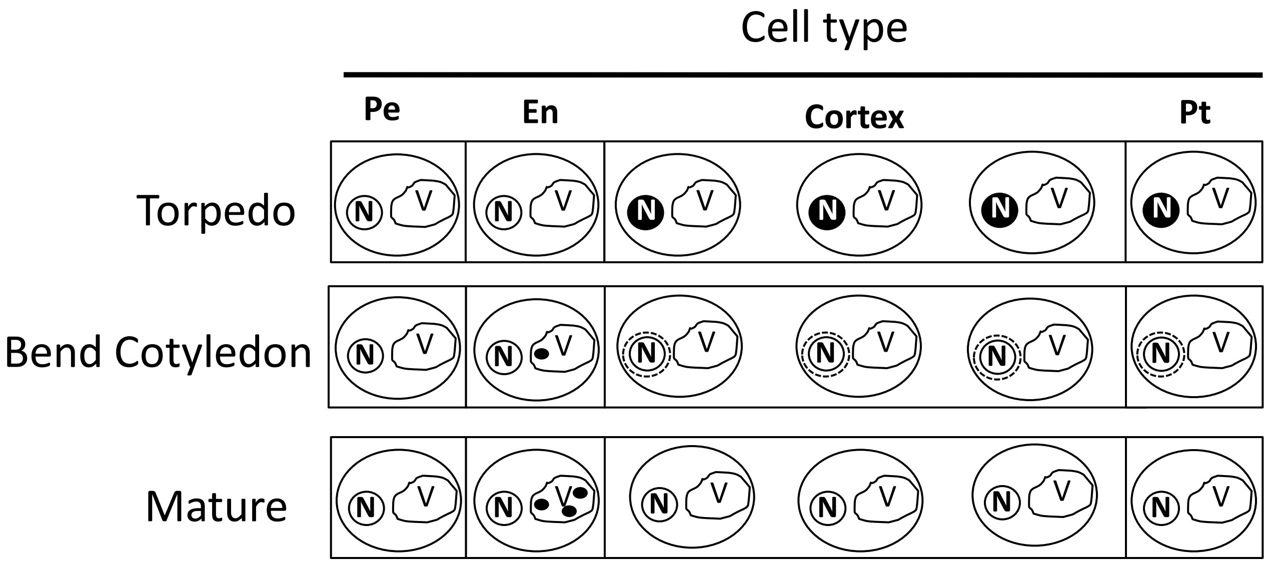
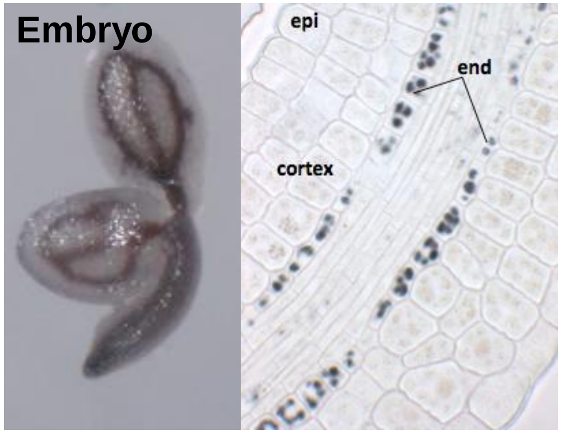


(Ibeas el al., 2017)

Can plant embryos to accumulate iron in cortex cells?

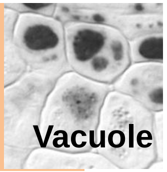
***Perls/DAB* staining**

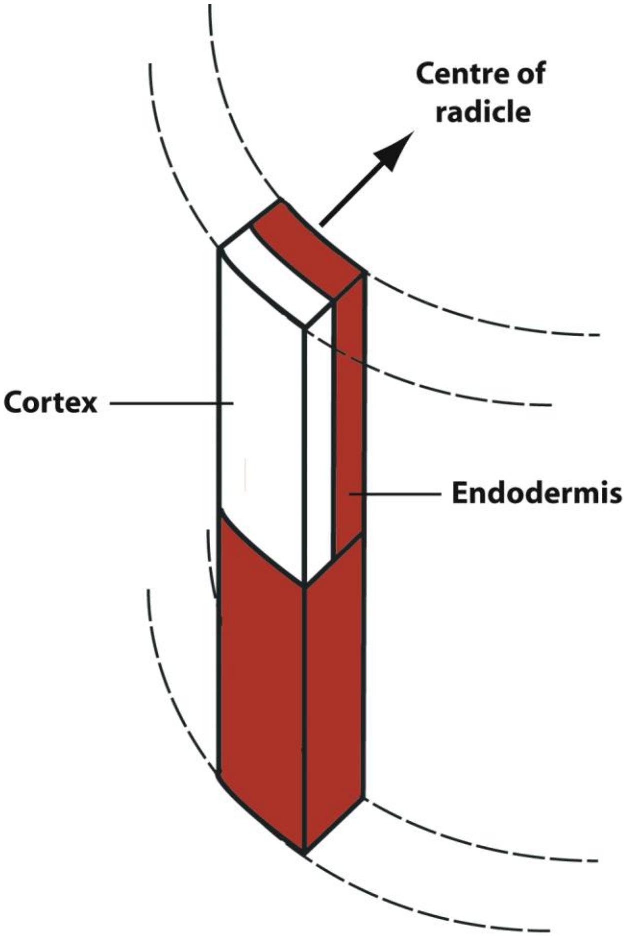


-Easy to perform

-Specific

-Sensitive

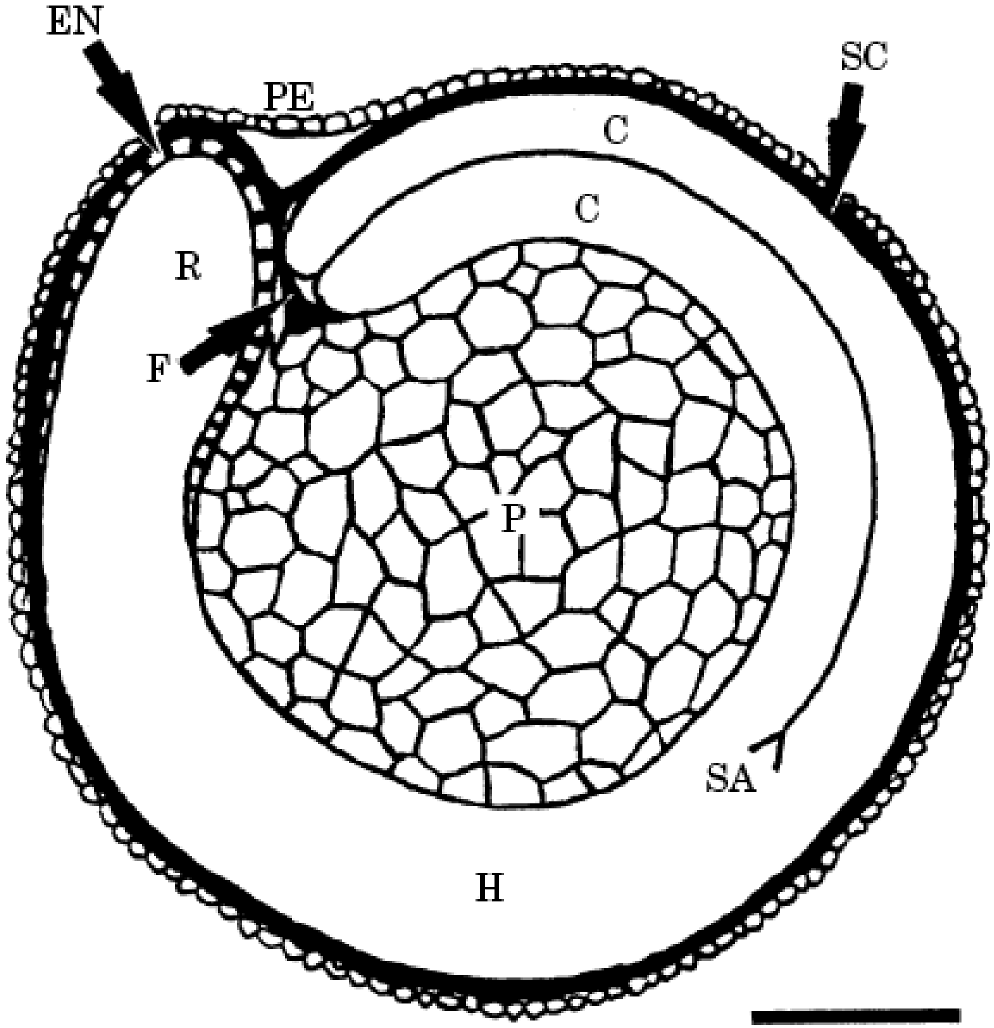




(Adapted from Leyser and Day, 2002)

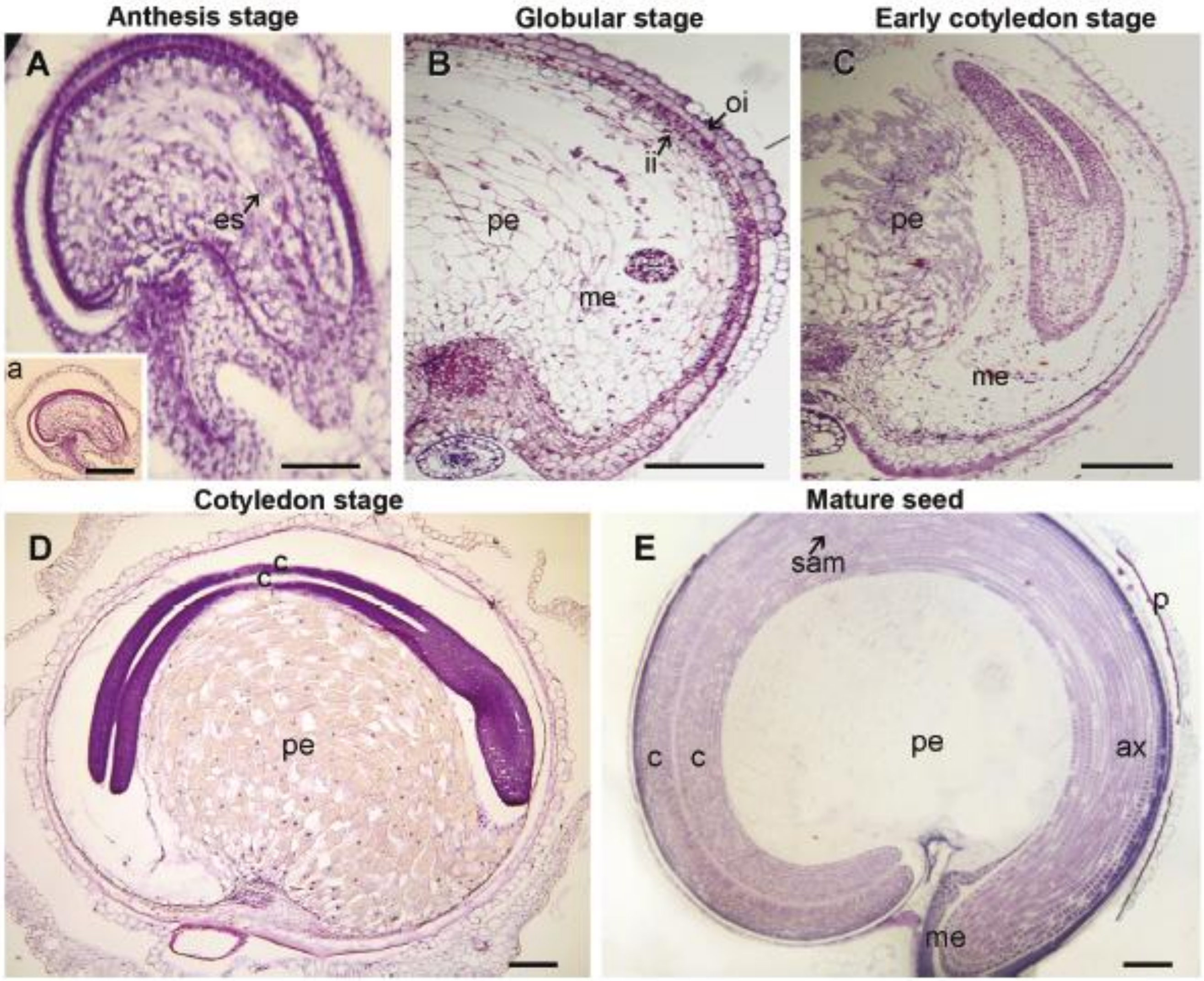
How conserved is iron distribution in plant embryos?

Chenopodium quinoa



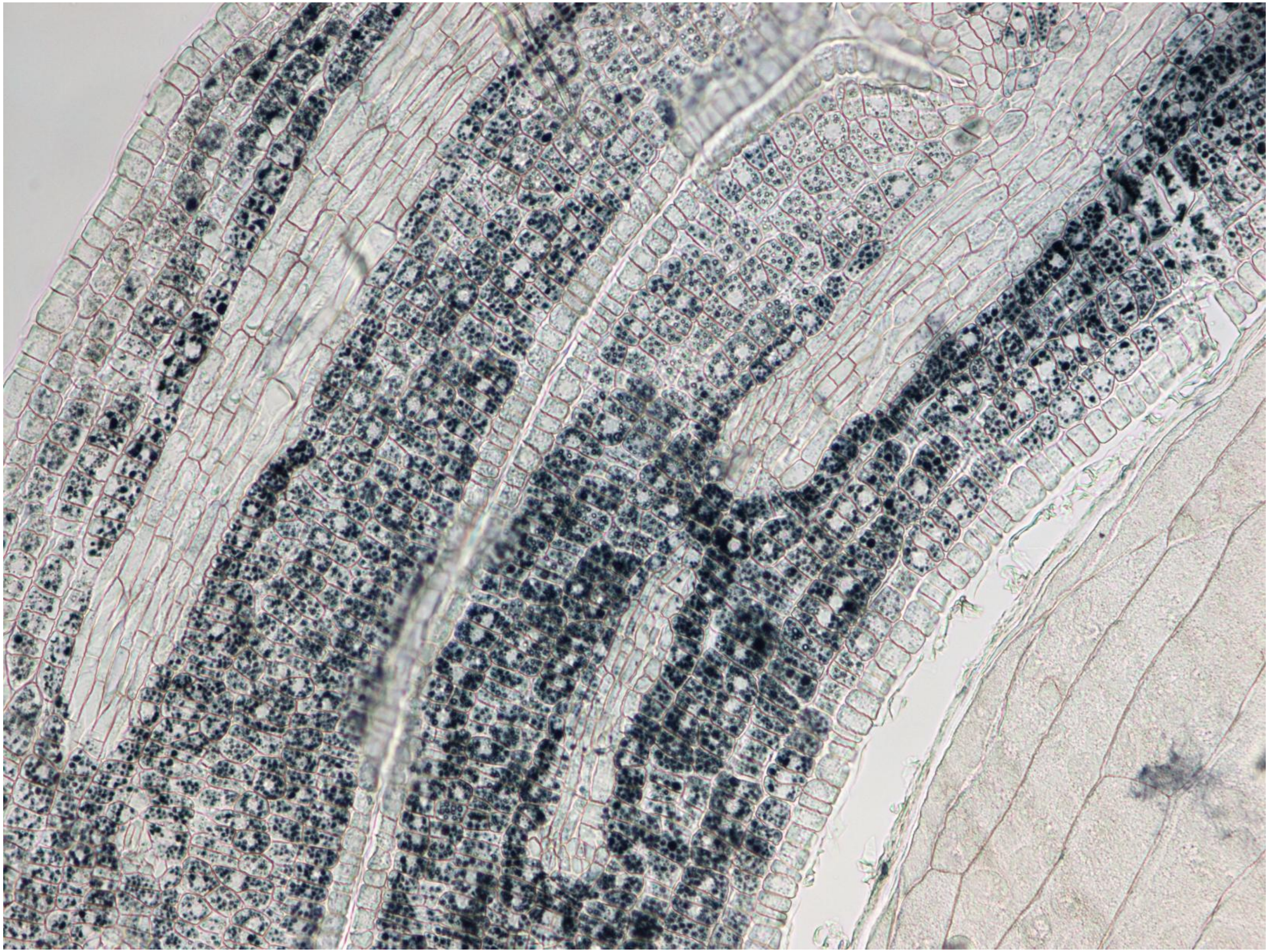
(Prego et al., 1998)

Quinoa Embryogenesis



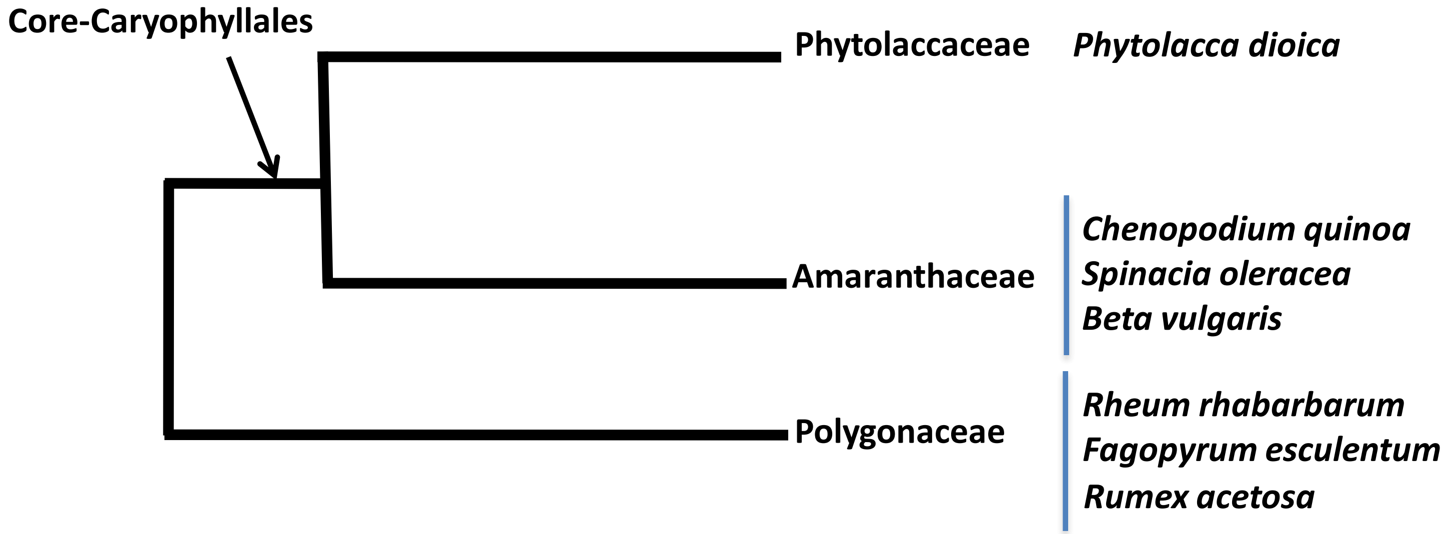
(Prego et al., 1998)

Iron Localization in *Chenopodium quinoa*

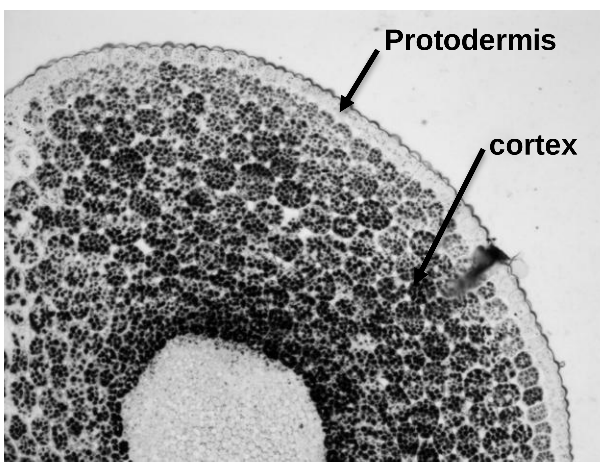


(Ibeas et al., 2019)

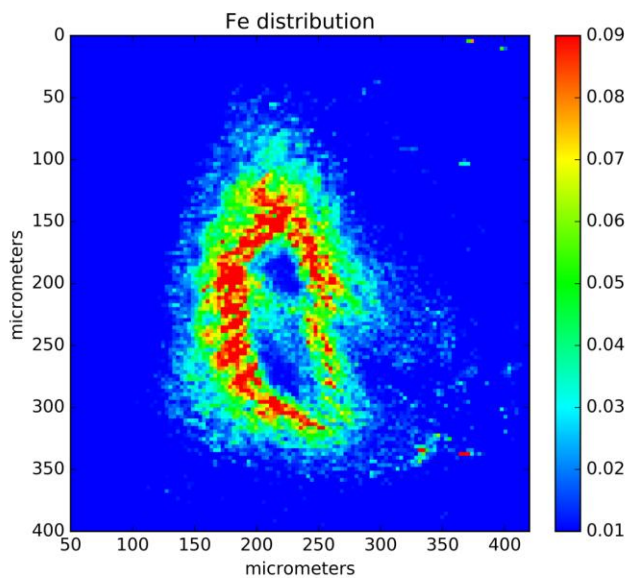
Caryophyllales



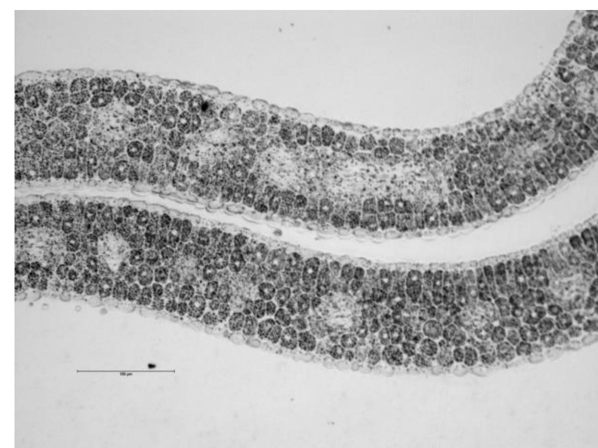
Phytolaccaceae
Phytolacca dioica



Amaranthaceae

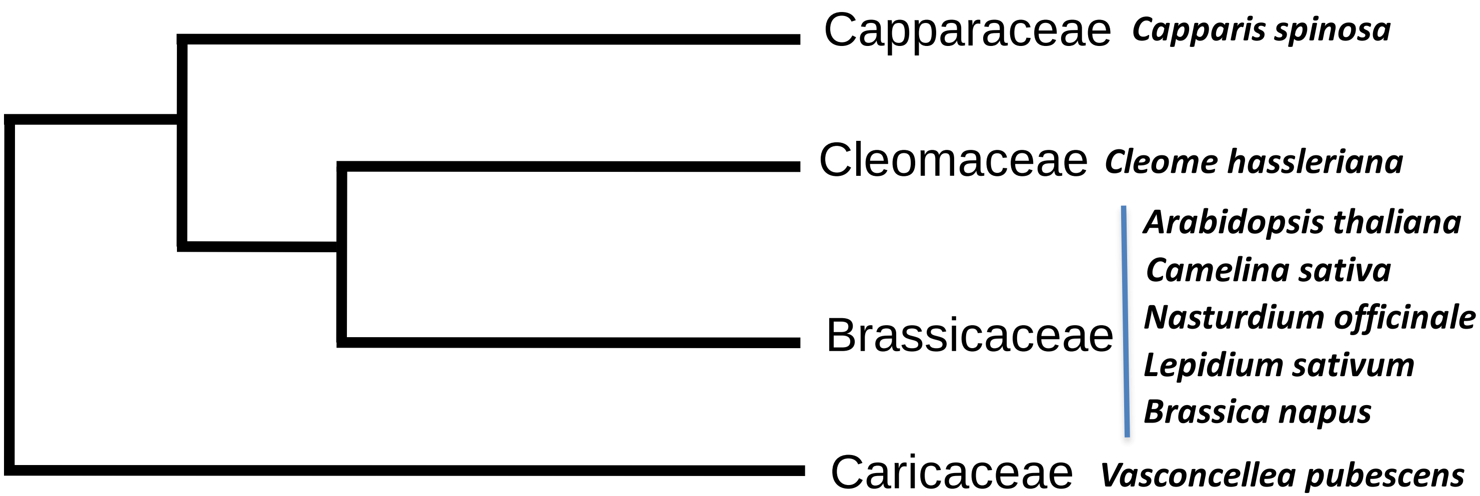


Polygonaceae
Fagopyrum esculentum



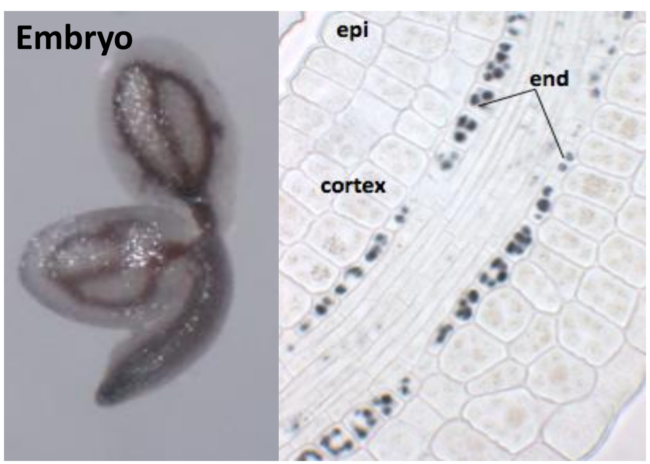
(Ibeas et al., 2019)

Brassicales



Brassicaceae

Arabidopsis thaliana



(Roschzttardtz et al., 2009)

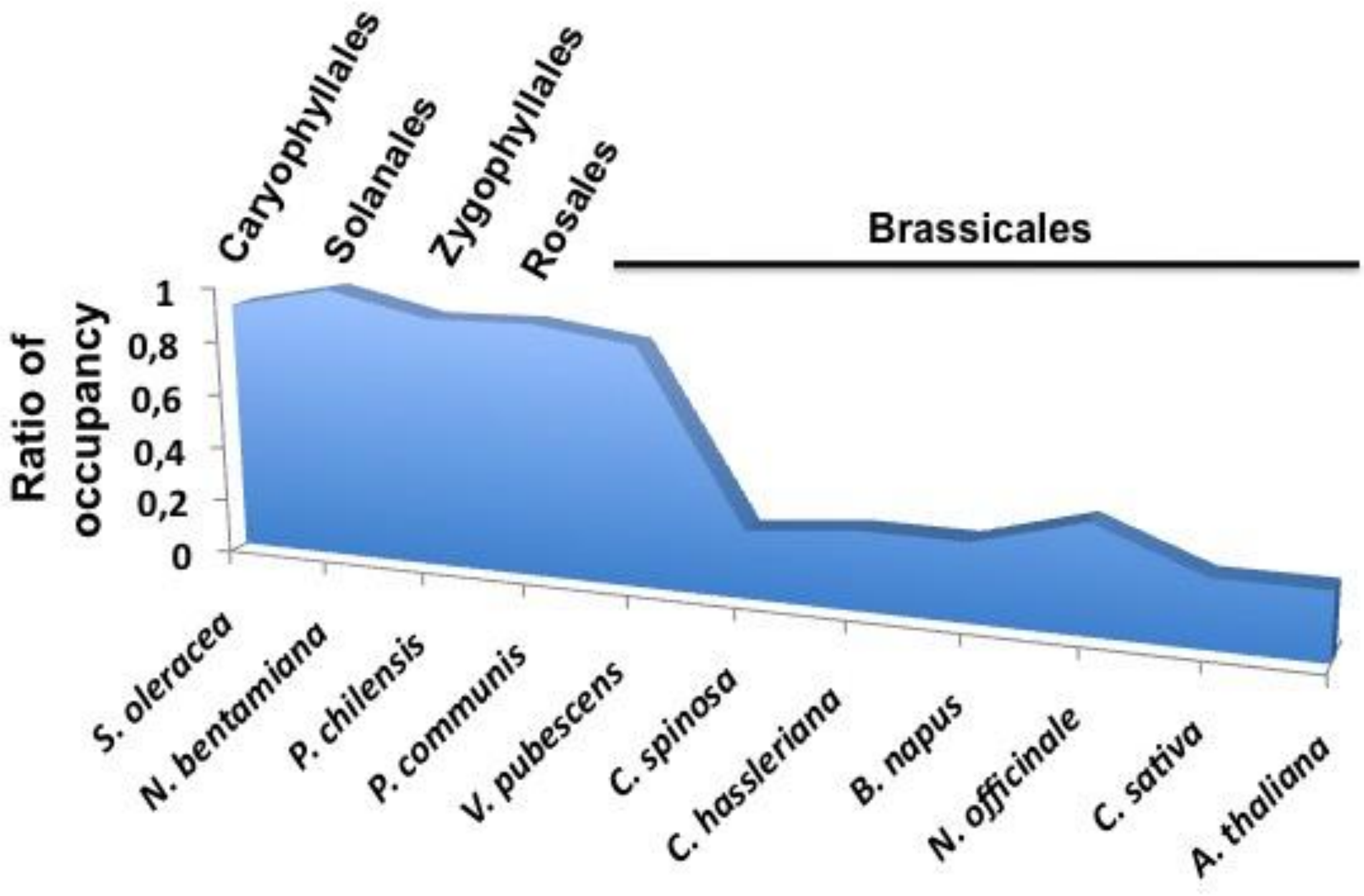
1 Cell Layer → Several Cell layers

Caricaceae

Vasconcellea pubescens

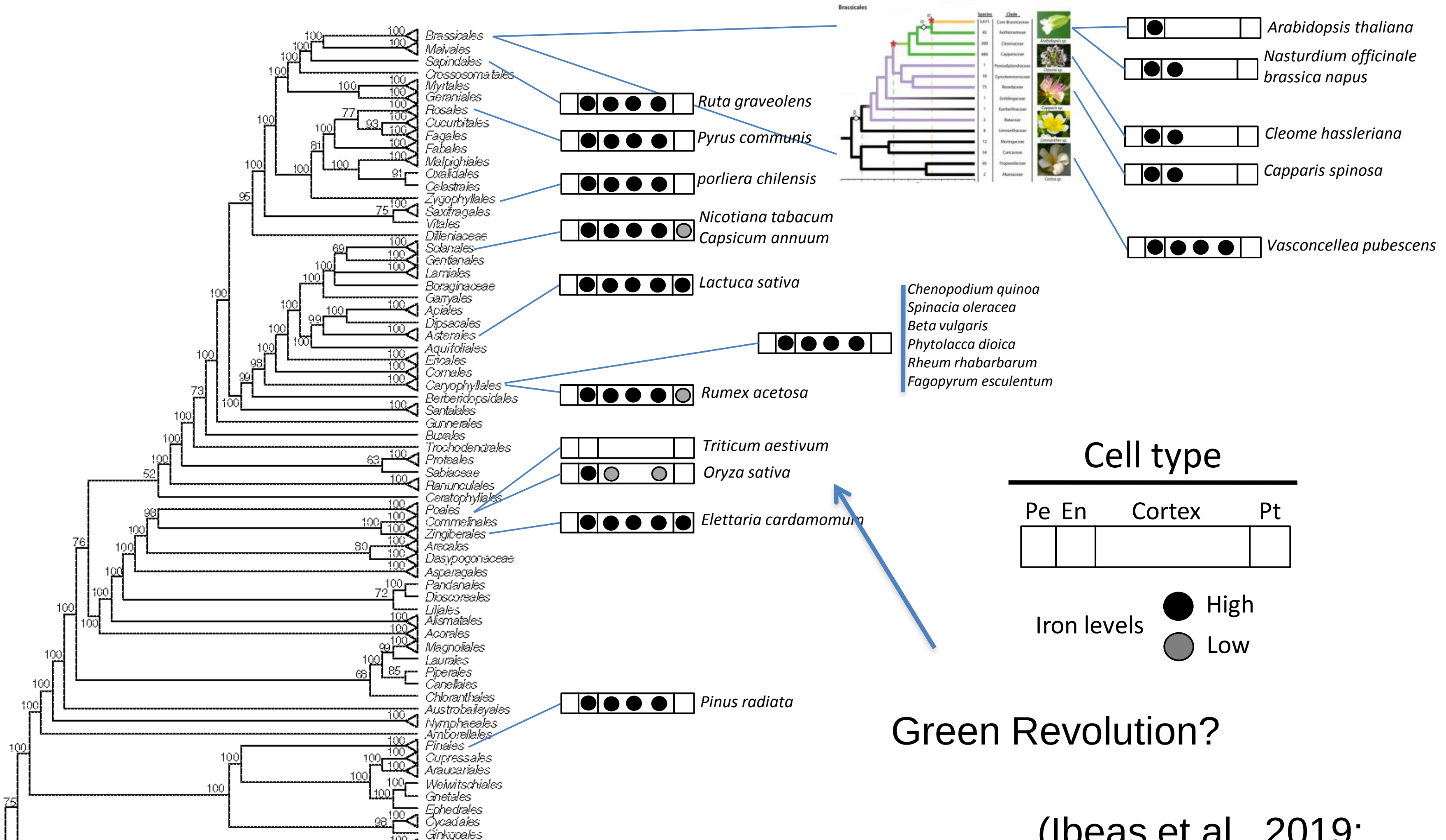
(Ibeas et al., 2019)

Number of cells layers accumulating iron



Iron distribution in seed embryos

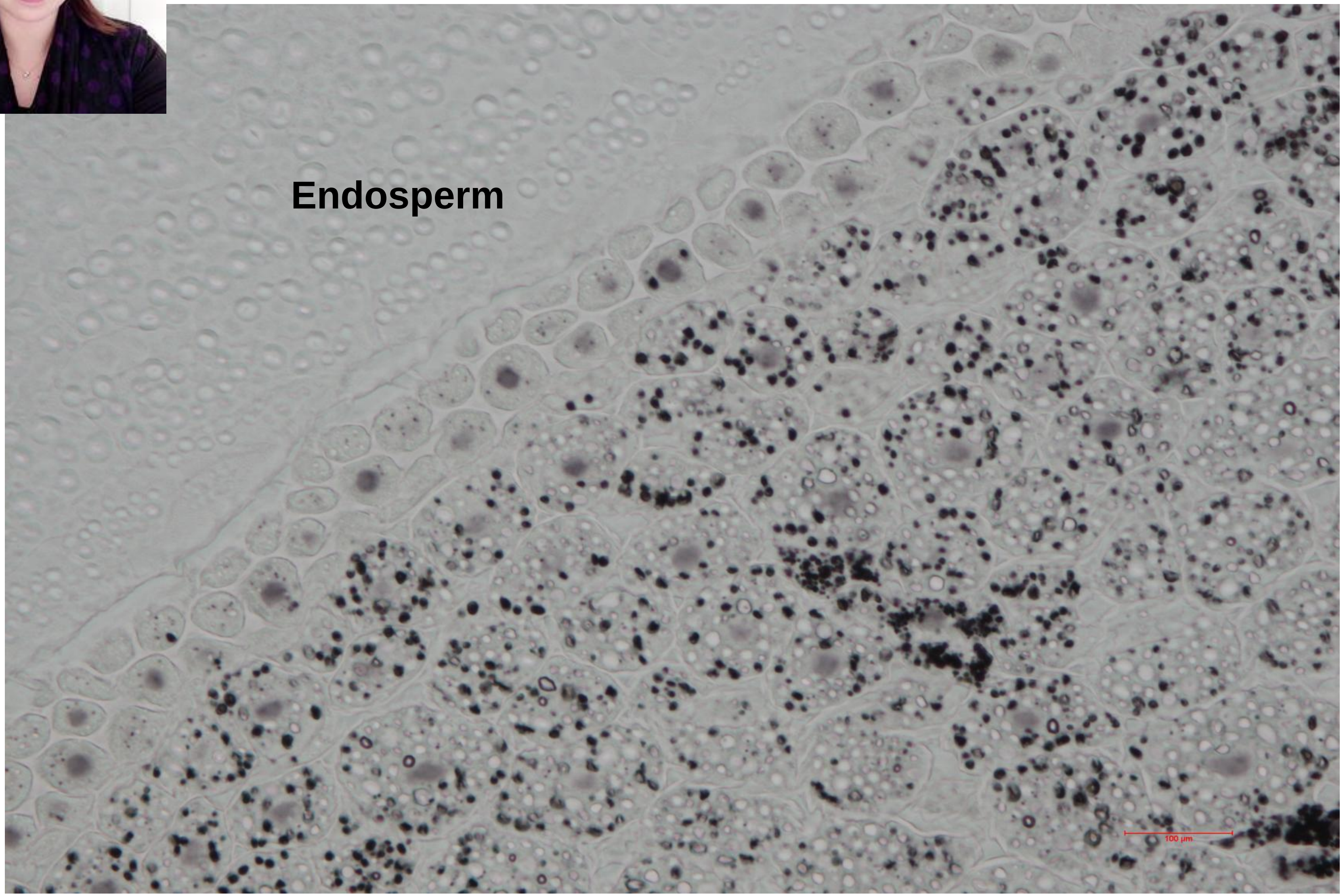
Iron distribution in Arabidopsis embryo is an apomorphic trait



(Ibeas et al., 2019; Unpublished data)

Archaeological maize from Atacama desert

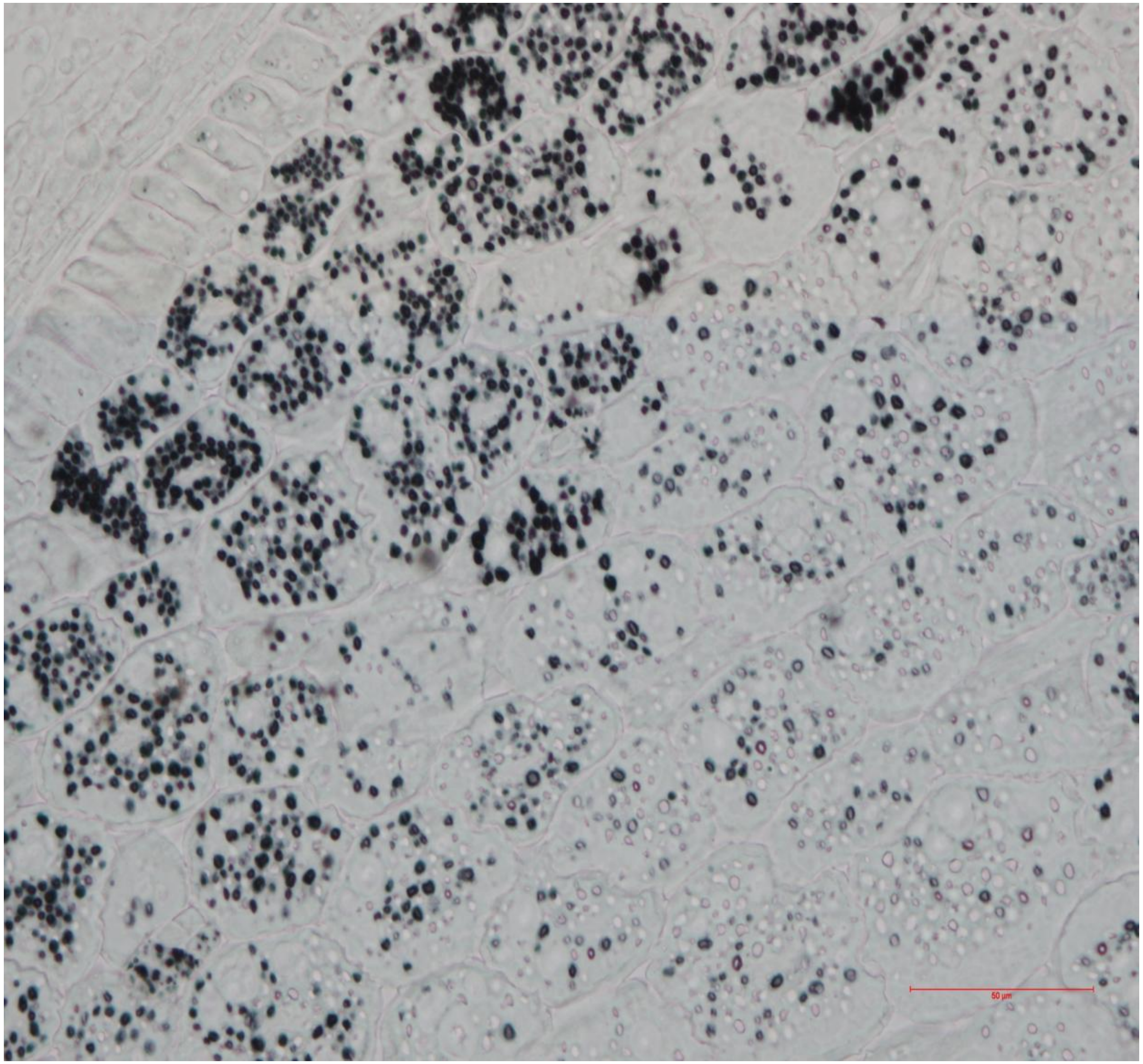
1400 years old



Vidal et al., in preparation

Archaeological maize from Atacama desert

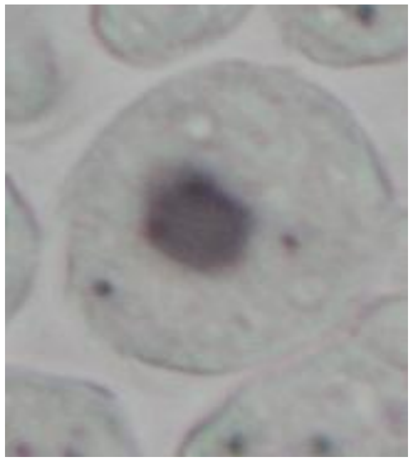
800 years old

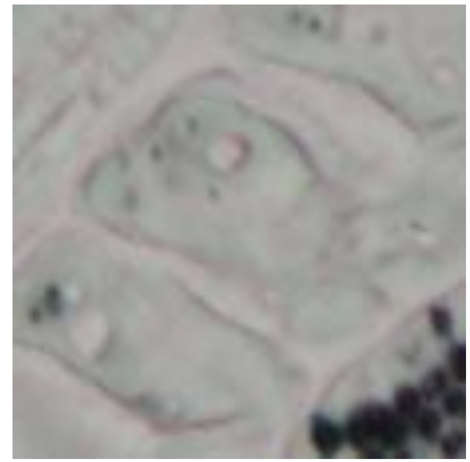


Vidal et al., in preparation

Iron in the nuclei

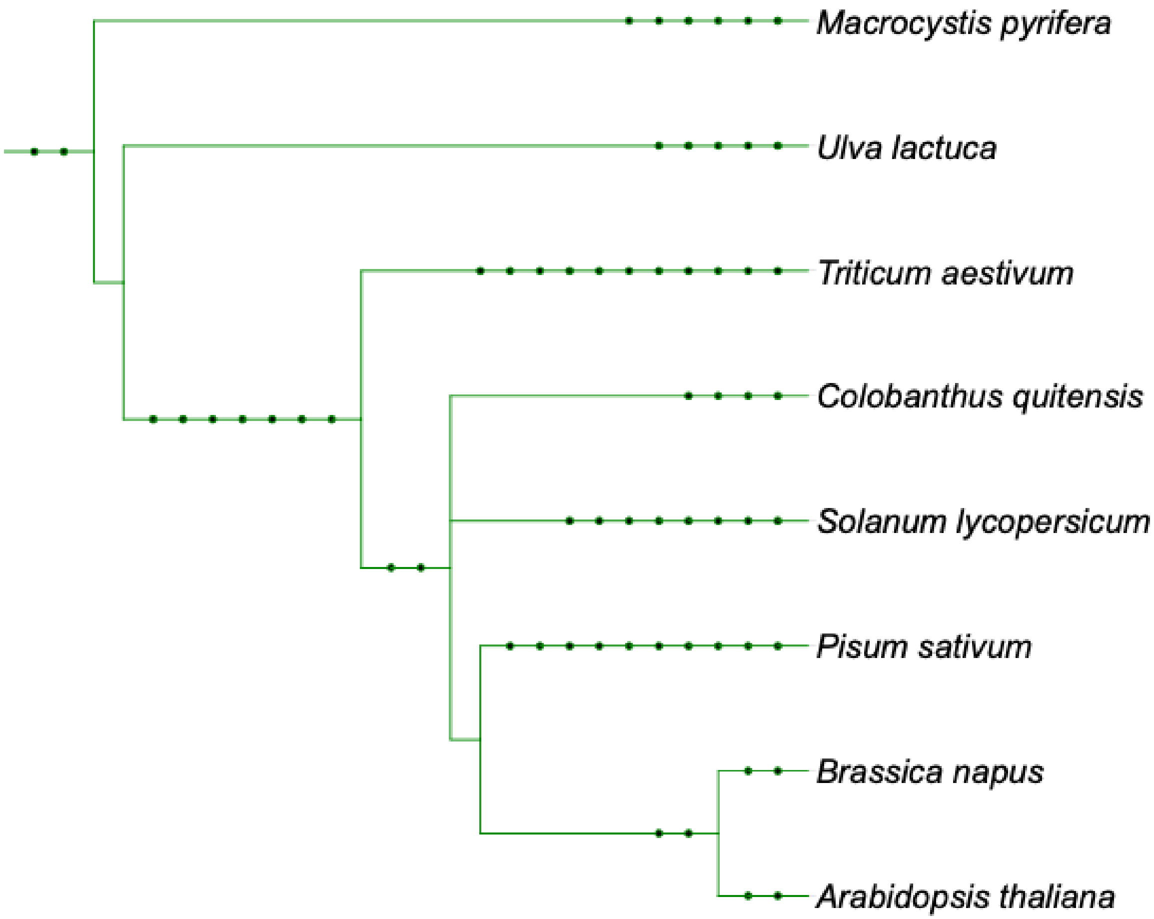
Domestication?



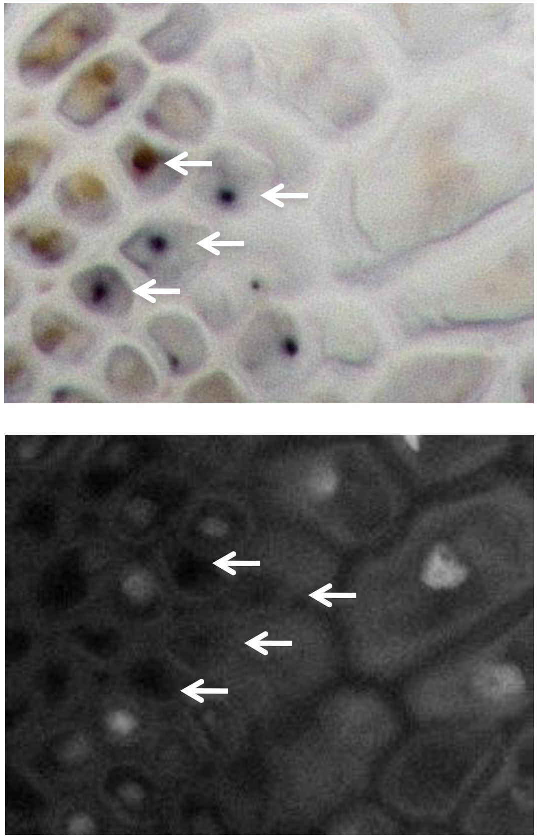


Iron distribution at subcellular level during maize seed development

Is nucleolar iron pool a "plant" cell reservoir?

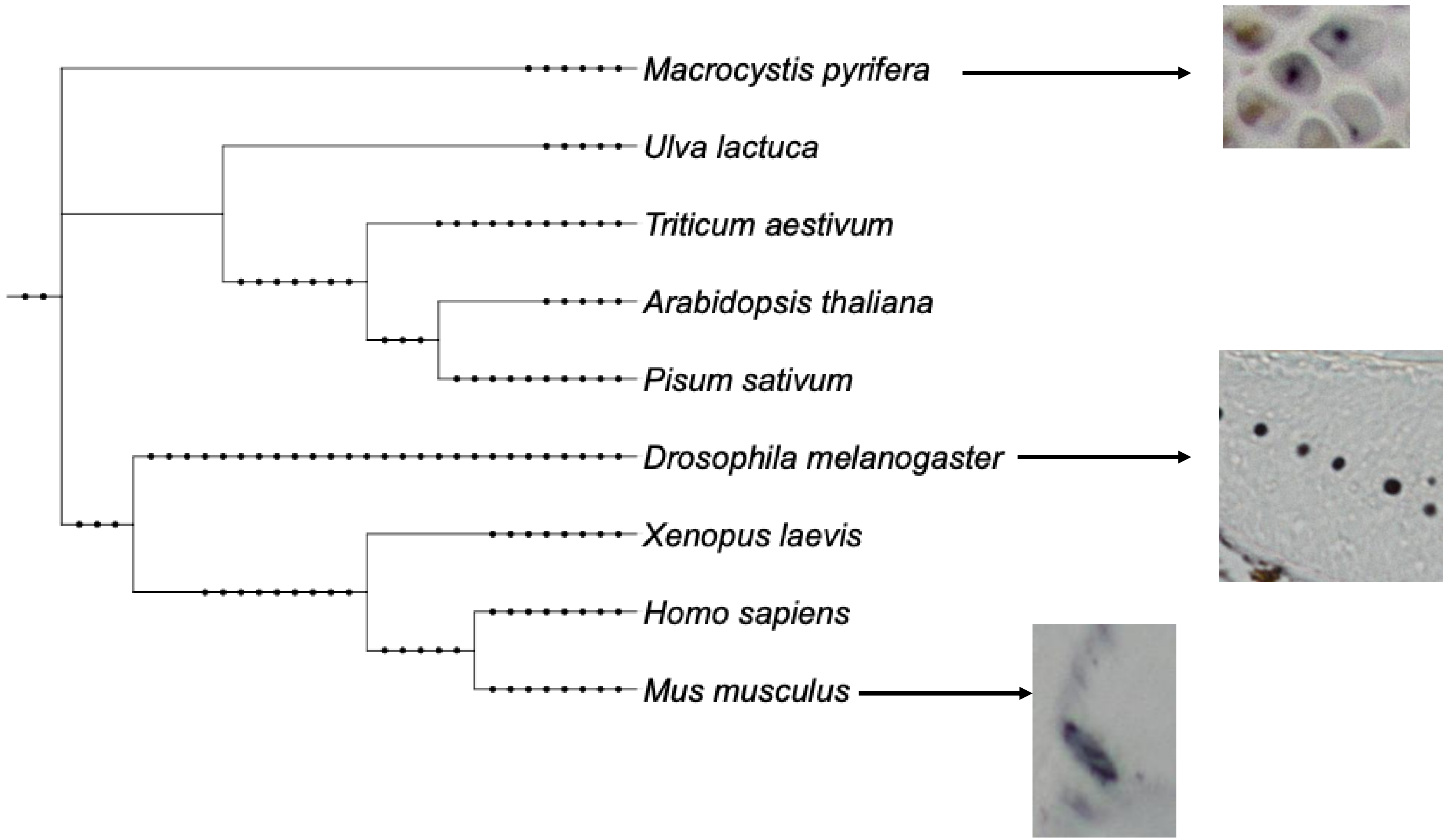


Macrocystis pyrifera



Avalos-Cembrano et al., in preparation

Intranuclear pool of iron is wide conserved in eukaryotes



Avalos-Cembrano et al., in preparation

Conclusions

Iron distribution through plant phylogeny and other kingdoms

-Iron distribution in Arabidopsis embryos is an apomorphy.

-Iron is accumulated in different subcellular compartments during embryogenesis.

-Nuclei may be a reservoir of iron during seed development.

-Intranuclear pool of iron is wide conserved in eukaryotes.

Ibeas et al., 2017
Ibeas et al., 2019
Avalos-Cembrano et al., in preparation
Vidal et al., in preparation

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Iron Nutrition and Plant Development

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