

# C8545 Developmental Biology

## Lesson 6

### Plant Reproduction

Jan Hejátko

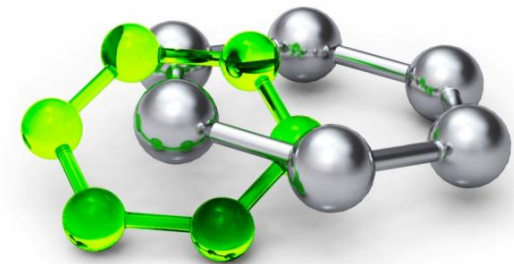
**Laboratory of Molecular Plant Physiology,**  
Department of Functional Genomics and Proteomics,  
and

**Functional Genomics and Proteomics of Plants**  
CEITEC

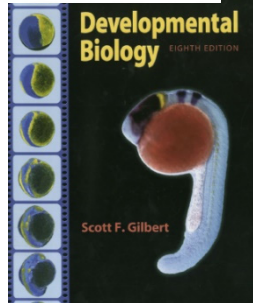
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**M U N I**  
**S C I**



# Literature



- **Fred H. Wilt and Sarah Hake, Principles of Developmental Biology** (W.W. Norton & Company, New York, London, 2004)
- **Scott F. Gilbert, Developmental Biology**, eighth edition (Sinauer Associates, Inc., Publishers Sunderland, Massachusetts, USA, 2006)
- Dubová J., Hejátko J., Friml J. (2005) Reproduction of Plants, in Encyclopedia of Molecular Cell Biology and Molecular Medicine (ed, R. A. Meyers), pp. 249 – 295. Wiley-VCH, Weinheim, Germany
- Selected original papers in scientific journals

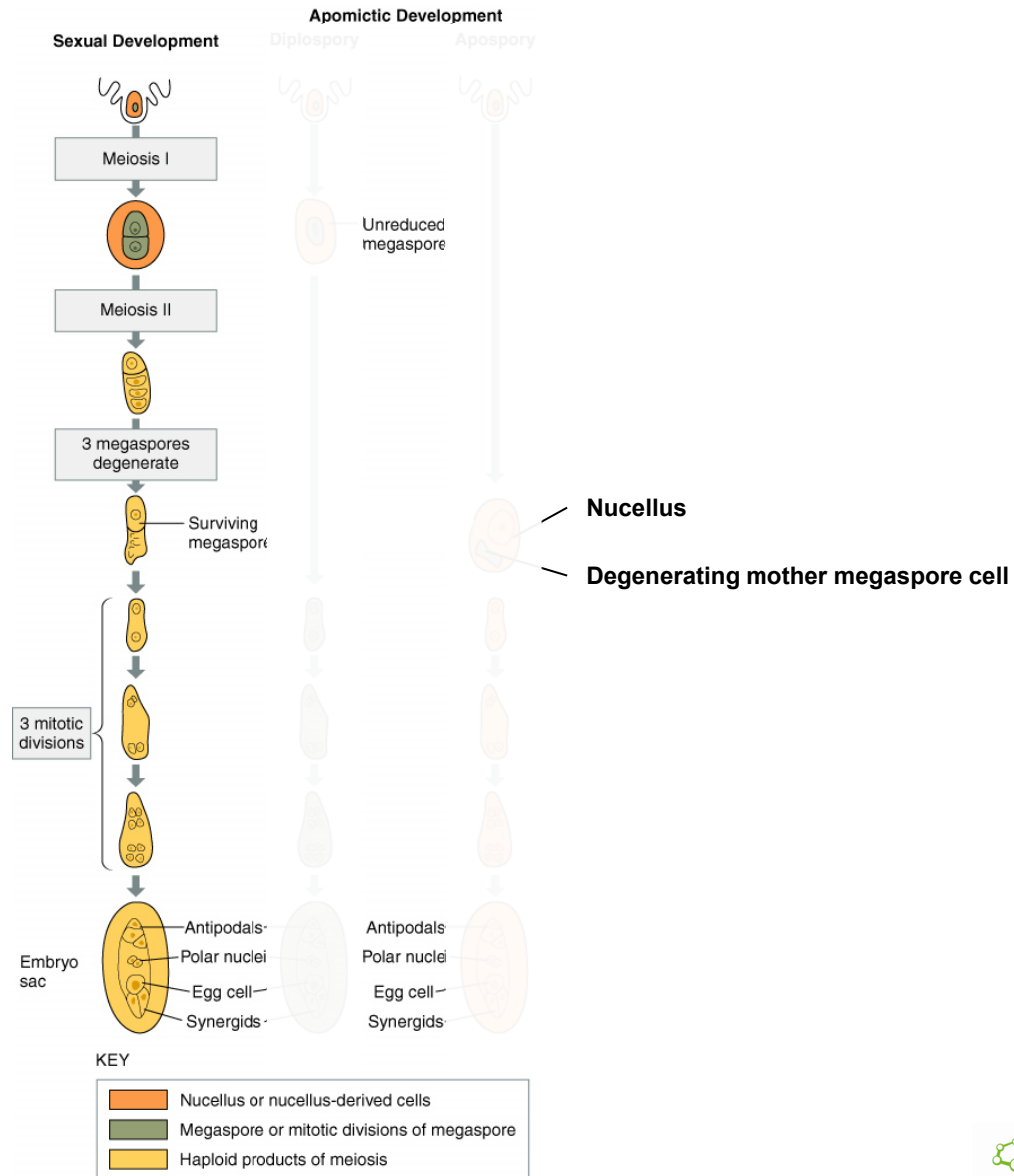
# Outline

- Sexual and asexual plant reproduction
- Plant life cycle
- Initiation of flowering
- Determination of floral organ identity
- Microgametogenesis
- Megagametogenesis
  - Female gametophyte patterning
- Pollen tube growth, guidance and fertilization
- Endosperm and seed formation

# Outline

- Sexual and asexual plant reproduction

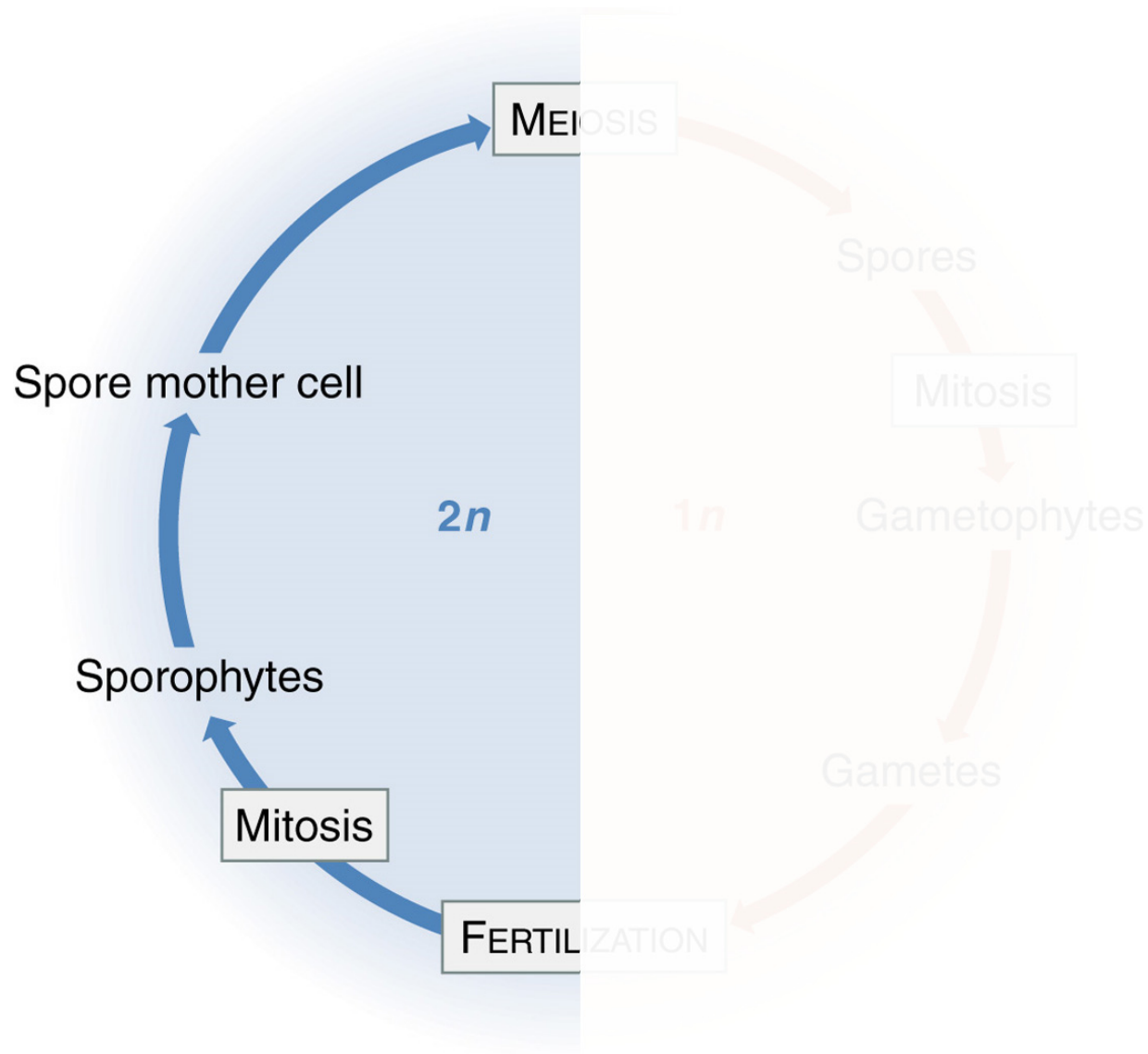
# Asexual Plant Reproduction



# Outline

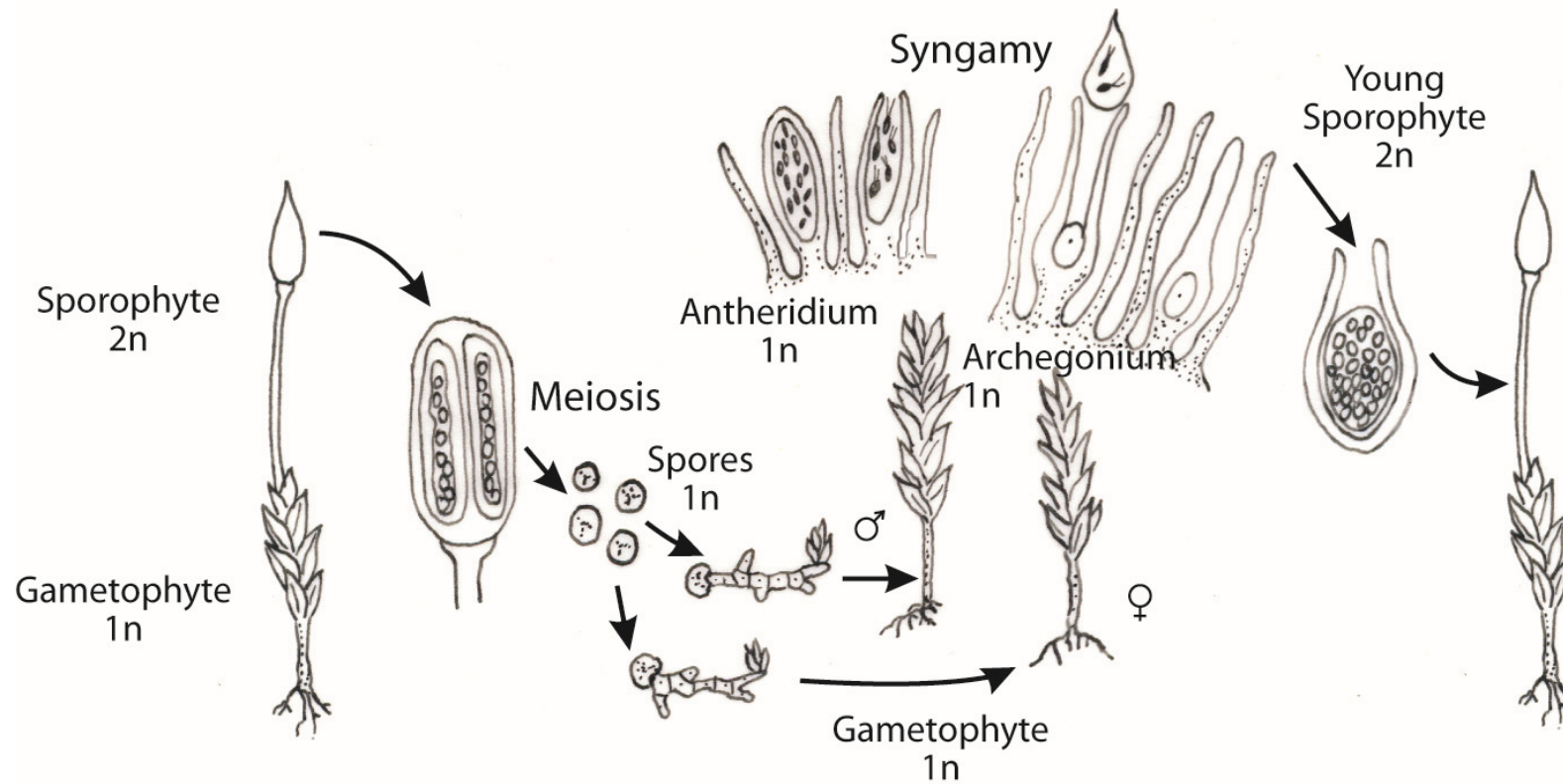
- Sexual and asexual plant reproduction
- Plant life cycle

# Plant Life Cycle



# Plant Life Cycle

## Mosses

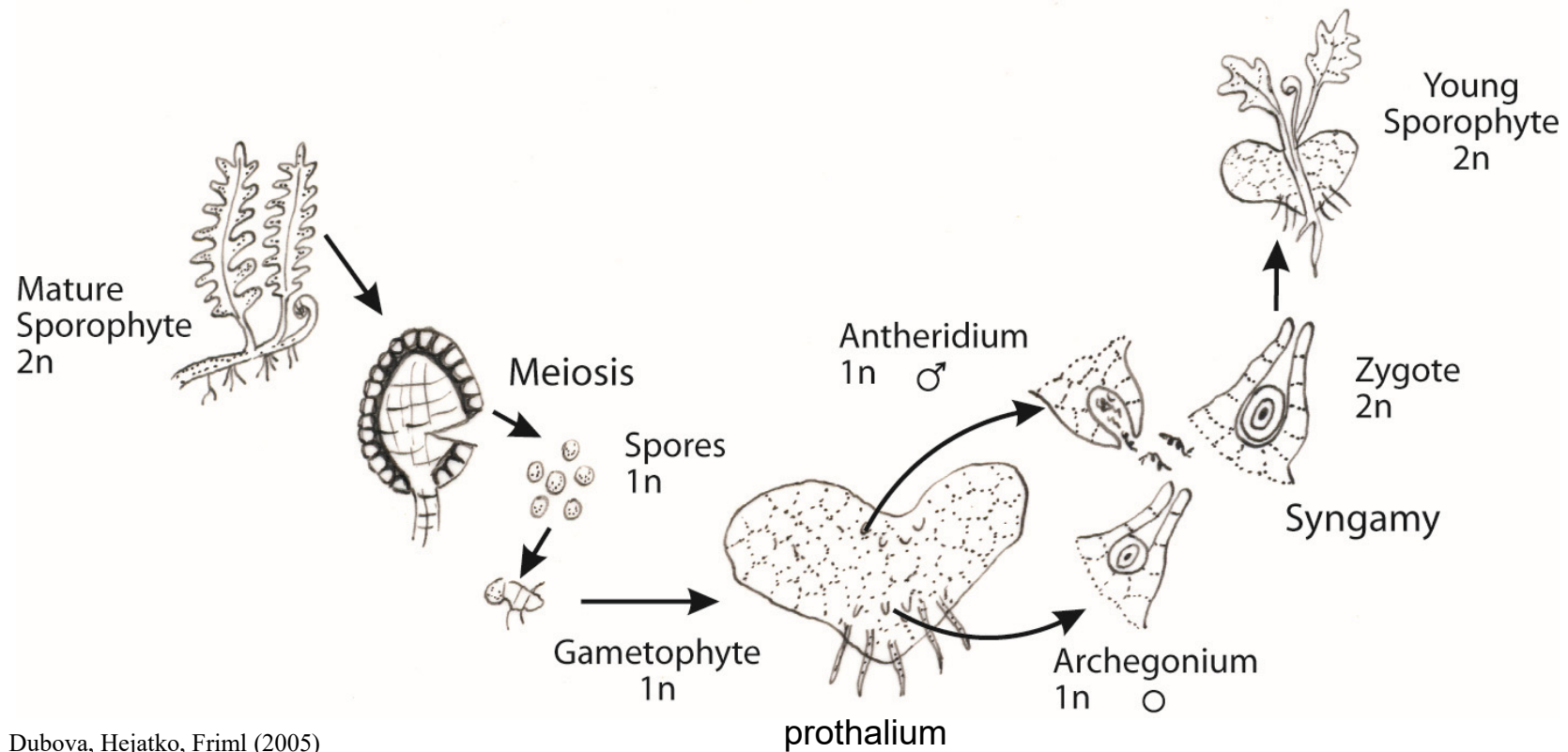


Dubova, Hejatko, Friml (2005)



# Plant Life Cycle

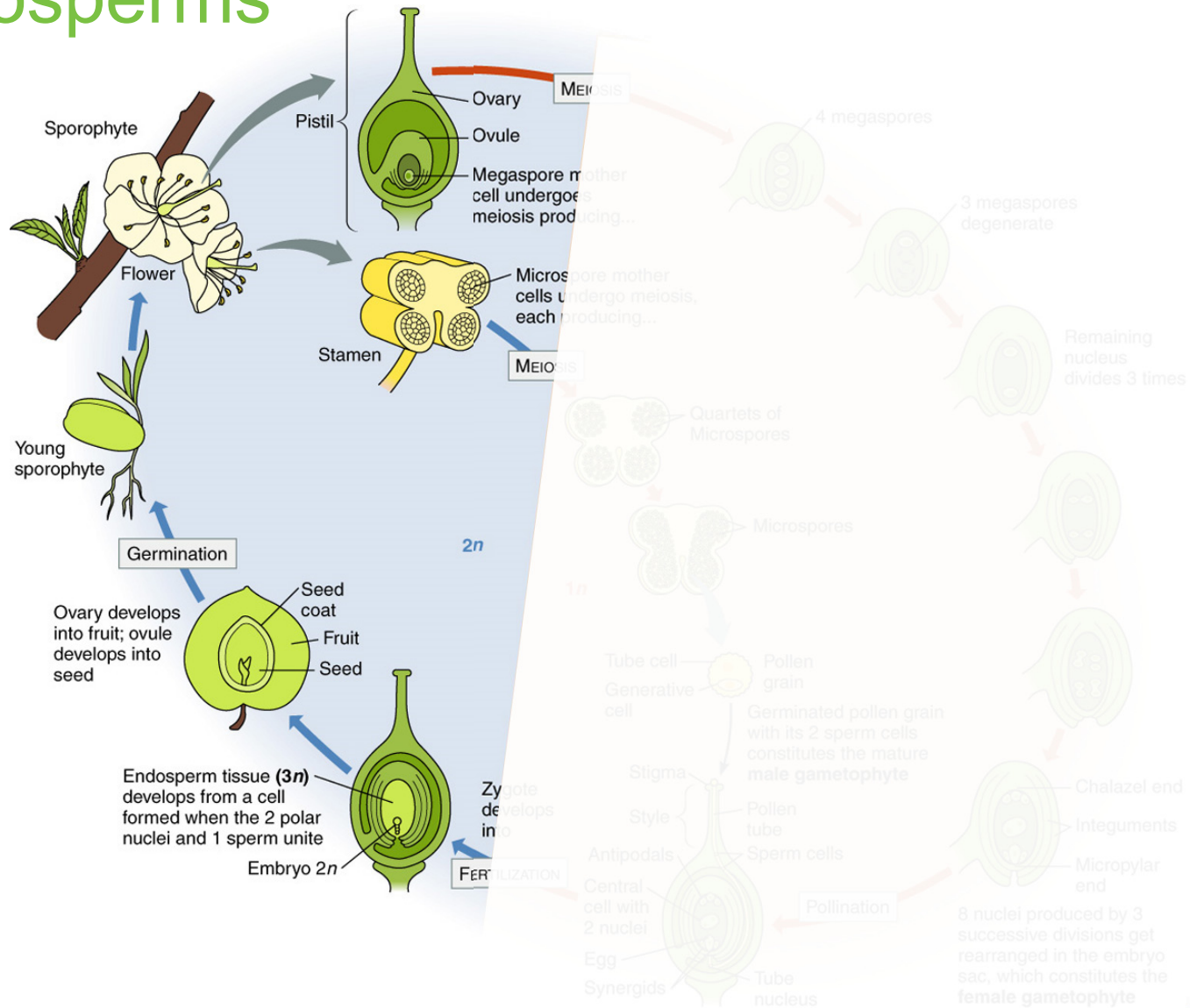
## Ferns



Dubova, Hejatko, Friml (2005)

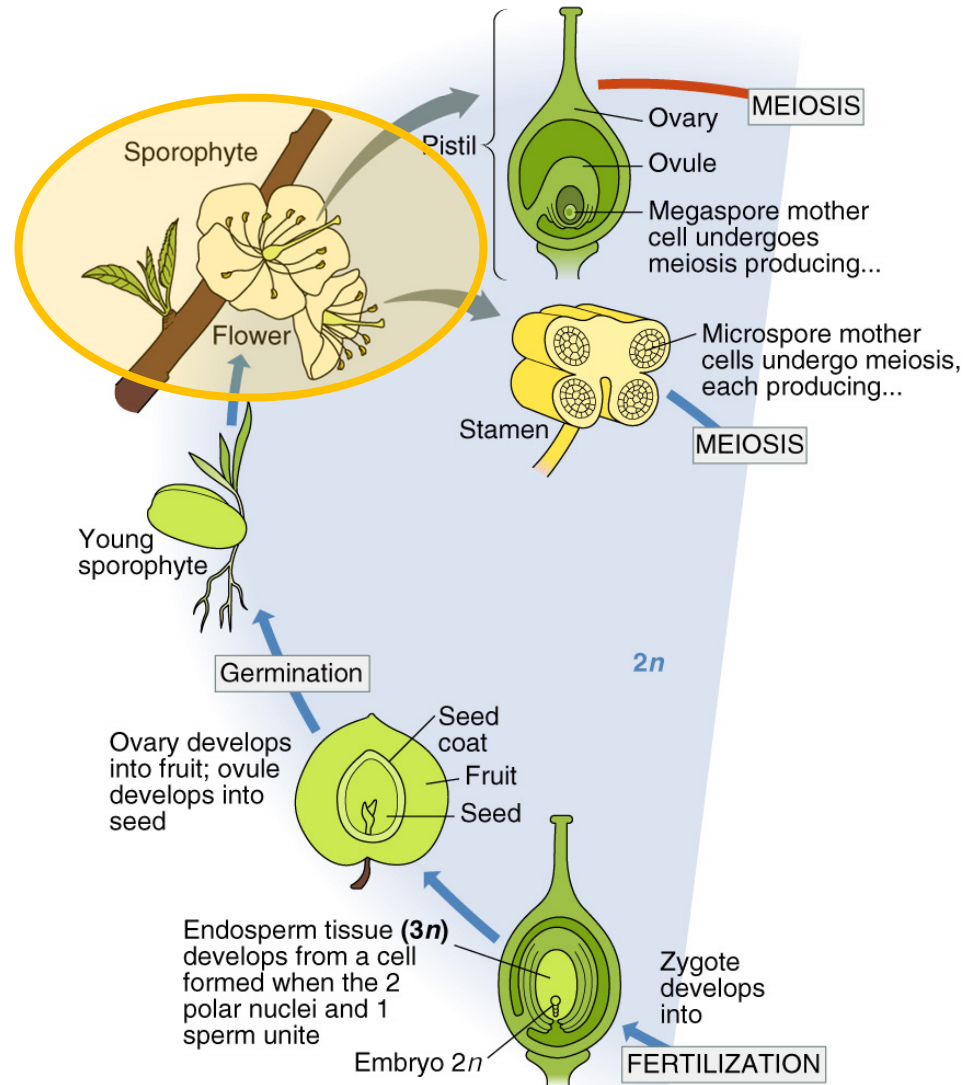
# Plant Life Cycle

## Angiosperms



# Plant Life Cycle

## Angiosperms

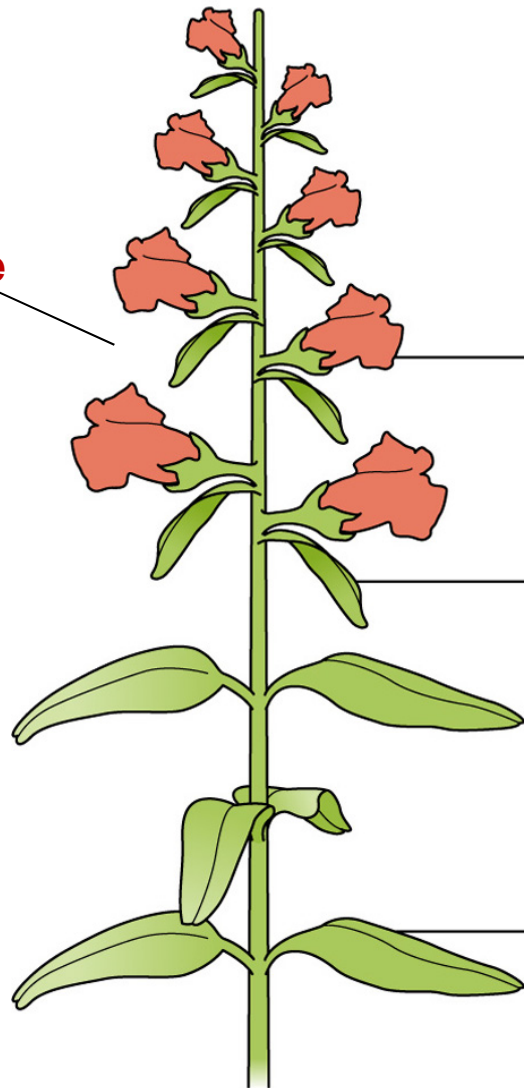


# Outline

- Sexual and asexual plant reproduction
- Plant life cycle
- **Initiation of flowering**

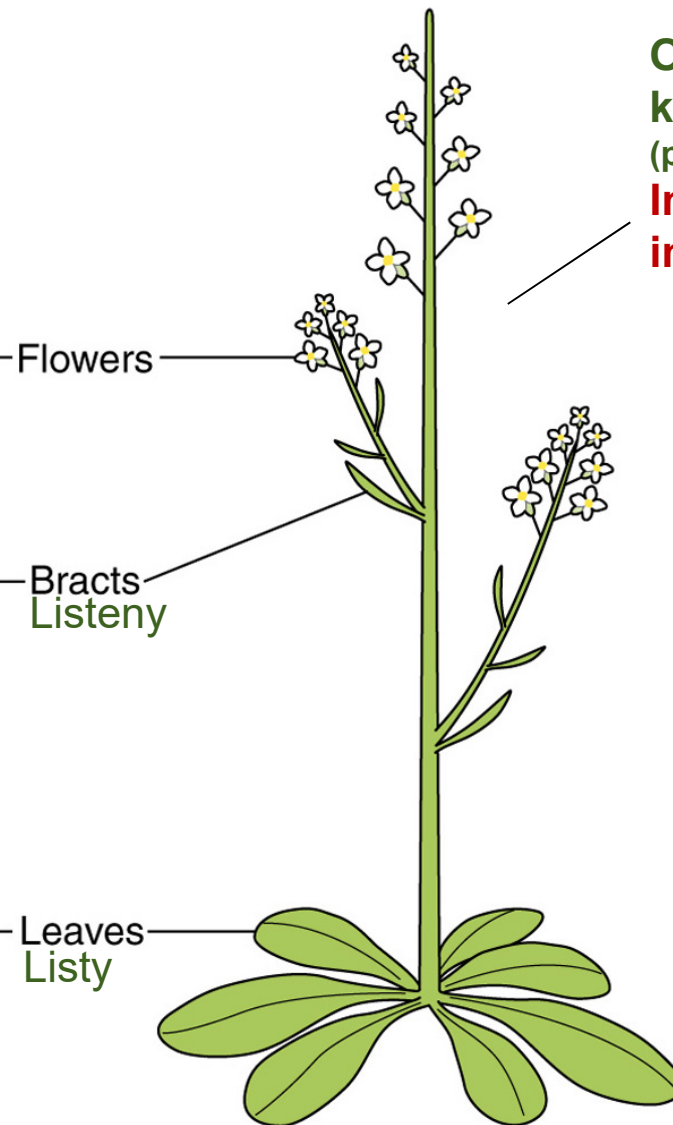
# Flowering

Uzavřené  
květenství  
(monotelické)  
**Determinate  
inflorescence**



*Antirrhinum*

Otevřené  
květenství  
(polytelické)  
**Indeterminate  
inflorescence**



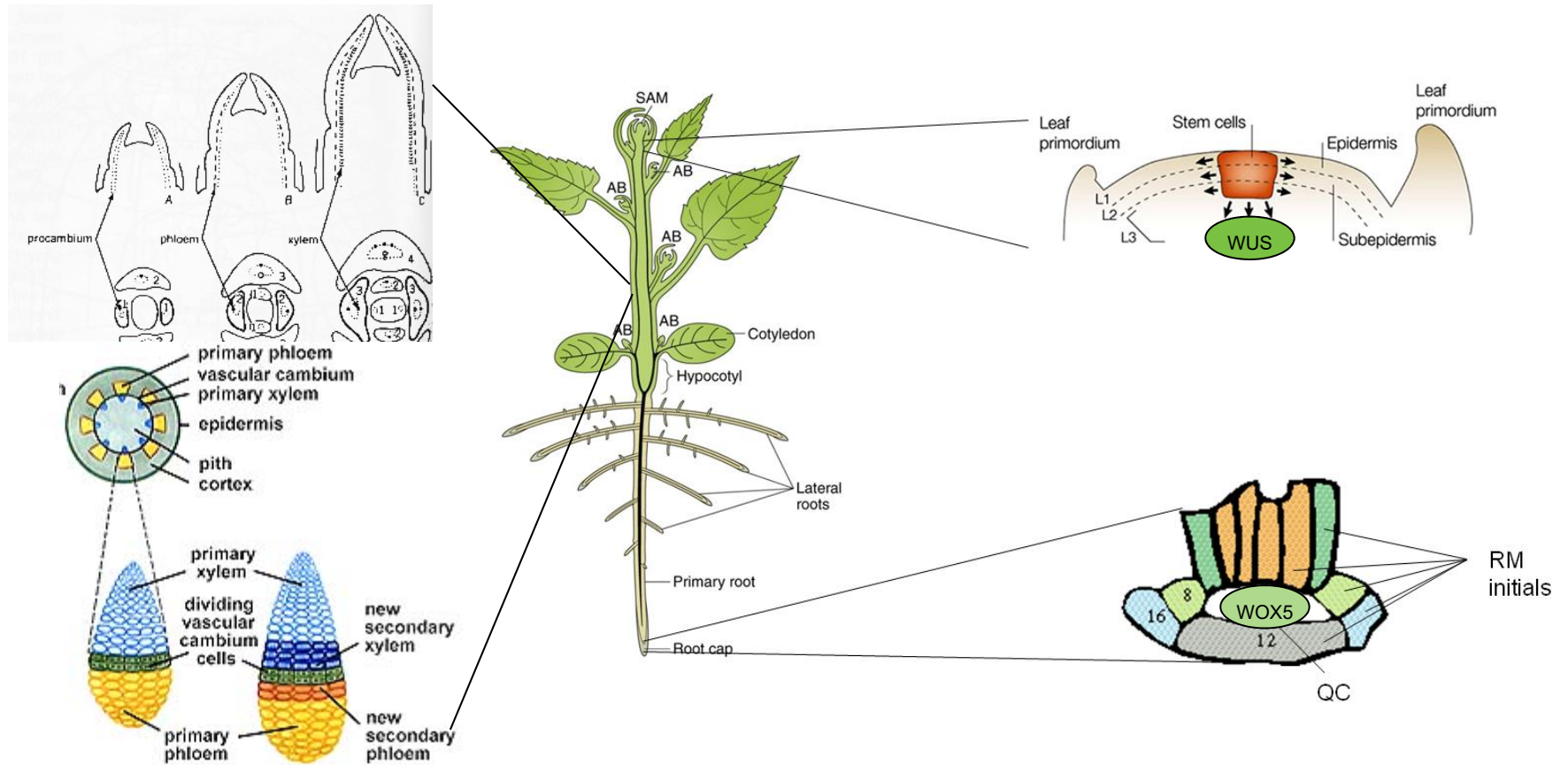
*Arabidopsis*

# Meristem Types

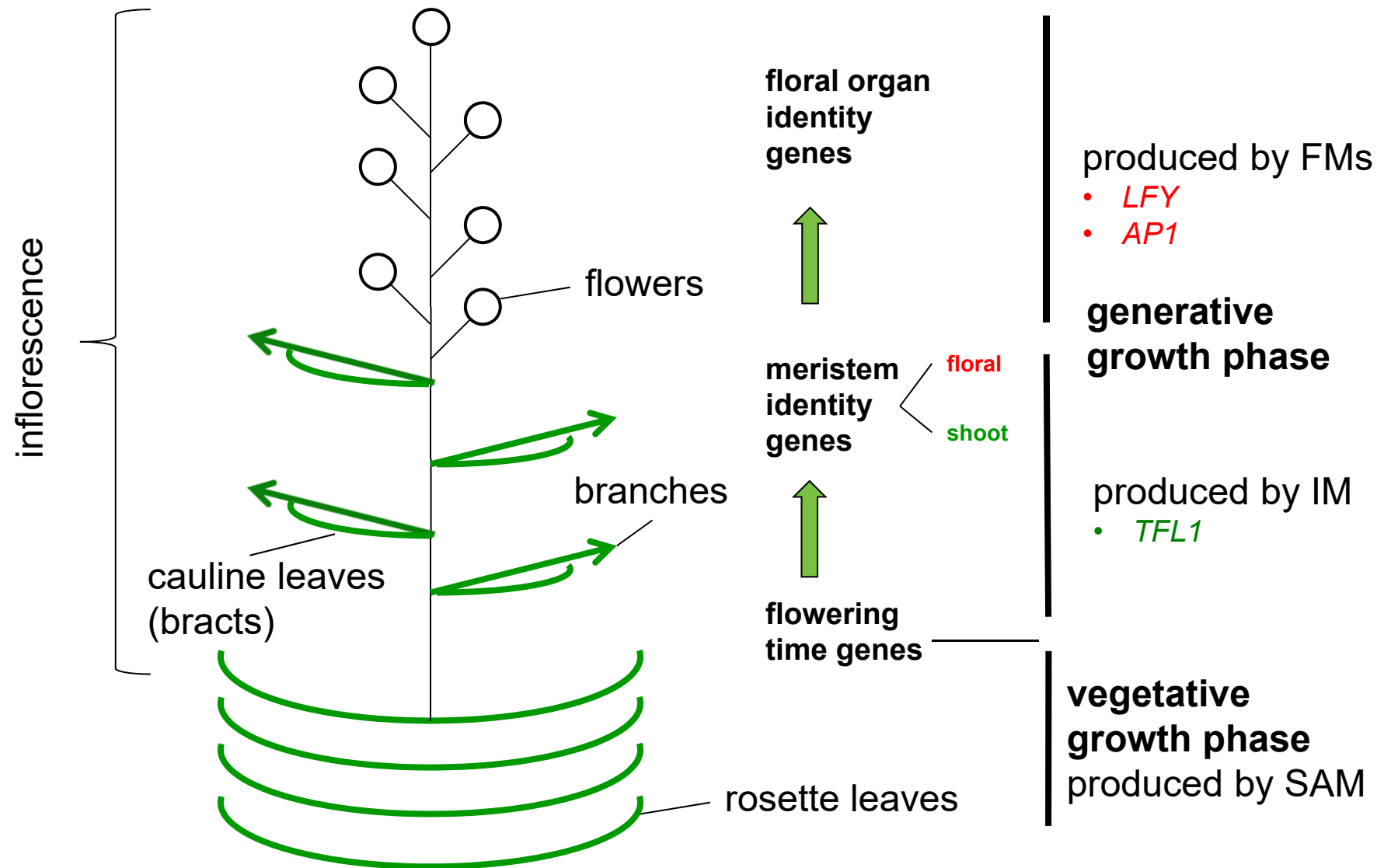
Plant Grow thanks to Meristems

Lateral meristems

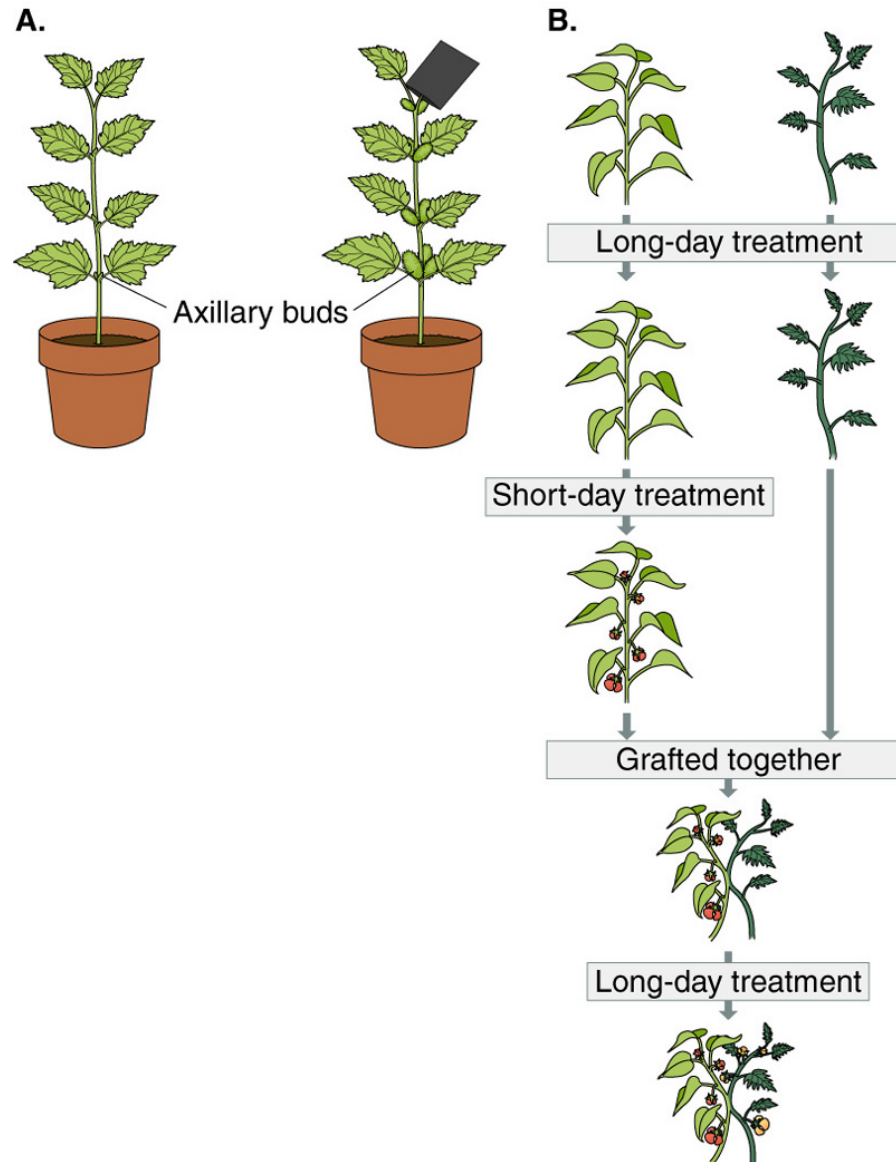
Apical meristems



# Changes in Meristem Identity



# Initiation of Flowering





# Initiation of Flowering

*In situ* hybridization with *INDETERMINATE (ID1)* mRNA...

....in leaves



Lata (klásků)  
Tassel

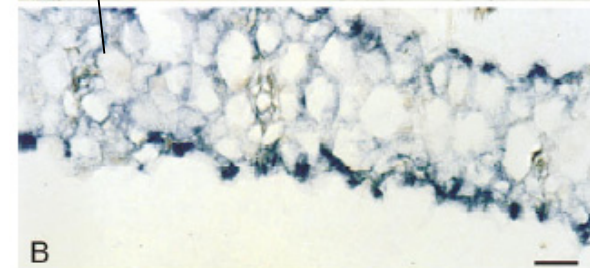
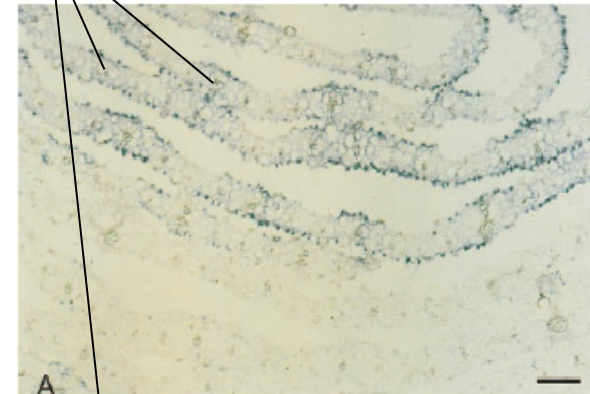
Palice  
Ear



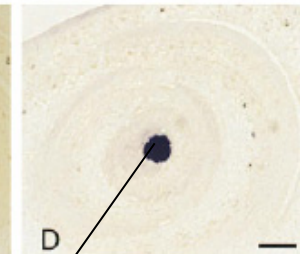
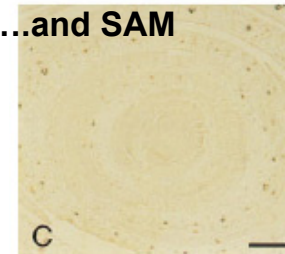
17 WT

*id1*

*id1*

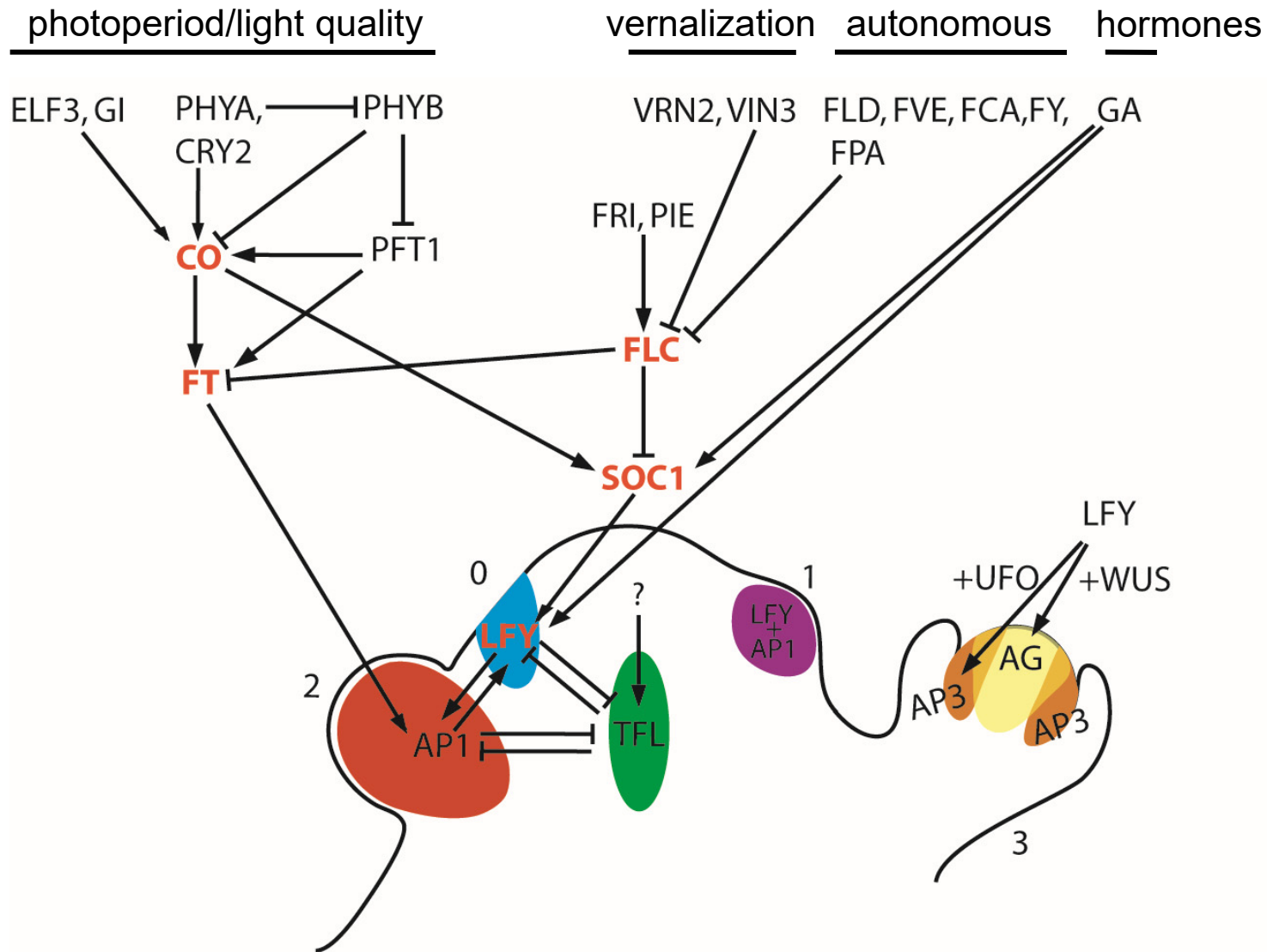


....and SAM



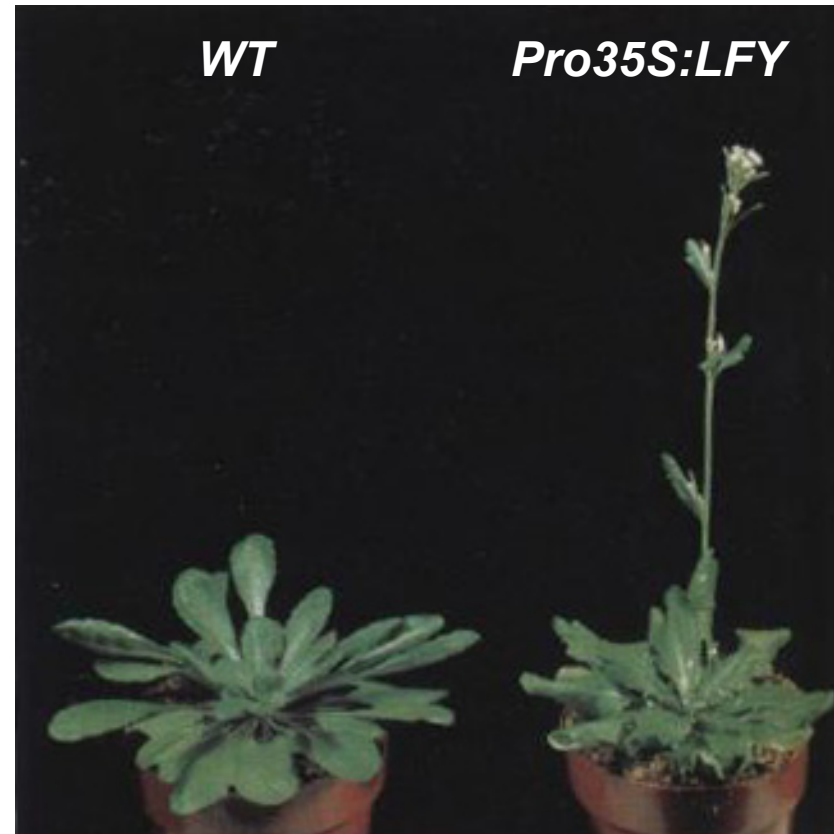
KN1

# Flowering Control



# Flowering Control

	Wild type	Overexpression of <i>leafy</i>
Short days	<p>Flowers</p> <p>Branches</p> <p>Bracts</p> <p>Leaves</p>	
Long days		

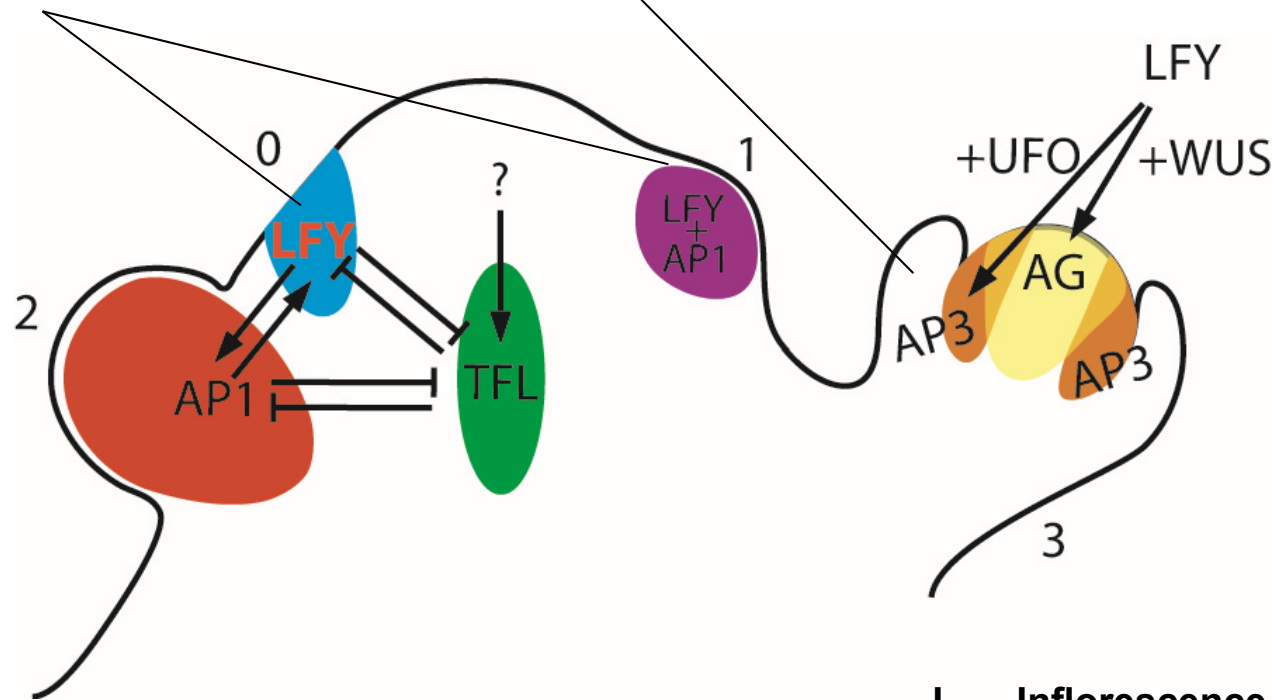


# Flowering Control

**II. Floral meristem identity acquisition**  
(LFY, AP1)

**III. Activation of floral organ identity genes**  
(whorl-specific)

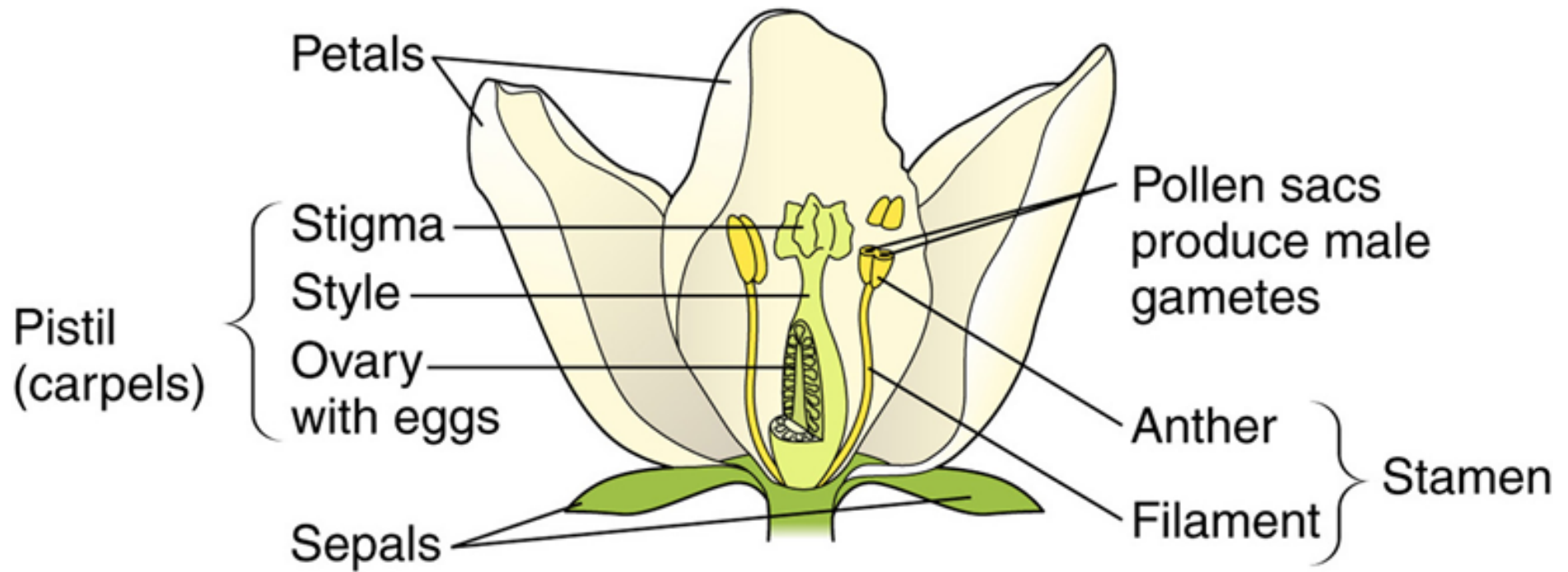
**IV. Activation of floral organ building genes**



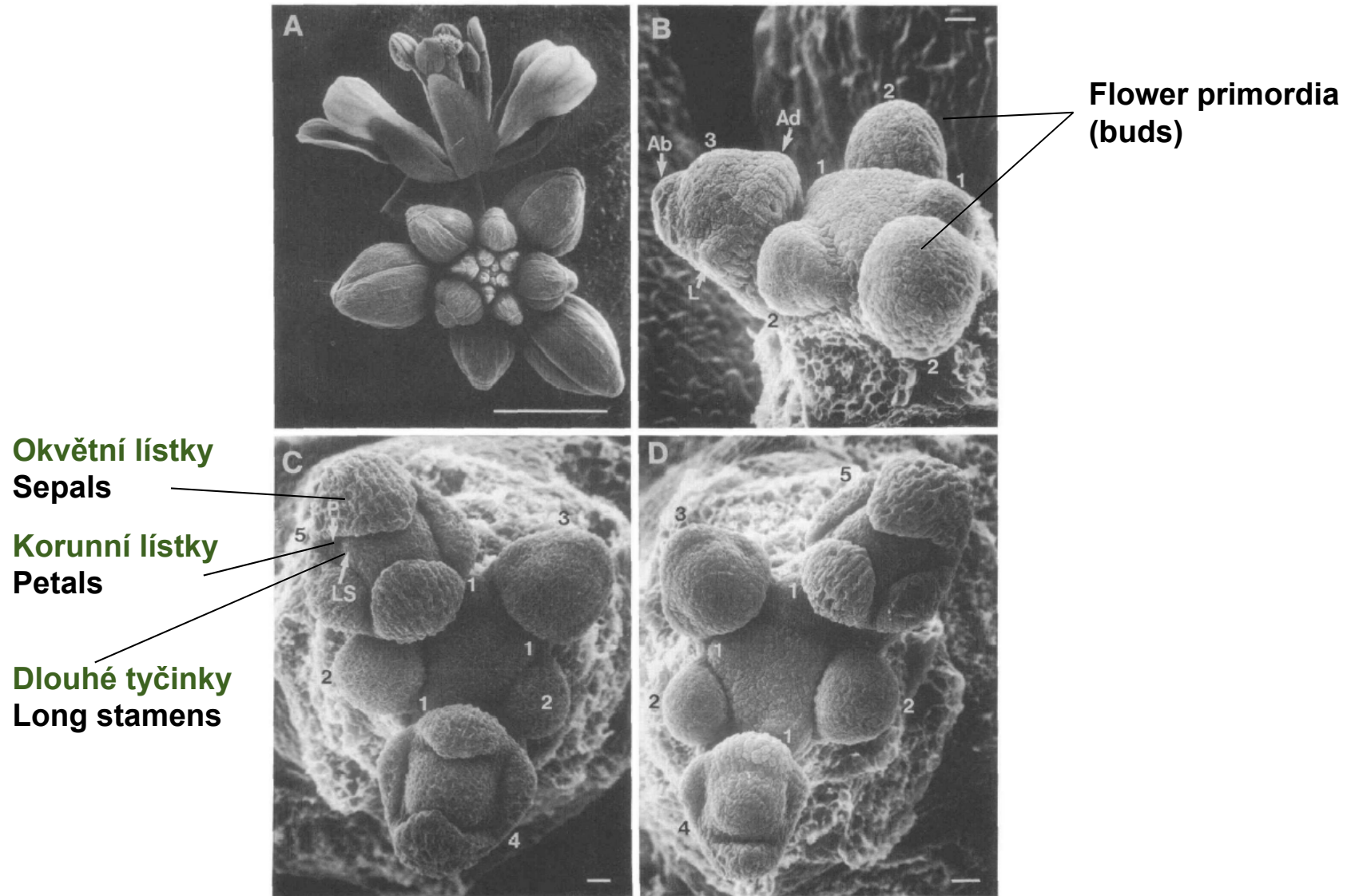
**I. Inflorescence meristem formation**  
(switch from vegetative to reproductive growth)

Dubova, Hejatko, Friml (2005)

# Flower Development

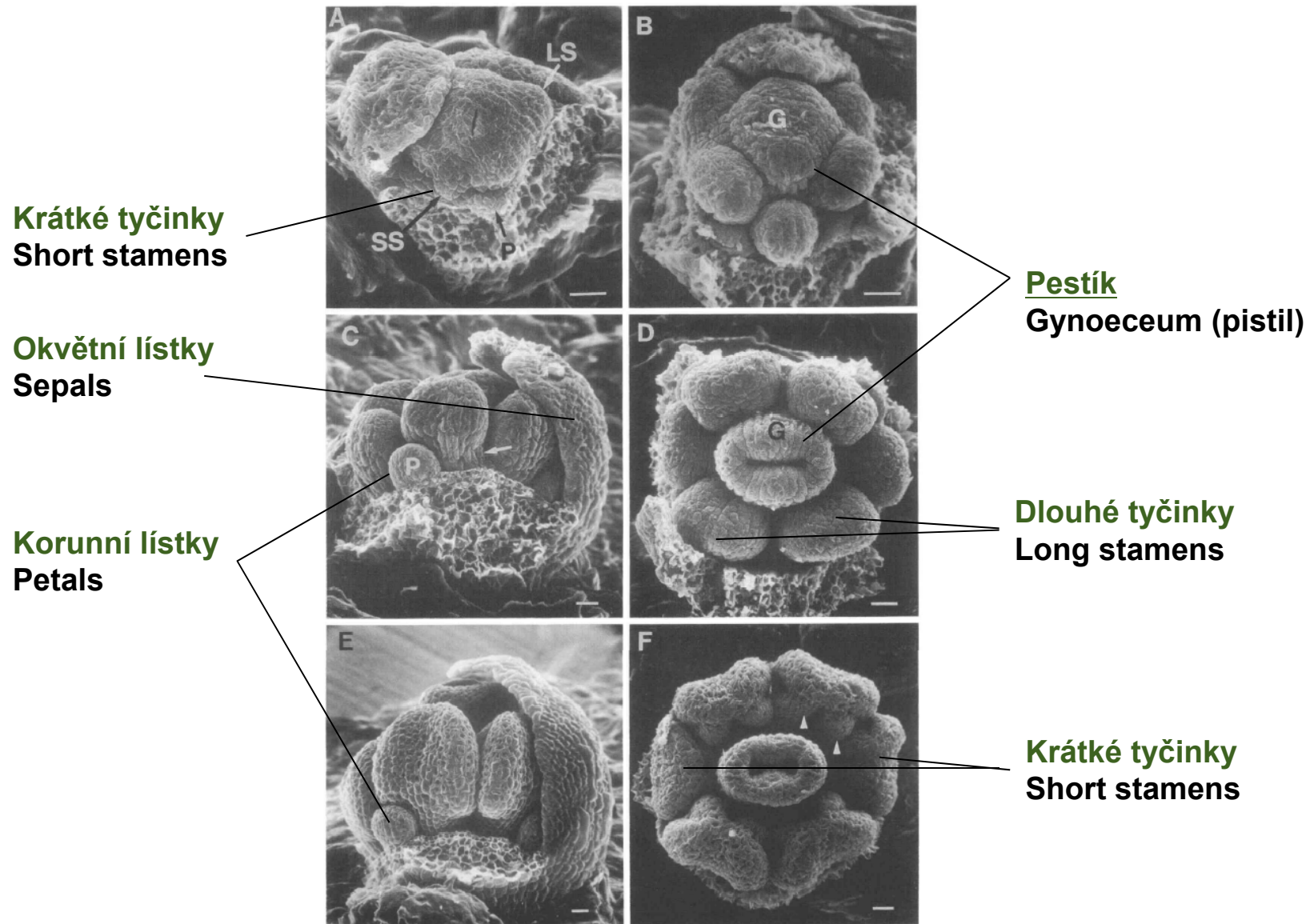


# Floral Organ Formation



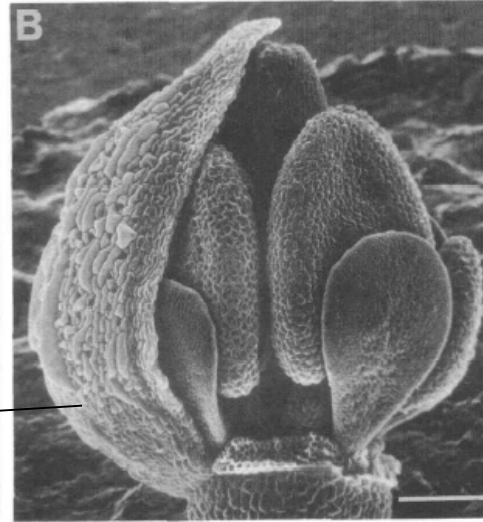
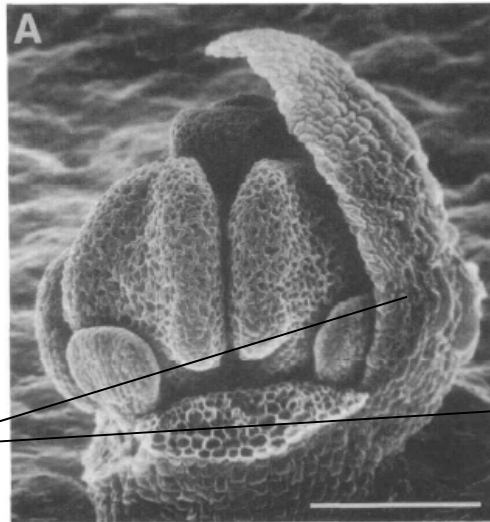
Smyth et al., *Plant Cell* (1990)

# Floral Organ Formation

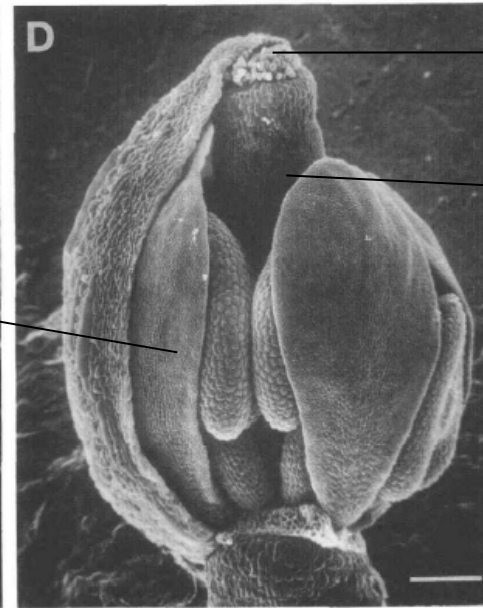
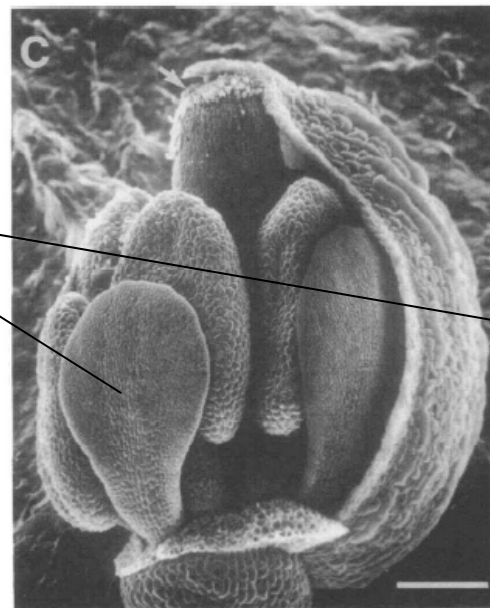


# Floral Organ Formation

Okvětní lístky  
Sepals



Korunní lístky  
Petals



Blizna  
Stigma

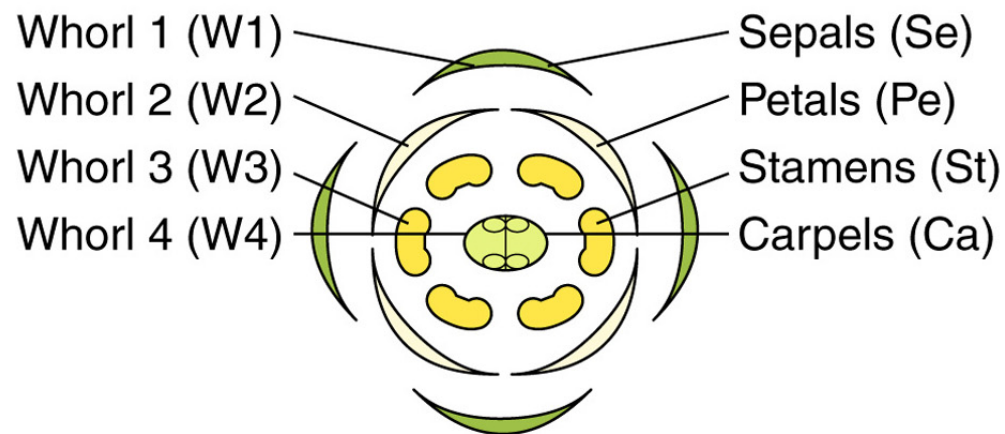
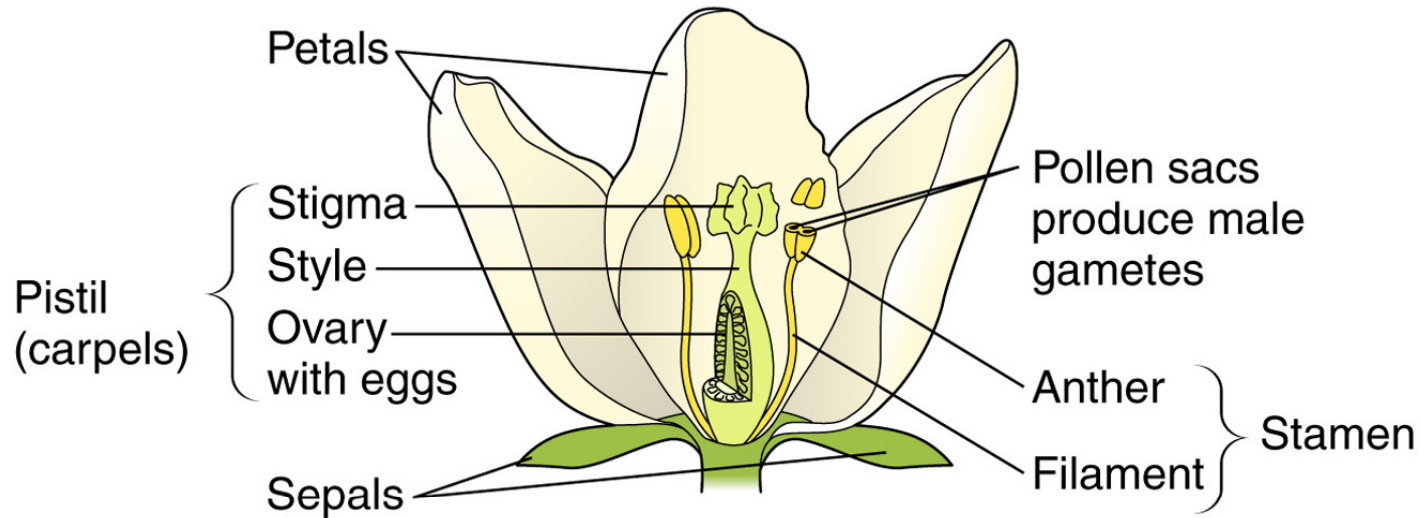
Pestík  
Gynoecium (pistil)



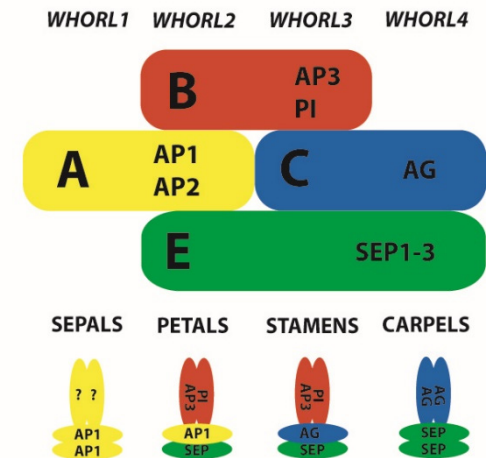
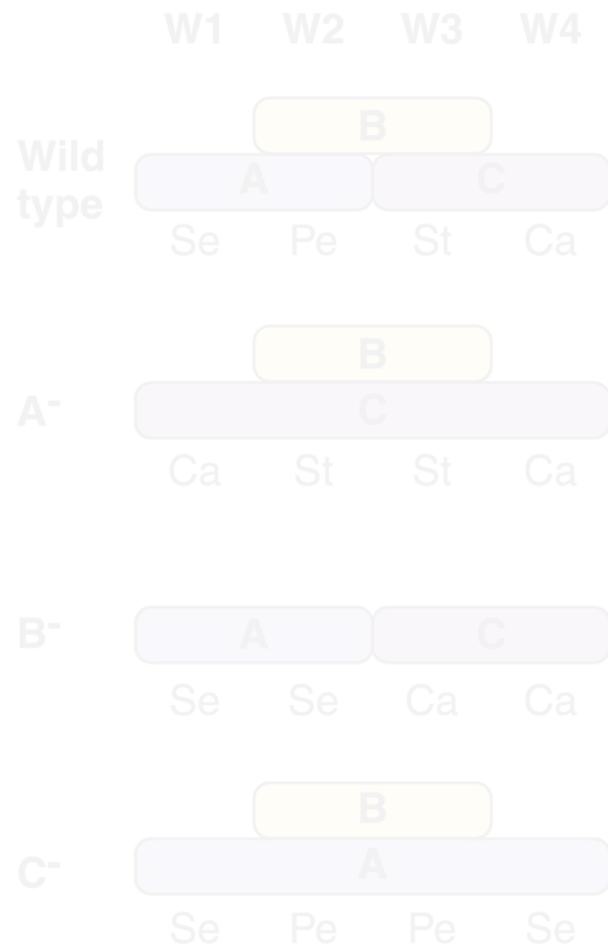
# Outline

- Sexual and asexual plant reproduction
- Plant life cycle
- Initiation of flowering
- **Determination of floral organ identity**

# Floral Organ Identity



# ABC Model



# ABC Model

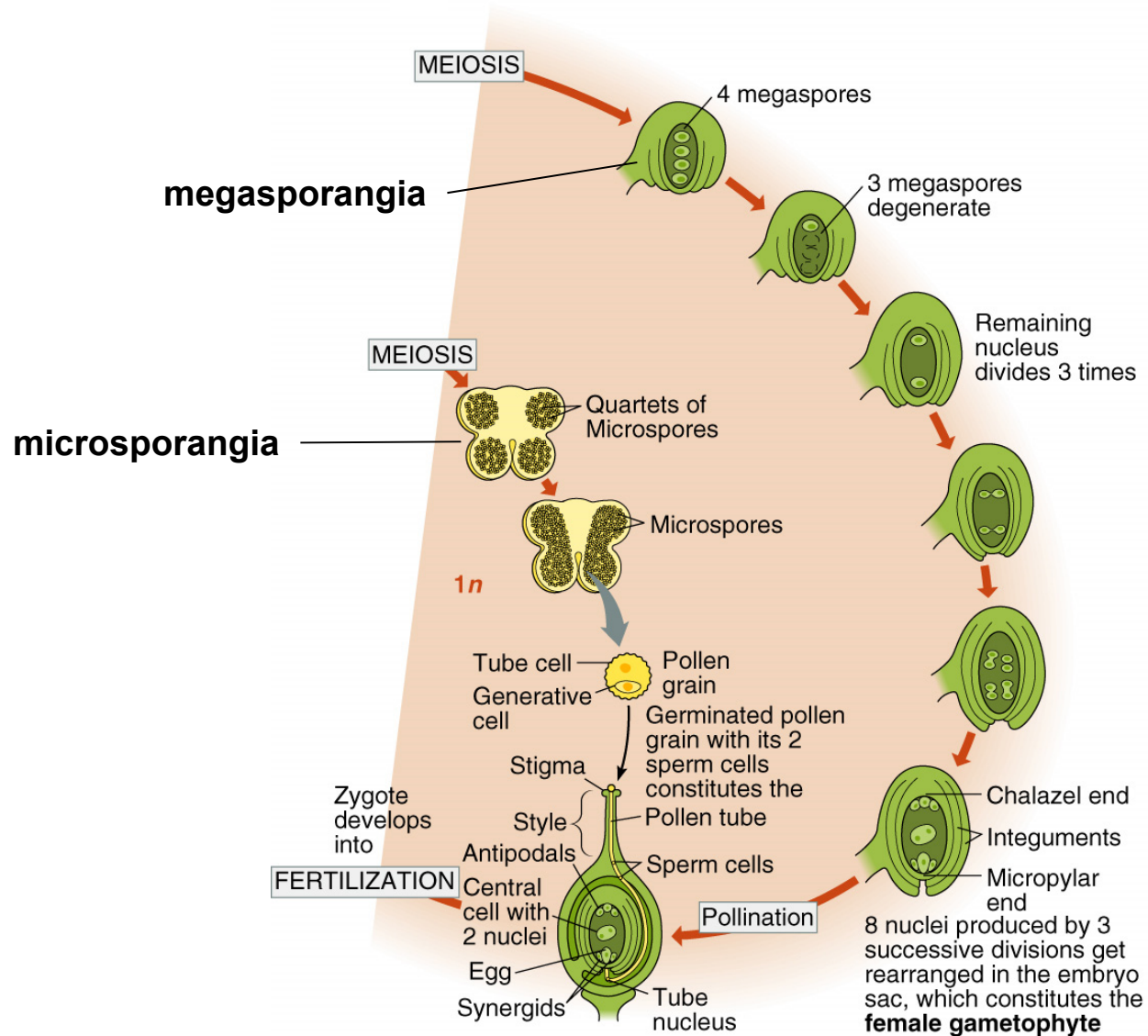


Author of ABC model, professor **Elliot Meyerowitz** (middle) during his visit of MU campus in Mar 2008

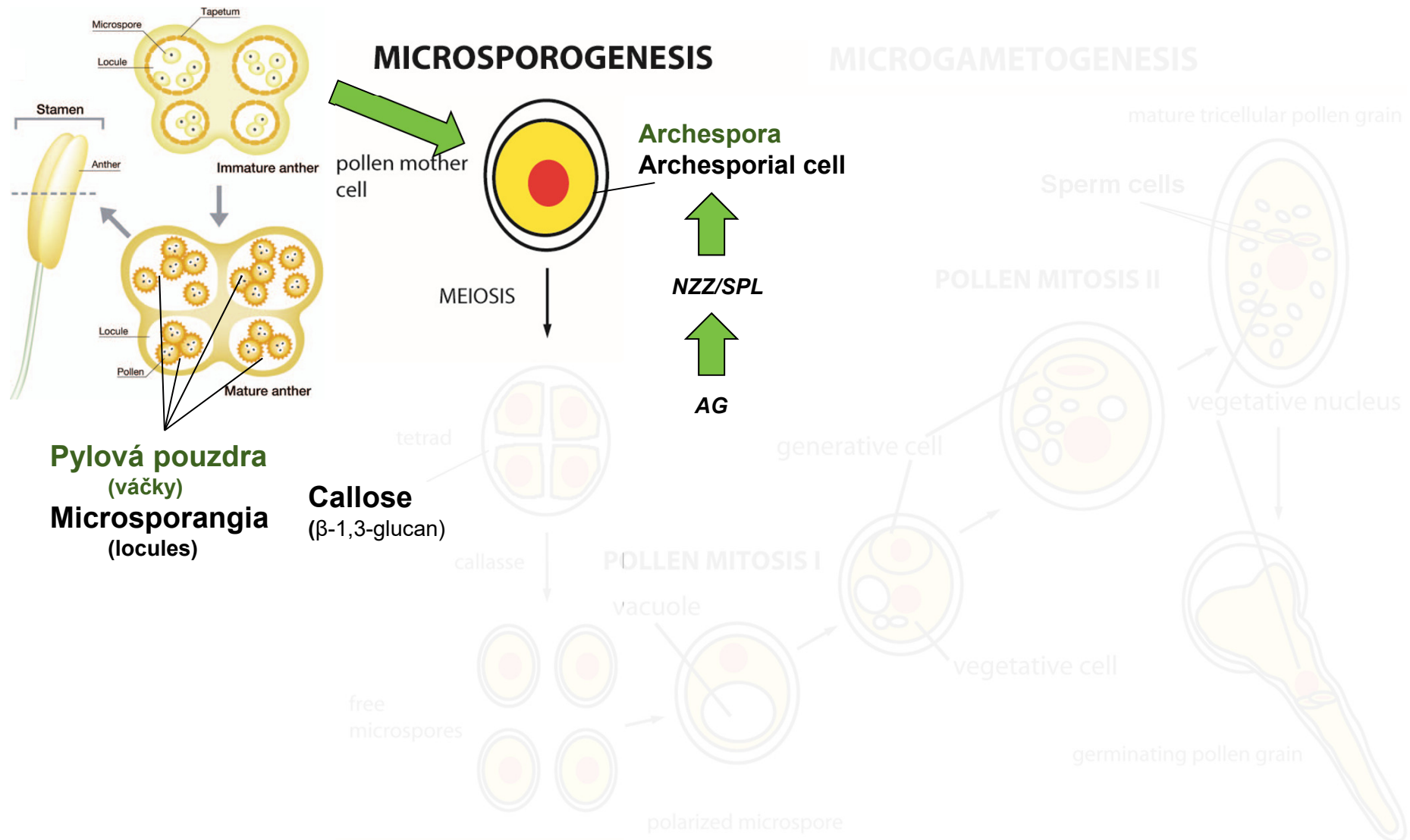
# Outline

- Sexual and asexual plant reproduction
- Plant life cycle
- Initiation of flowering
- Determination of floral organ identity
- **Microgametogenesis**

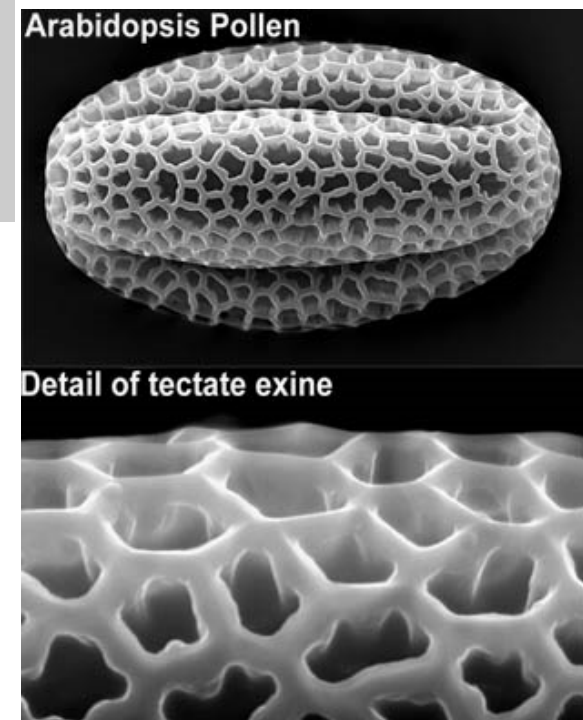
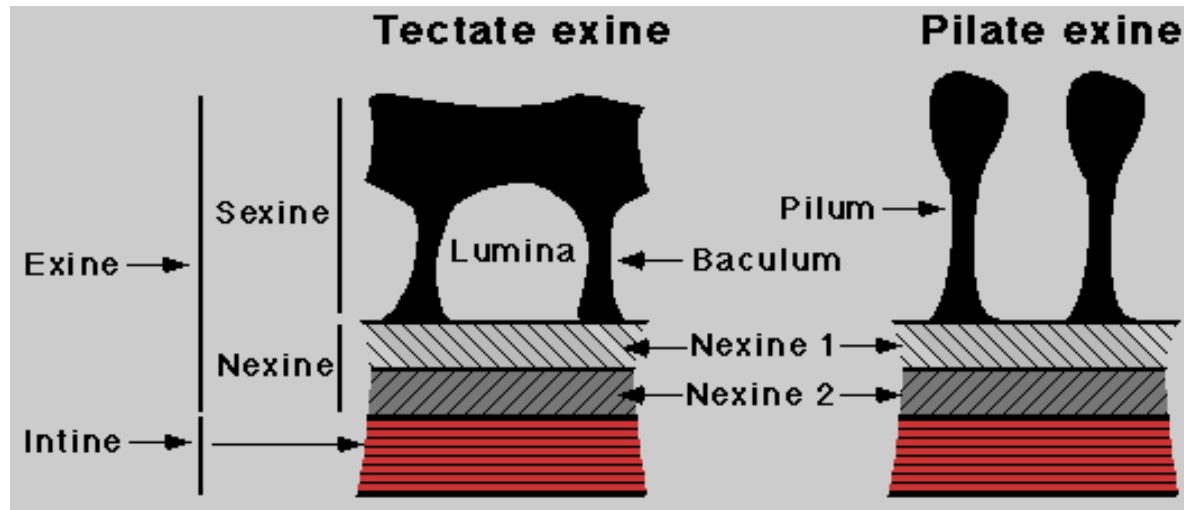
# Microgametogenesis



# Microgametogenesis



# Microgametogenesis

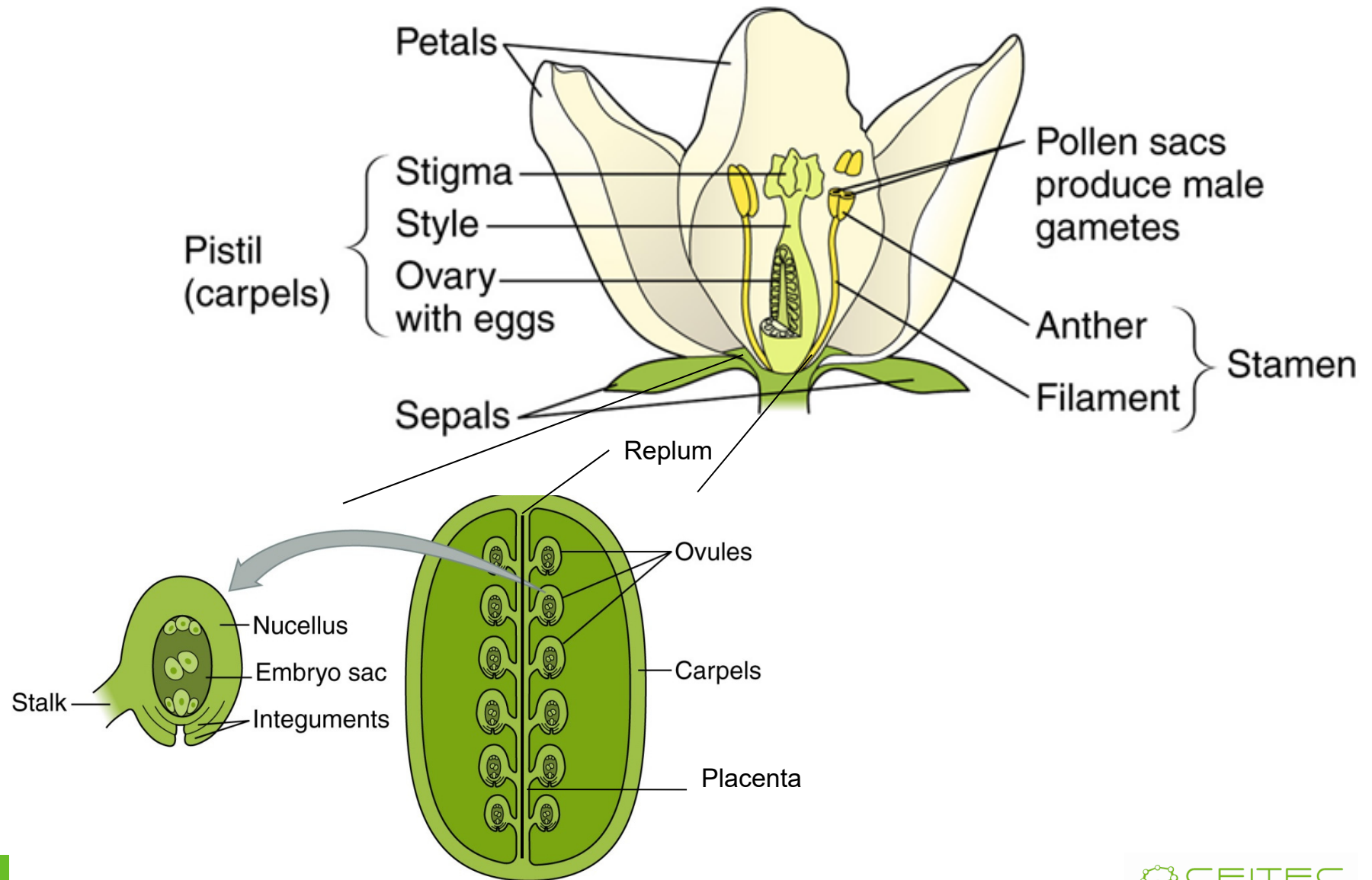




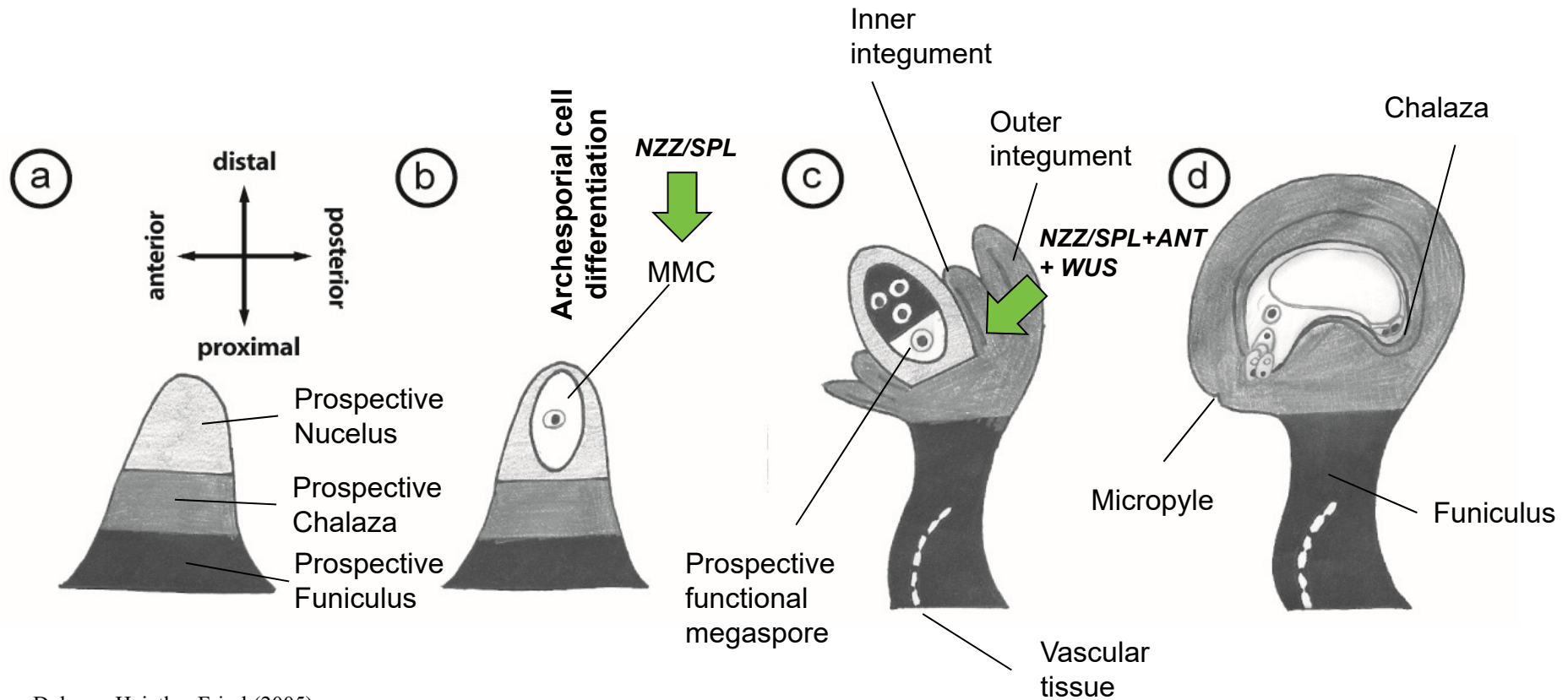
# Outline

- Sexual and asexual plant reproduction
- Plant life cycle
- Initiation of flowering
- Determination of floral organ identity
- Microgametogenesis
- **Megagametogenesis**

# Megagametogenesis

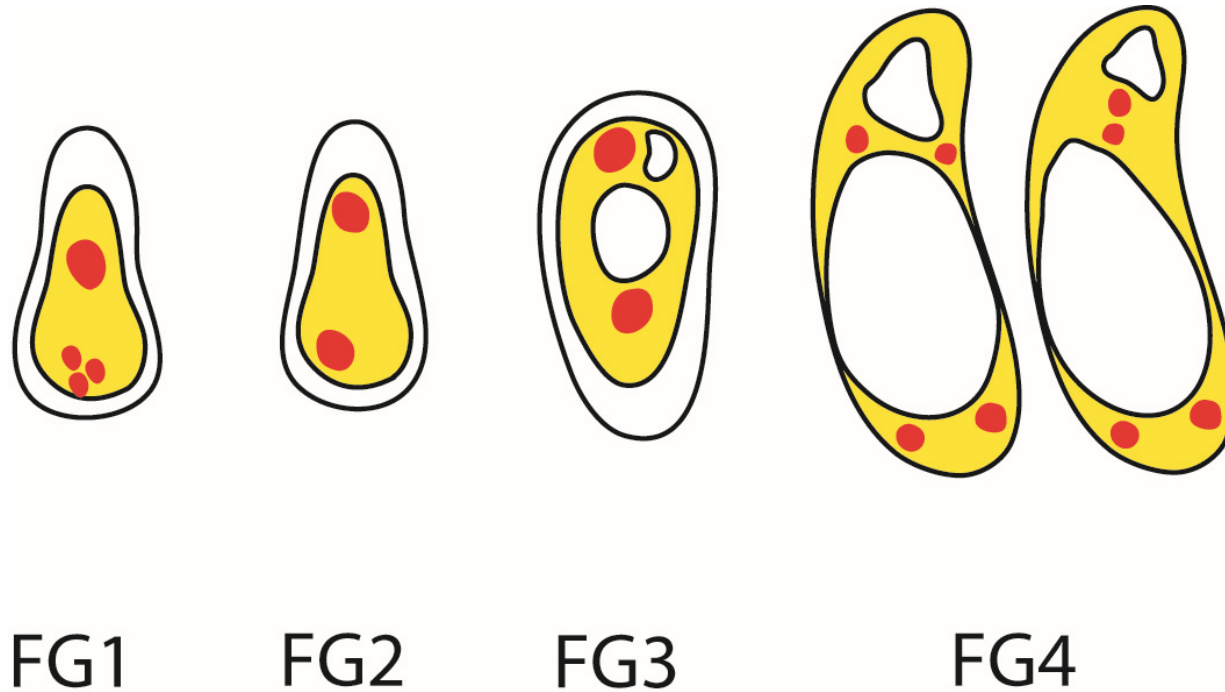


# Megagametogenesis



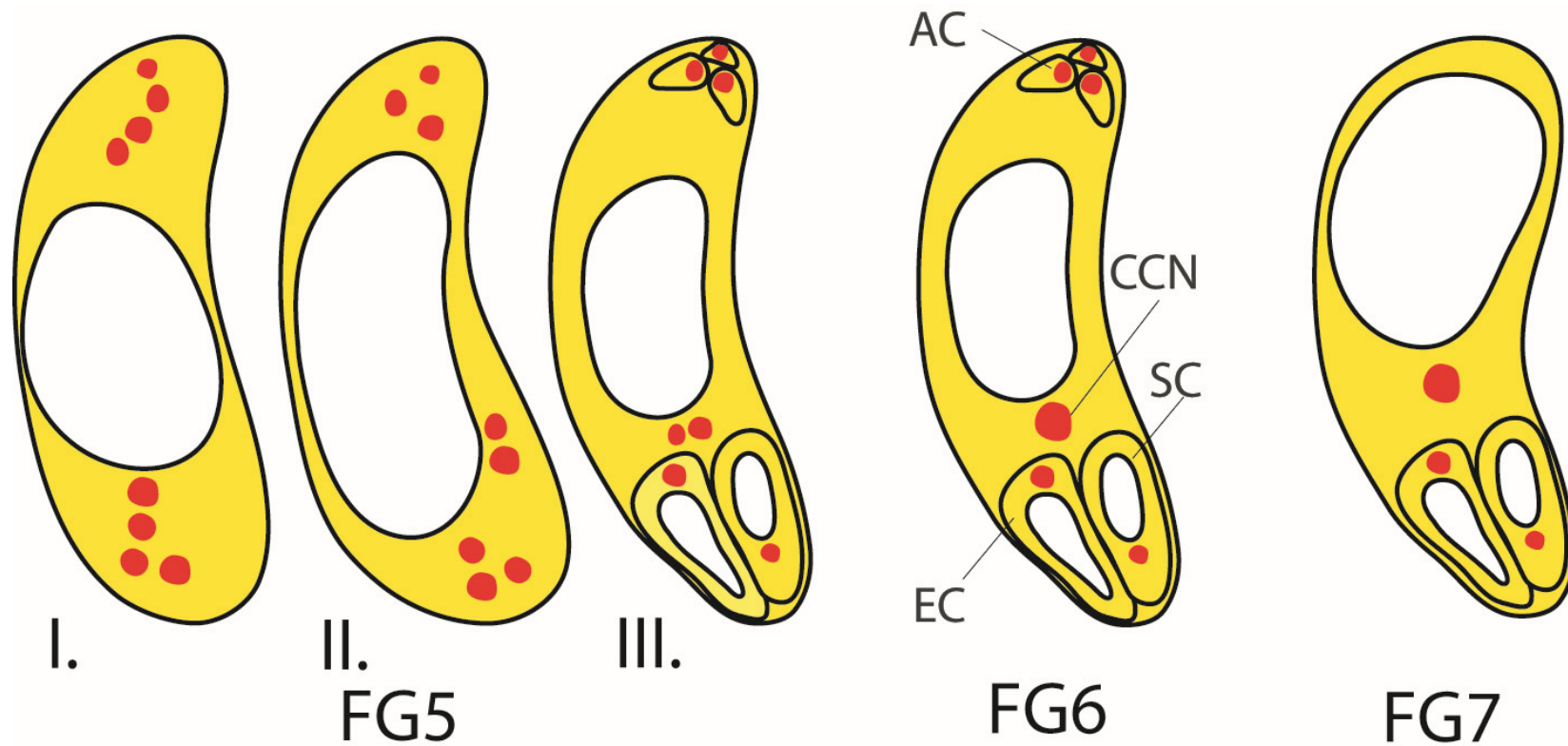
Dubova, Hejatko, Friml (2005)

# Megagametogenesis



Dubova, Hejatko, Friml (2005)

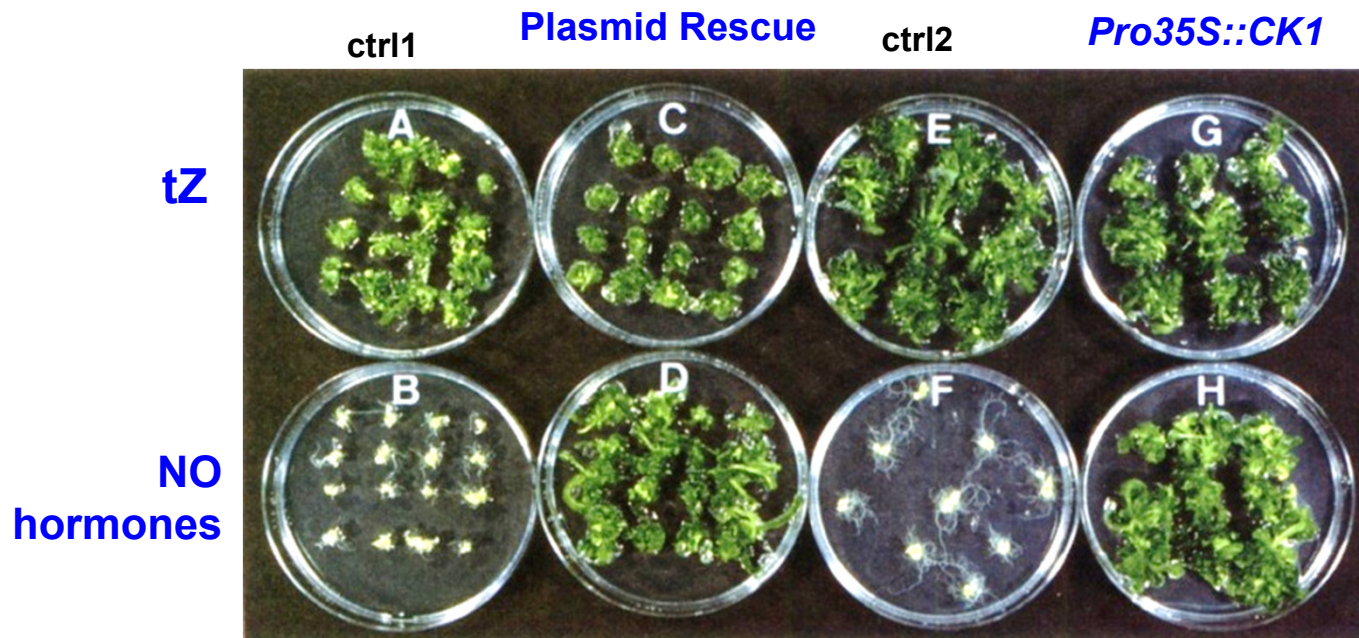
# Megagametogenesis



Dubova, Hejatko, Friml (2005)

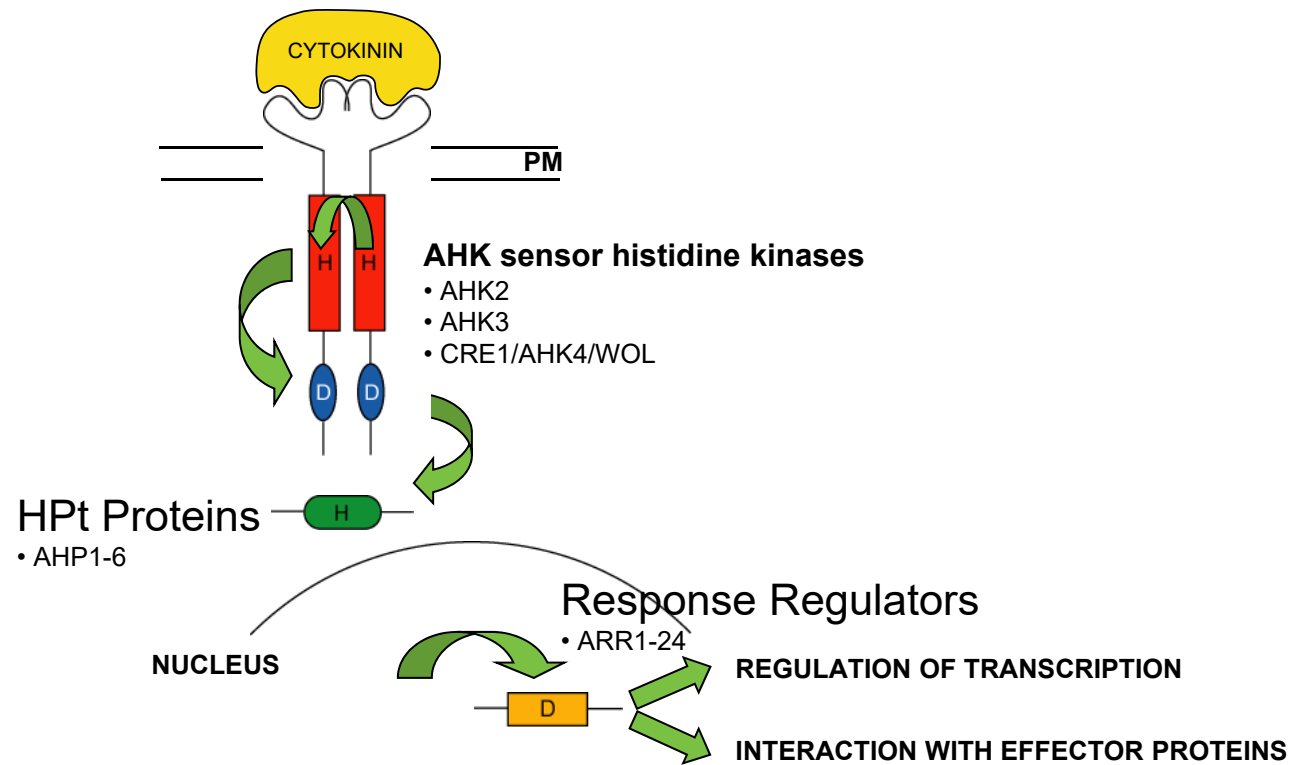
# Identification of *CK11* via Activation Mutagenesis

- *CK11* overexpression mimics cytokinin response



Kakimoto, *Science*, 1996

# Signal Transduction via MSP

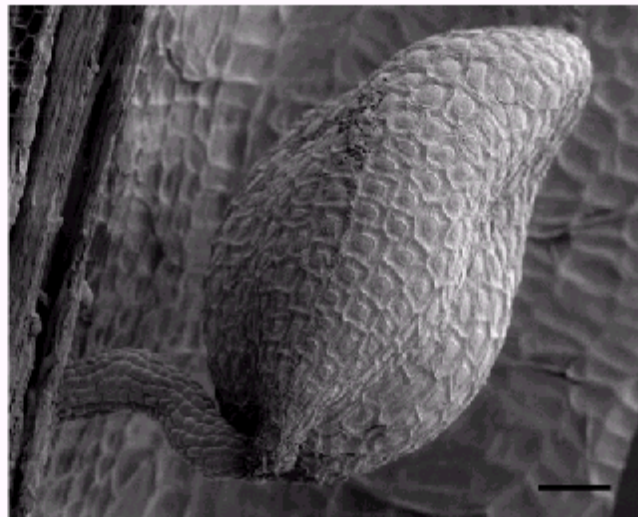
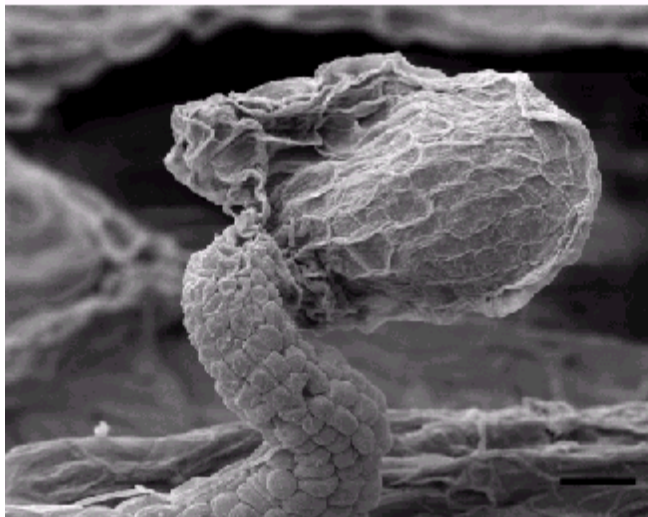


# CKI1 Controls Megagametogenesis

*CKI1/cki1-i*



*CKI1/CKI1*





# *cki1-i* reveals non-Mendelian inheritance

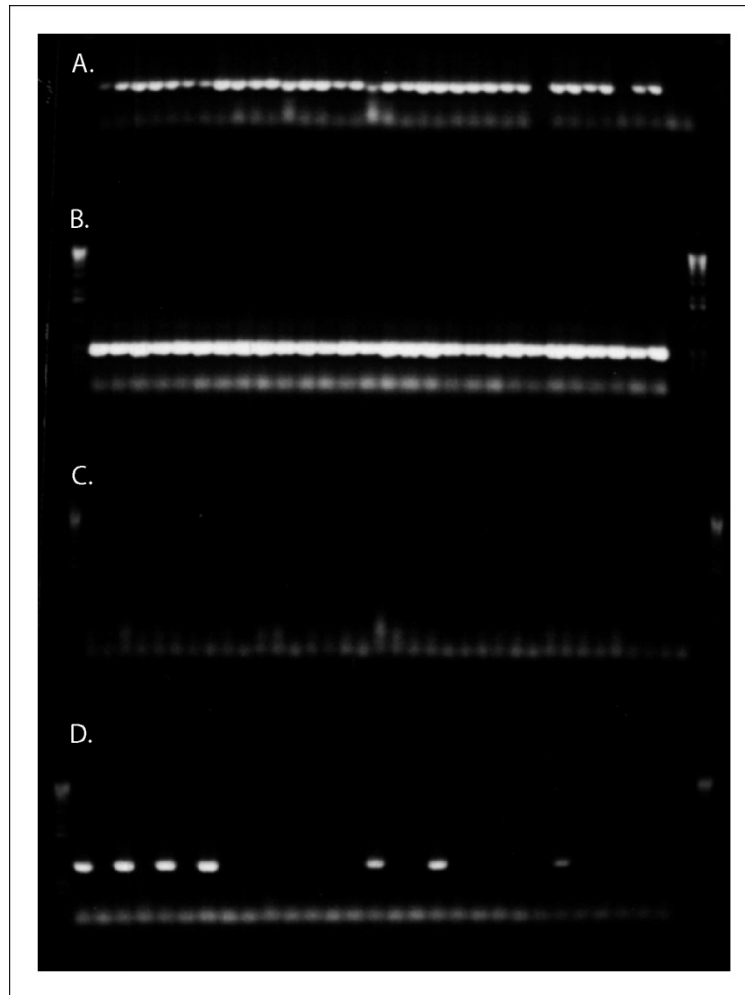
**P** *CKI1/cki1-i*

**F1** Anticipated: **1** *CKI1* : **2** *CKI1/cki1-i* : **1** *cki1-i*

Observed: **1** *CKI1* : **1** *CKI1/cki1-i*

	♀	♂
	<i>CKI1</i>	<i>cki1-i</i>
<i>CKI1</i>	<i>CKI1/CKI1</i>	<i>CKI1/cki1-i</i>
<i>cki1-i</i>	<i>CKI1/cki1-i</i>	

# CKI1 Controls Megagametogenesis



A. ♂ wt x ♀ *CKI1/cki1-i*

⇕ *CKI1* specific primers (PCR positive control)

B. ♂ *CKI1/cki1-i* x ♀ wt

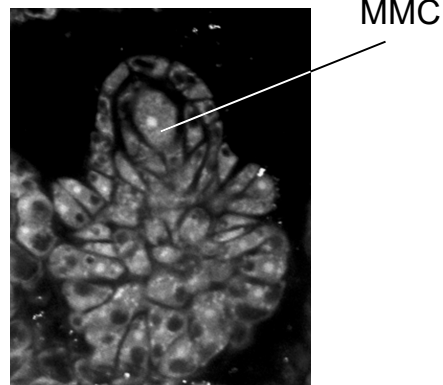
C. ♂ wt x ♀ *CKI1/cki1-i*

⇕ *cki1-i* specific primers

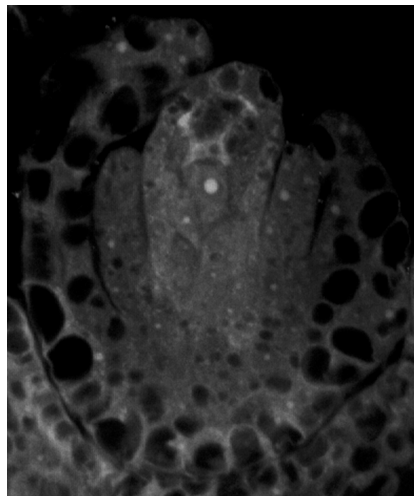
D. ♀ wt x ♂ *CKI1/cki1-i*

# CKI1 Controls Megagametogenesis

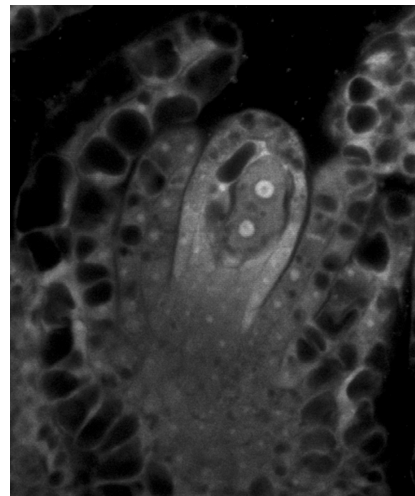
FG 0



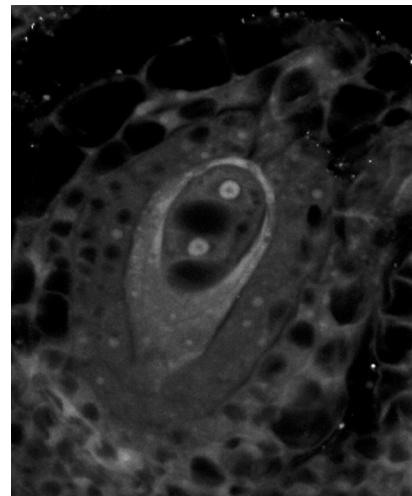
FG 1



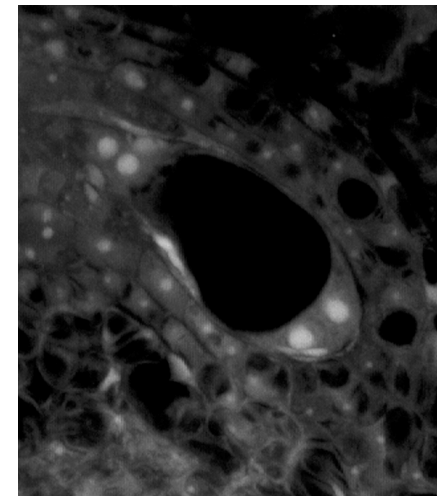
FG 2



FG 3



FG 4



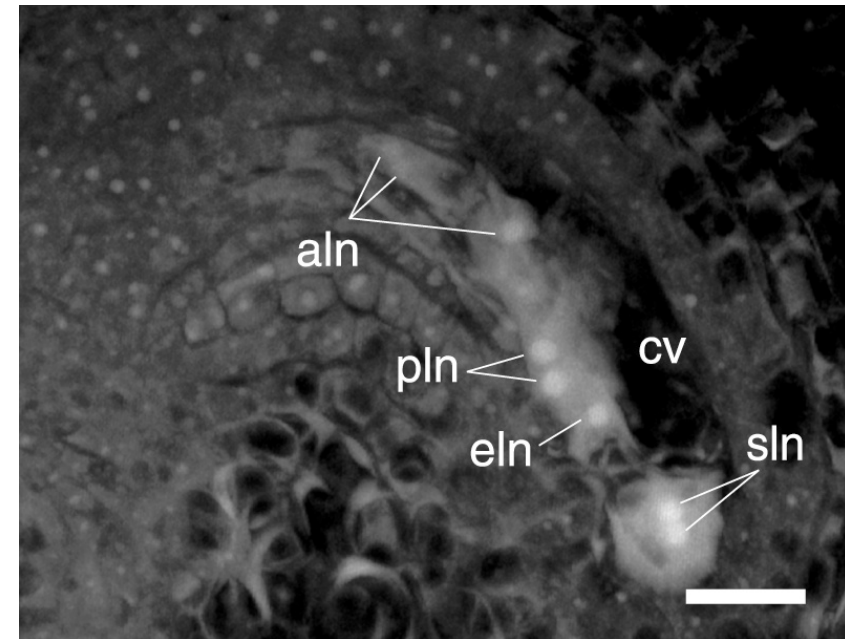
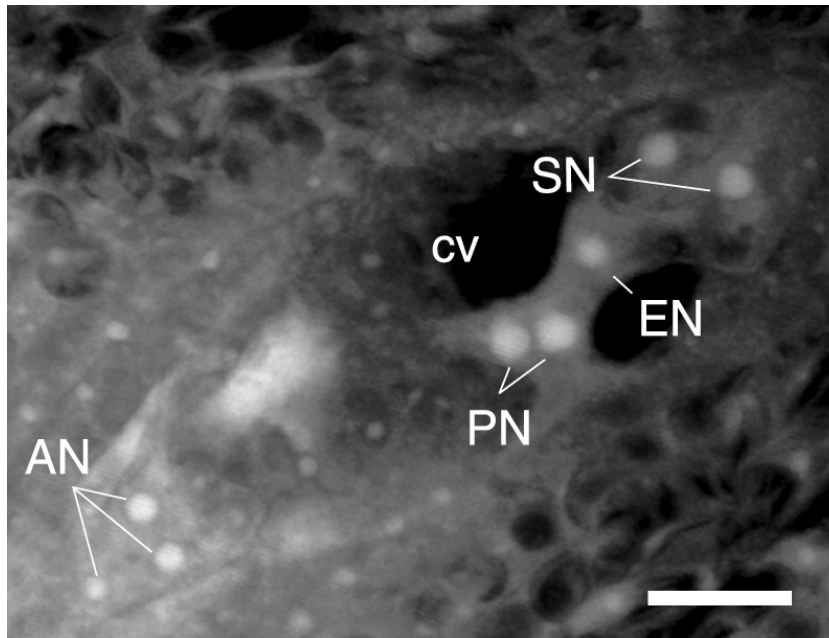
# CKI1 Controls Megagametogenesis

*CKI1*

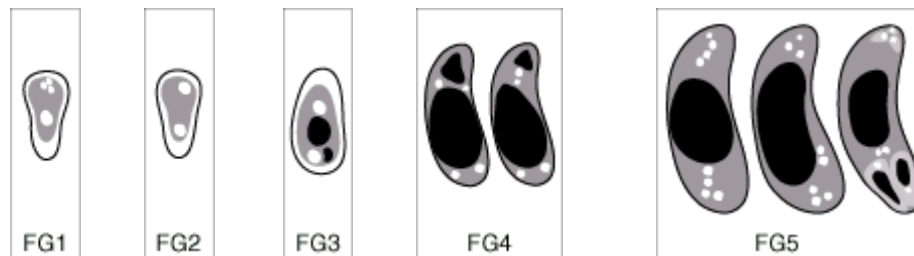
late FG5

*cki1-i*

24 HAE



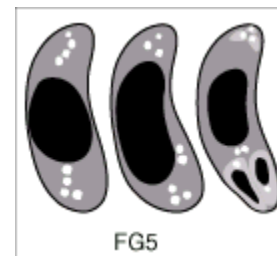
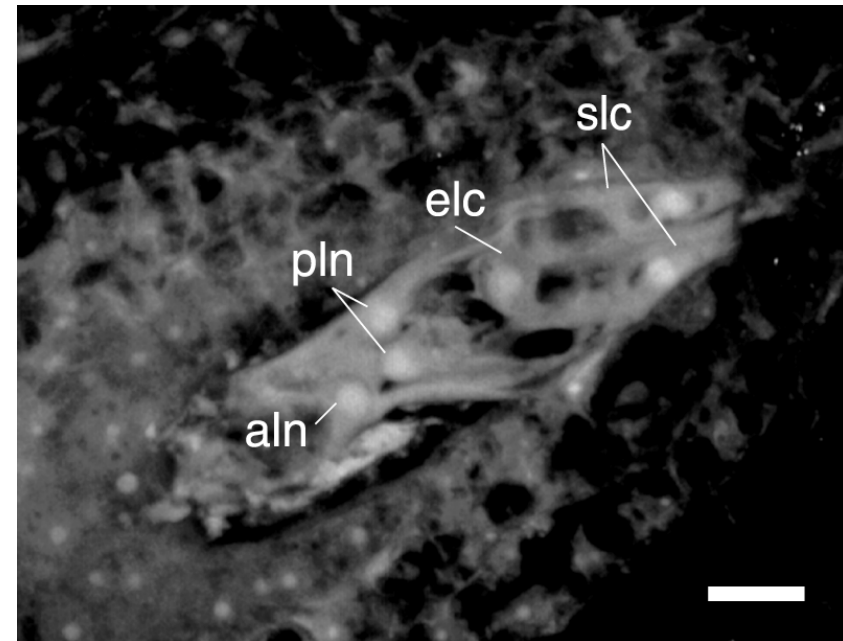
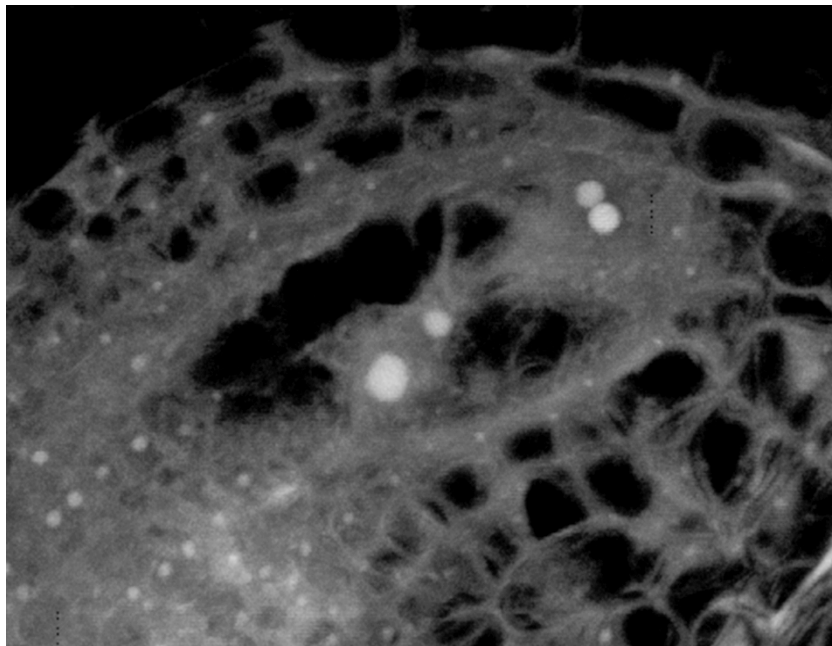
Hejátko et al., *Mol Genet Genomics* (2003)



# CKI1 Controls Megagametogenesis

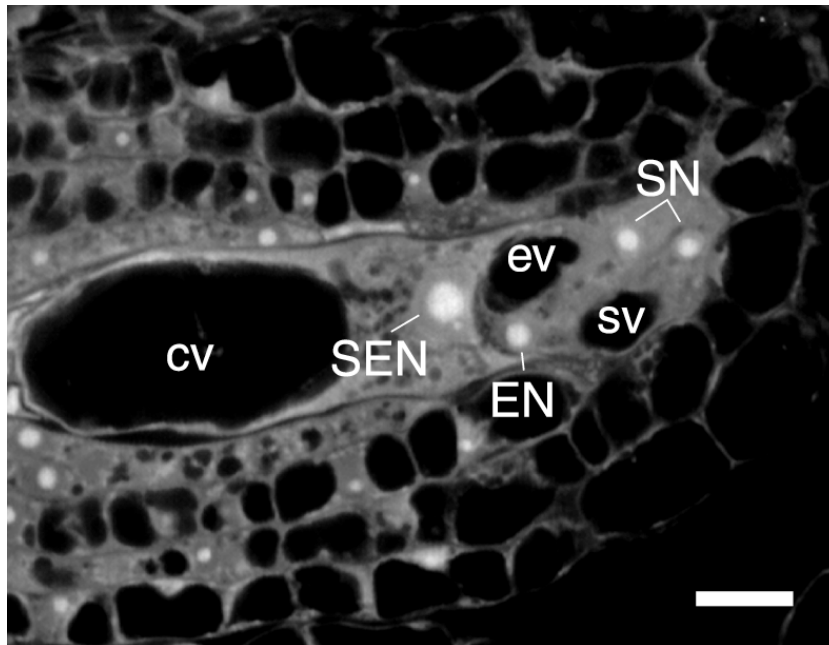
FG6

24 HAE

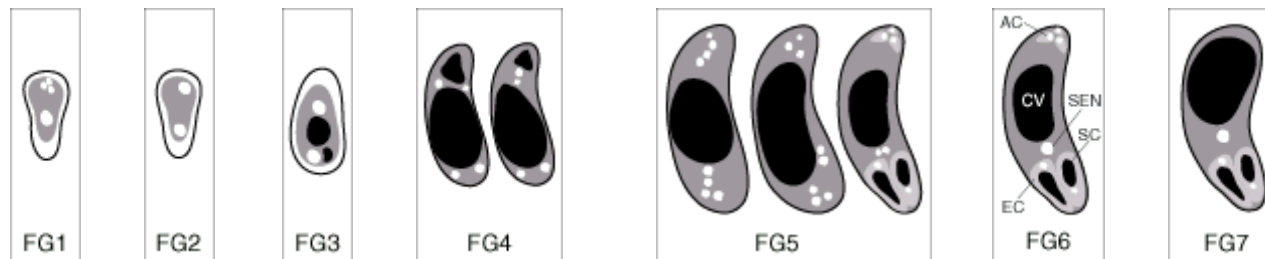
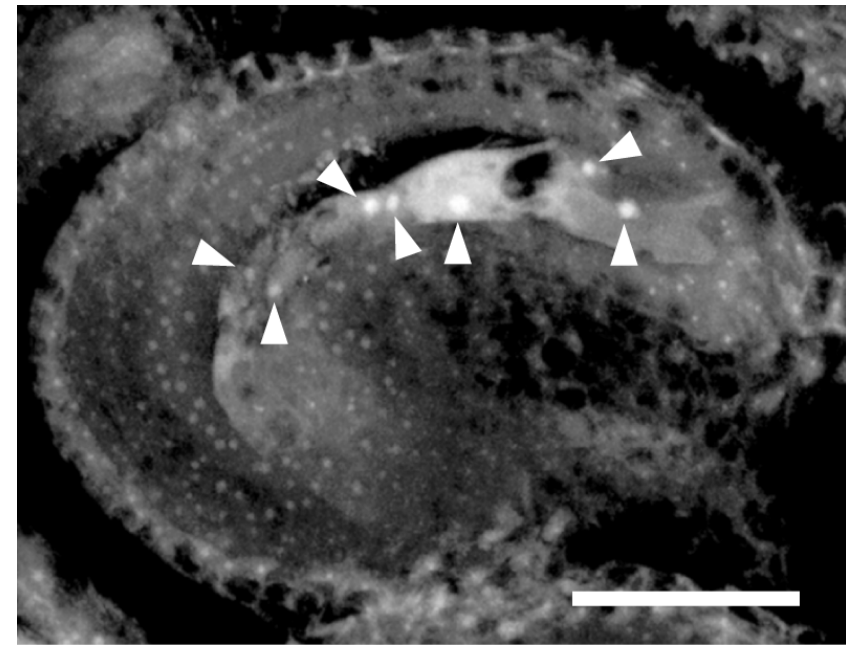


# CKI1 Controls Megagametogenesis

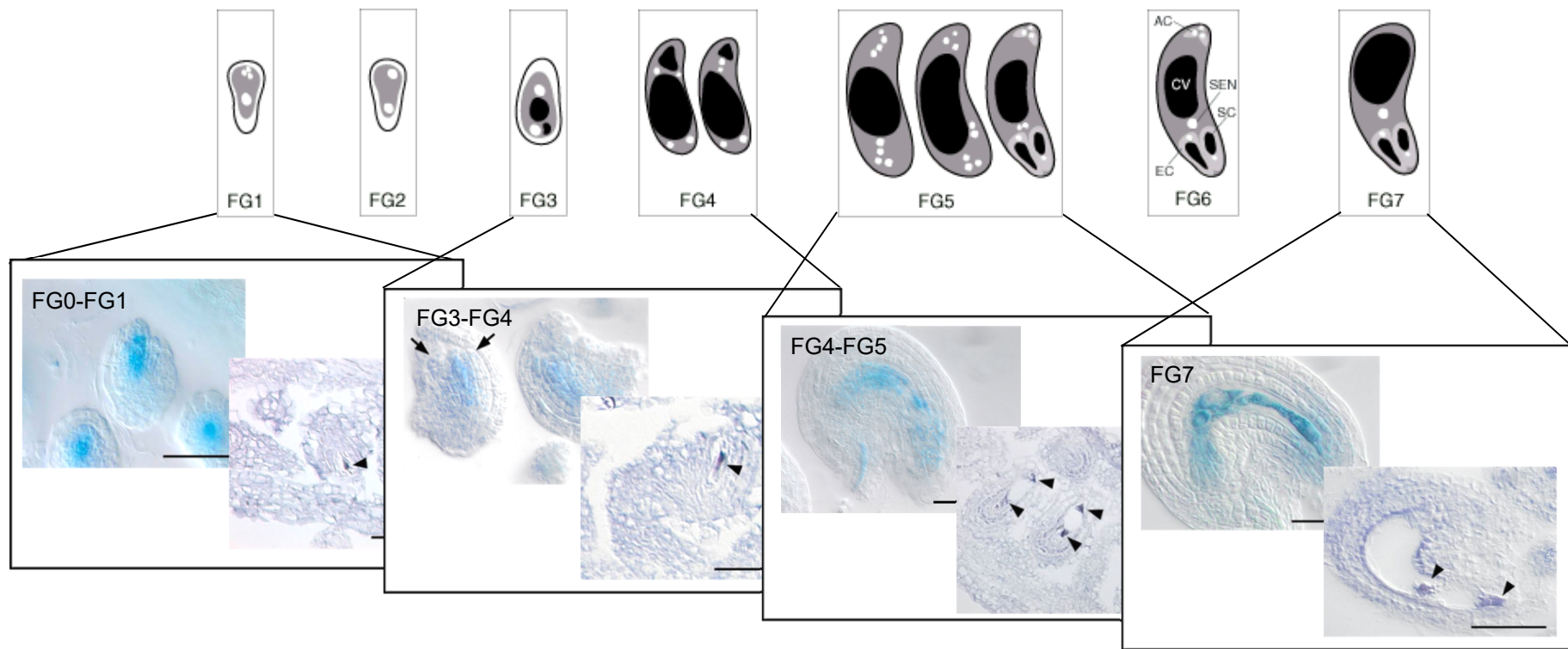
FG7



48 HAE



# CKI1 Activity during Megagametogenesis



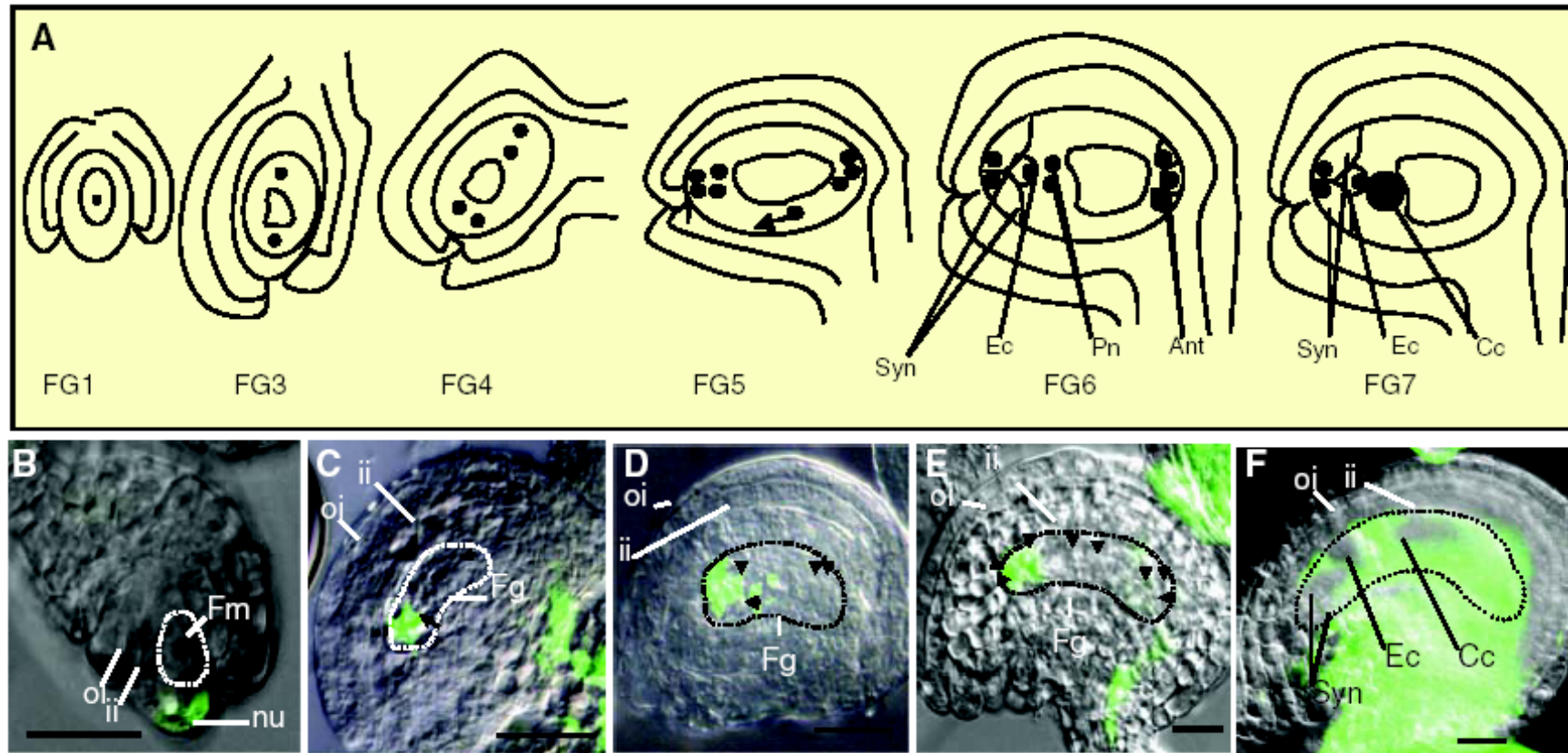
Hejátko et al., *Mol Genet Genomics* (2003)

# Outline

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- Megagametogenesis
  - Female gametophyte patterning

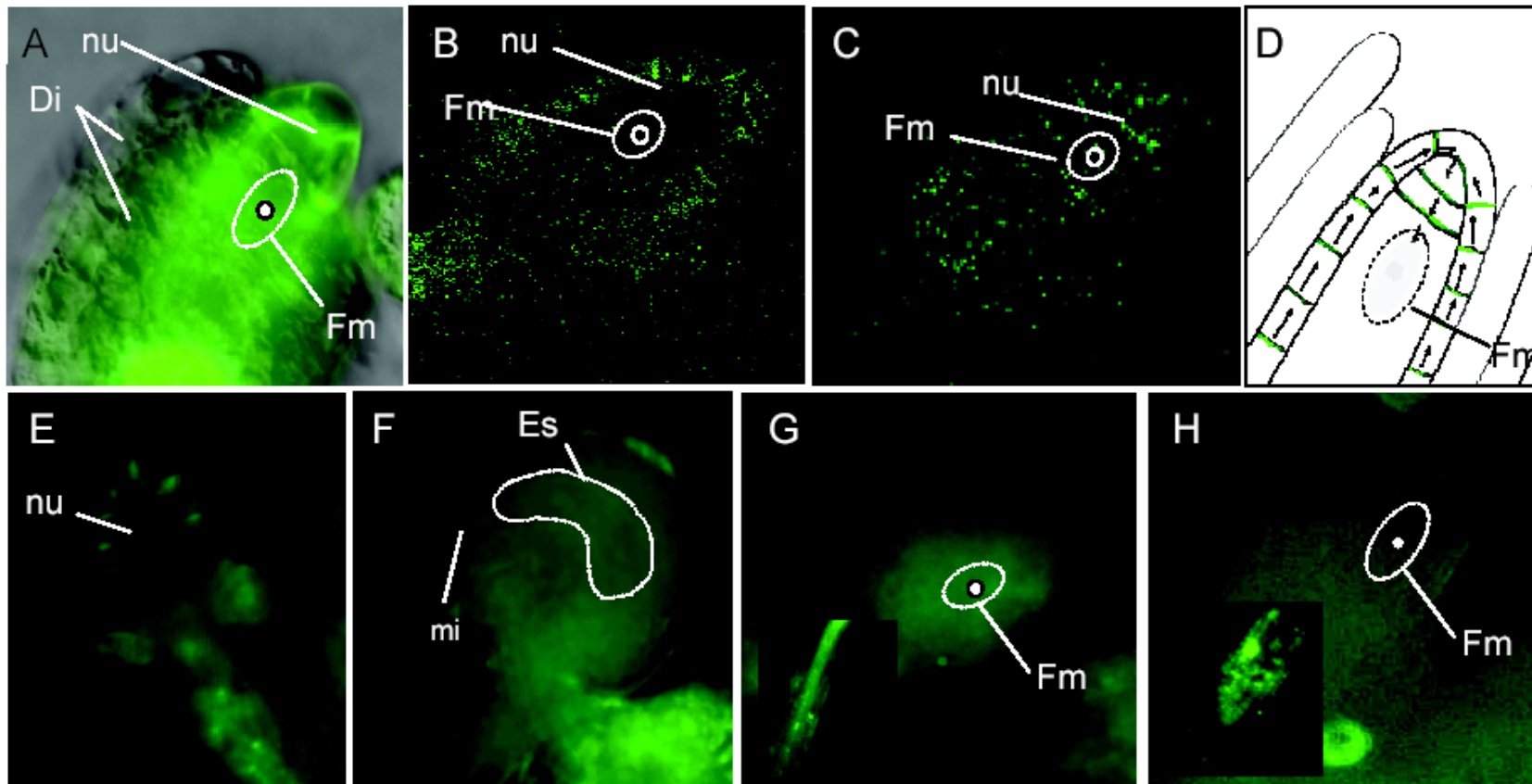


# Female Gametophyte Patterning



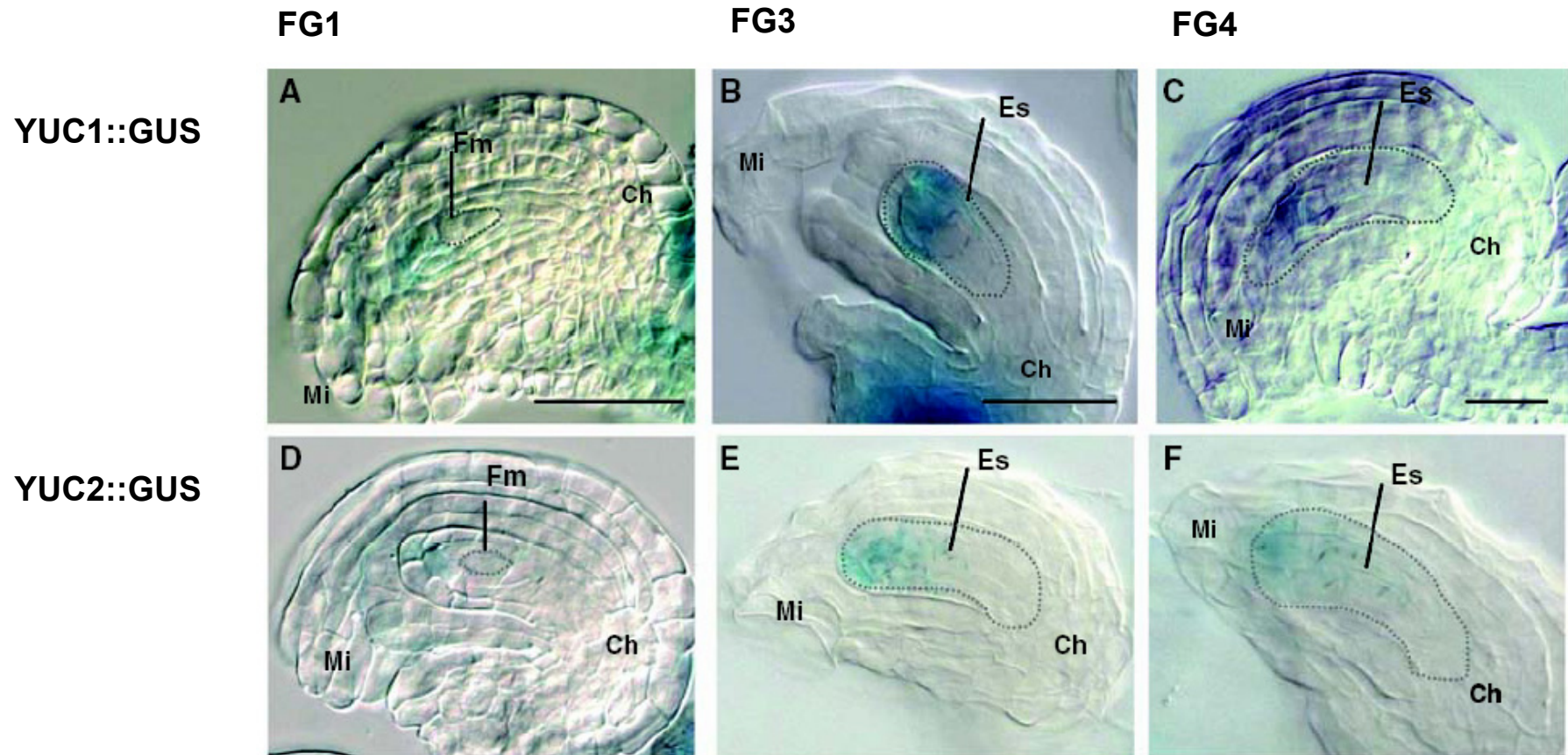
Pagnussat et al., *Science* (2009)

# Female Gametophyte Patterning



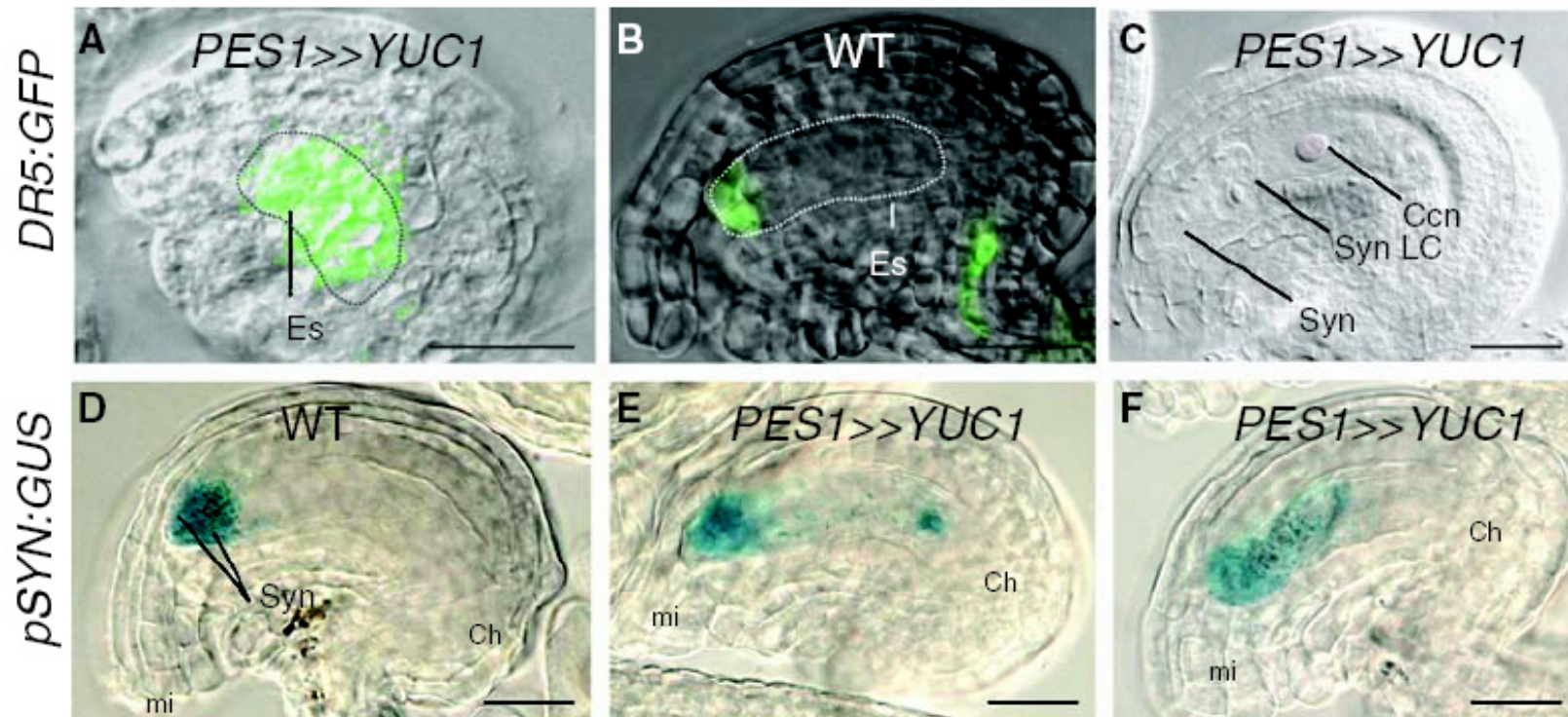
Pagnussat et al., *Science* (2009)

# Female Gametophyte Patterning



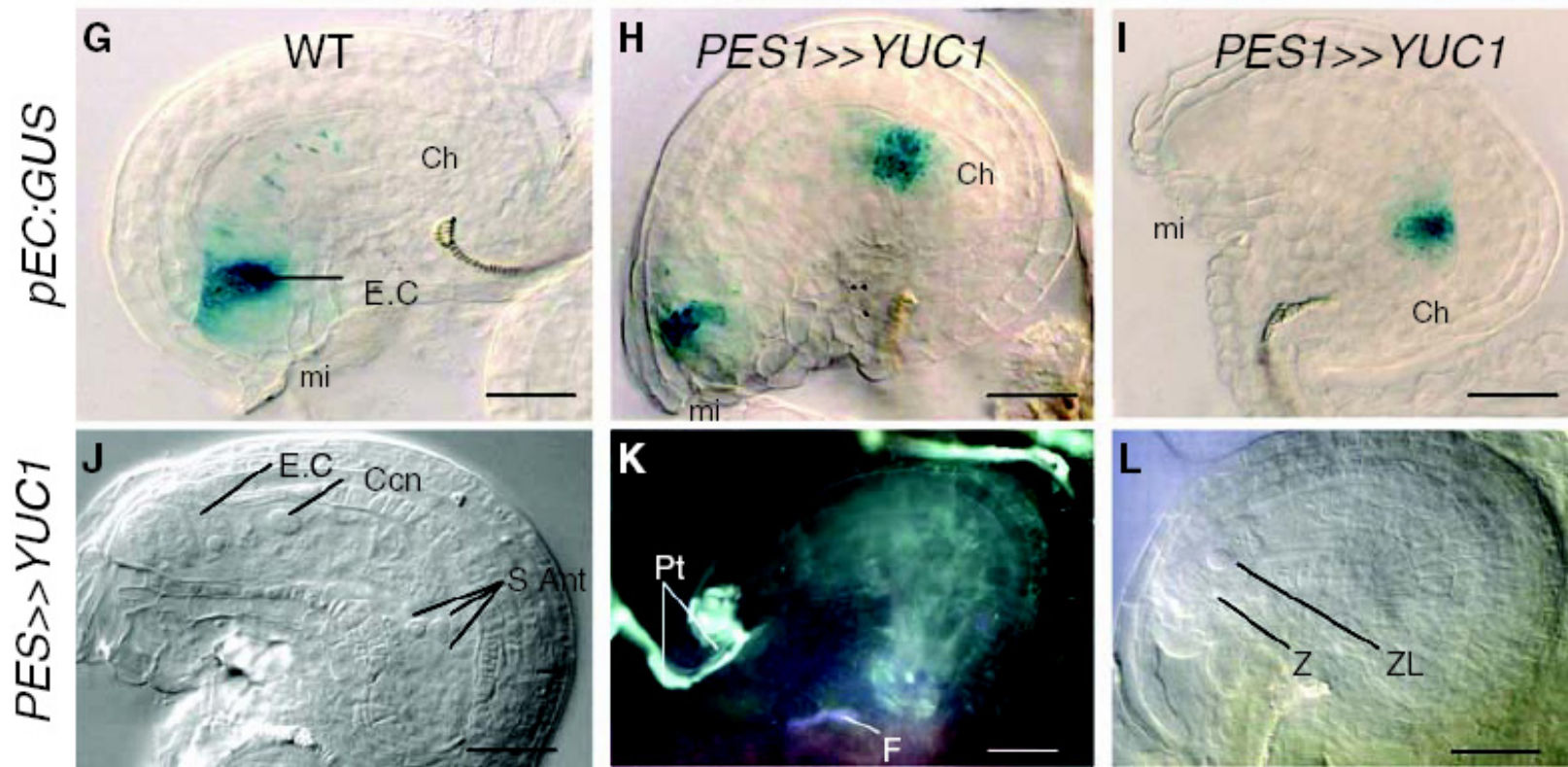
Pagnussat et al., *Science* (2009)

# Female Gametophyte Patterning



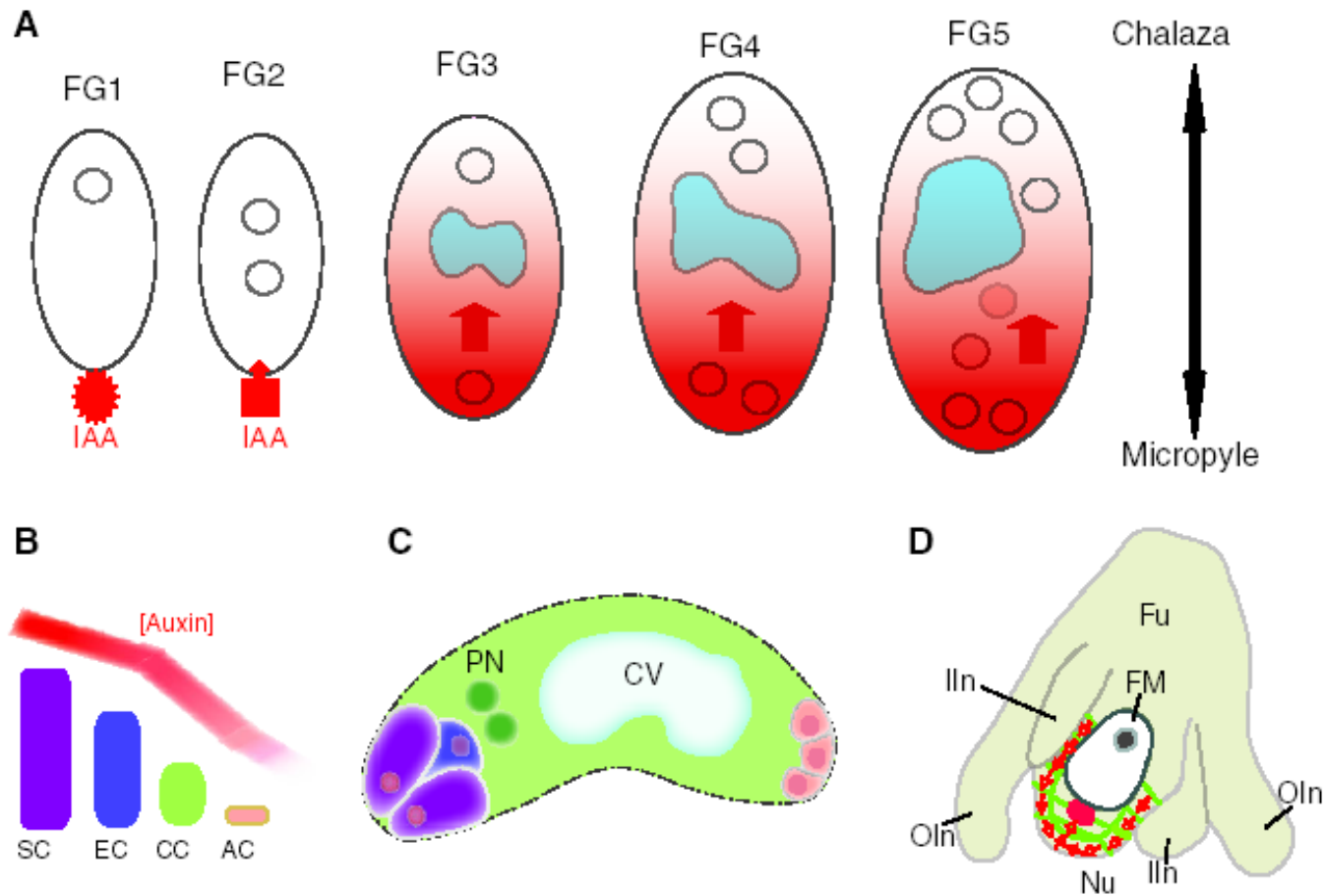
Pagnussat et al., *Science* (2009)

# Female Gametophyte Patterning



Pagnussat et al., *Science* (2009)

# Female Gametophyte Patterning

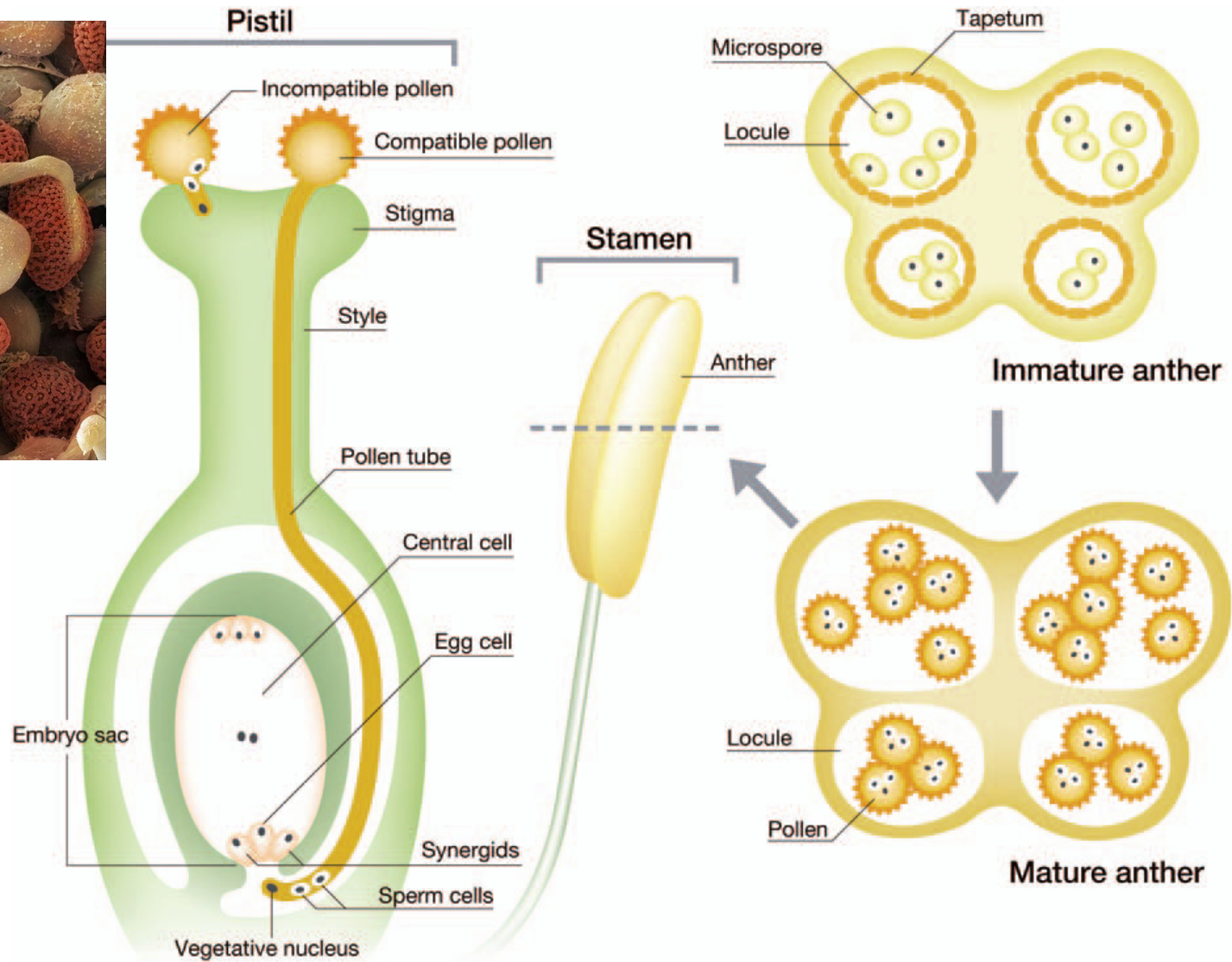


Sundaressan and Alandete-Saez, *Development* (2010)

# Outline

- Sexual and asexual plant reproduction
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  - Female gametophyte patterning
- Pollen tube growth, guidance and fertilization

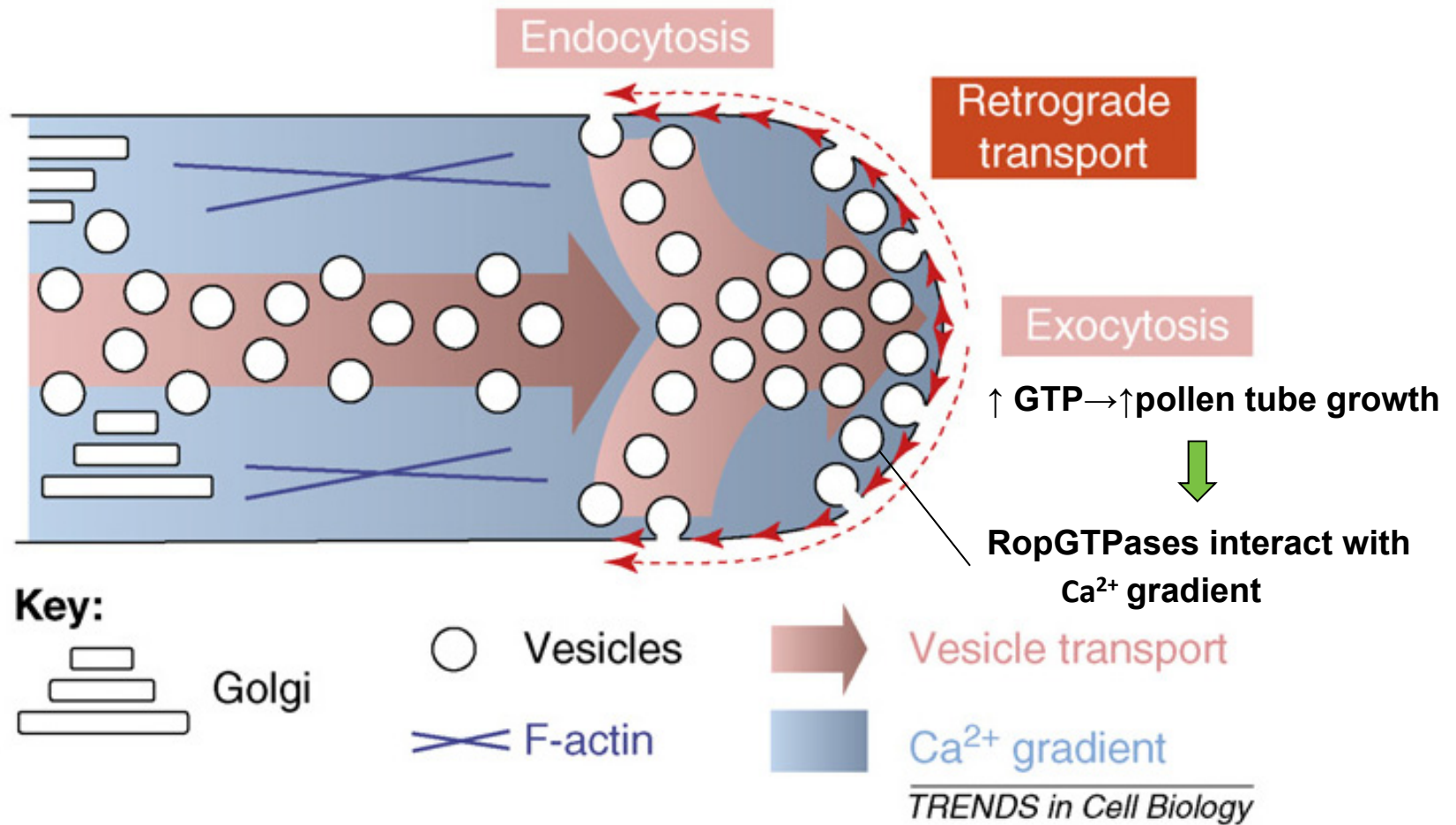
# Pollination and Fertilization



Suzuki, *Plant and Cell Physiol* (2009)



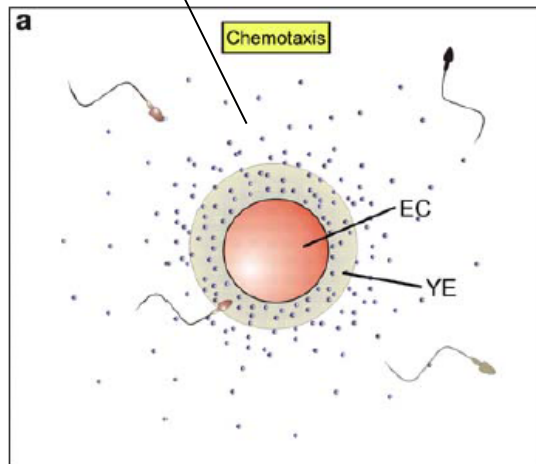
# Pollen Tube Growth



Kost., *Trends in Plant Science* (2008)

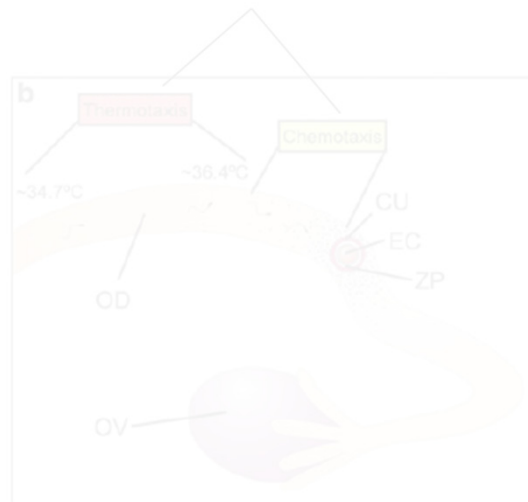
# Chemotaxis and Fertilization

## Chemotaxis



sea urchin

## Chemo- and Thermotaxis



mammals

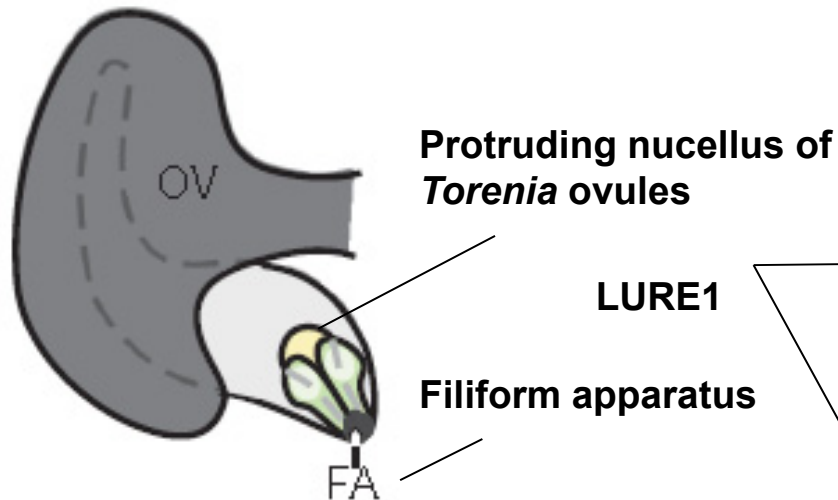
## Chemotaxis



plants

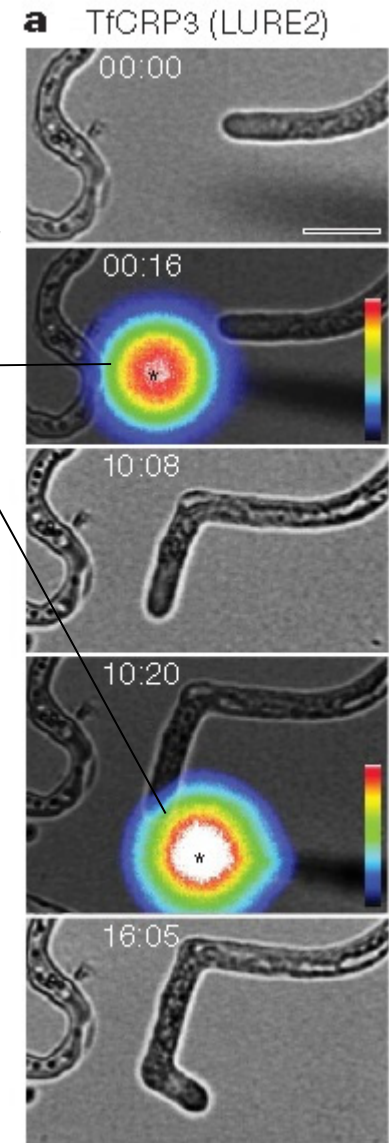
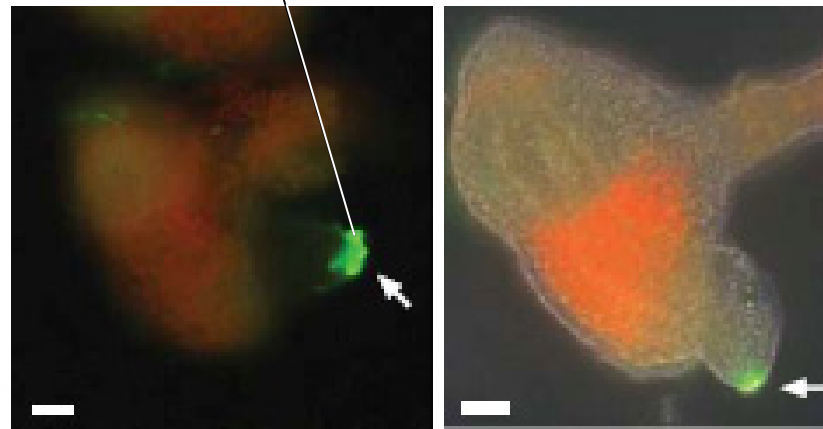
Marton and Dresselhaus., *Plant Sex Reprod* (2007)

# Pollen Tube Guidance



LURE1 and LURE2 (CRPs) → RLKs → pollen tube and synergid behavior

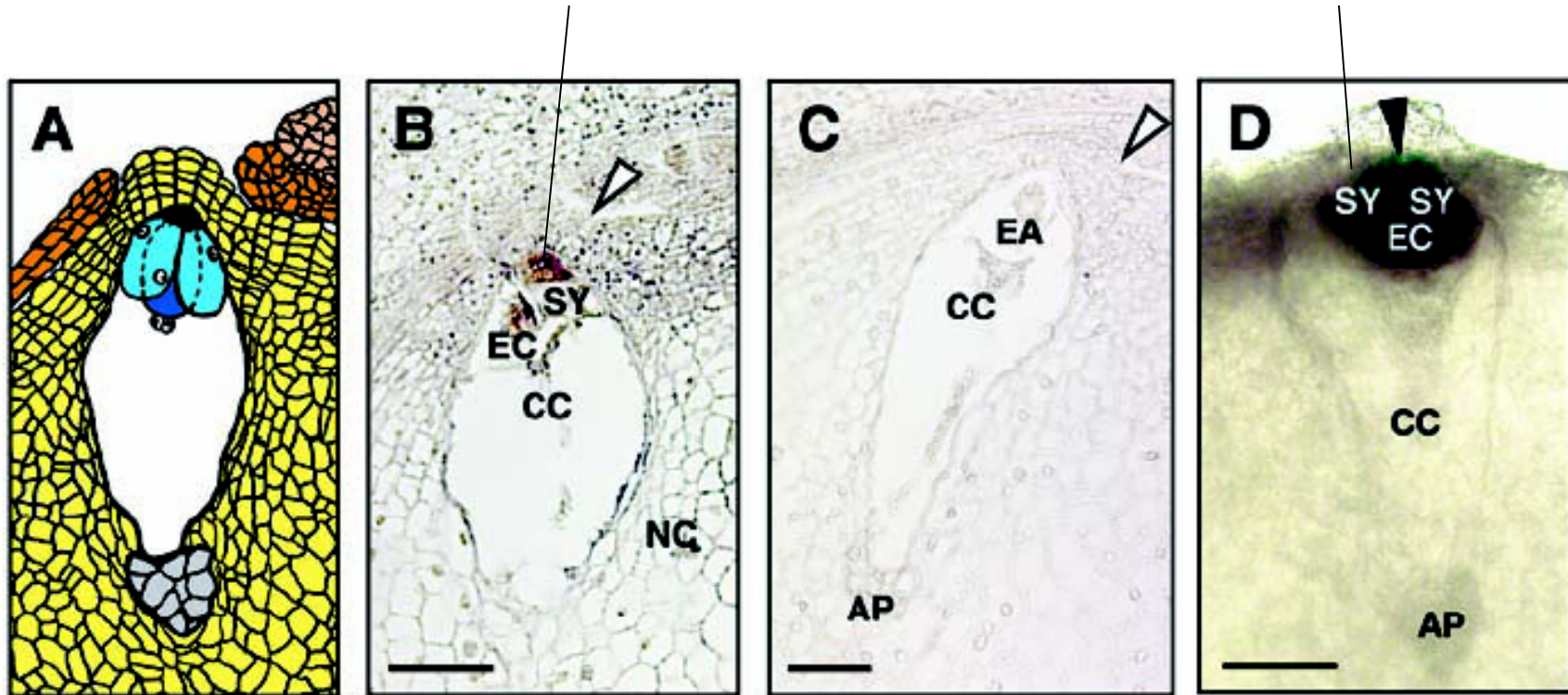
Anti-TfCRP3



# Pollen Tube Guidance

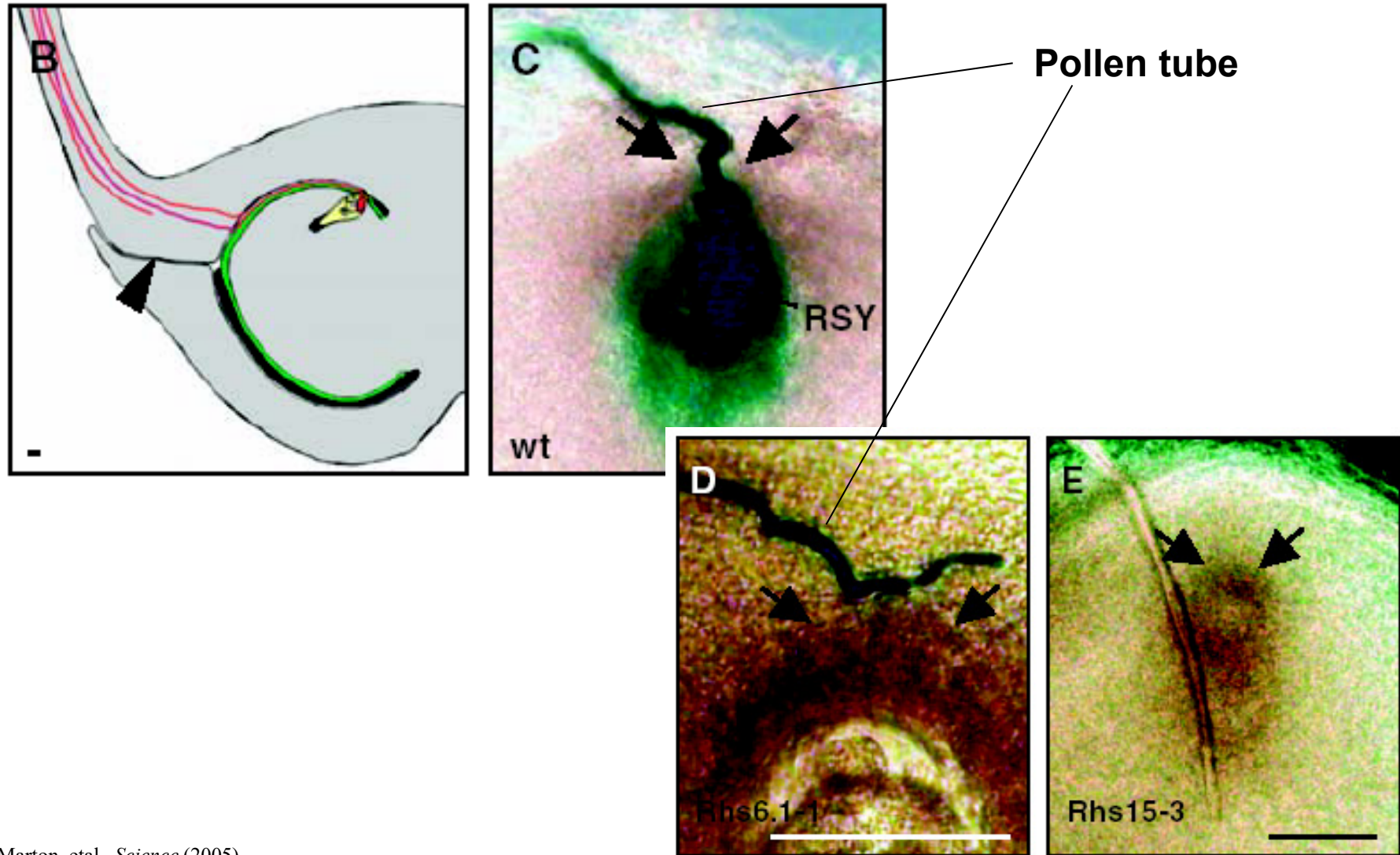
*Zm EGG APARATUS1* mRNA

*ProZmEA1:GUS*



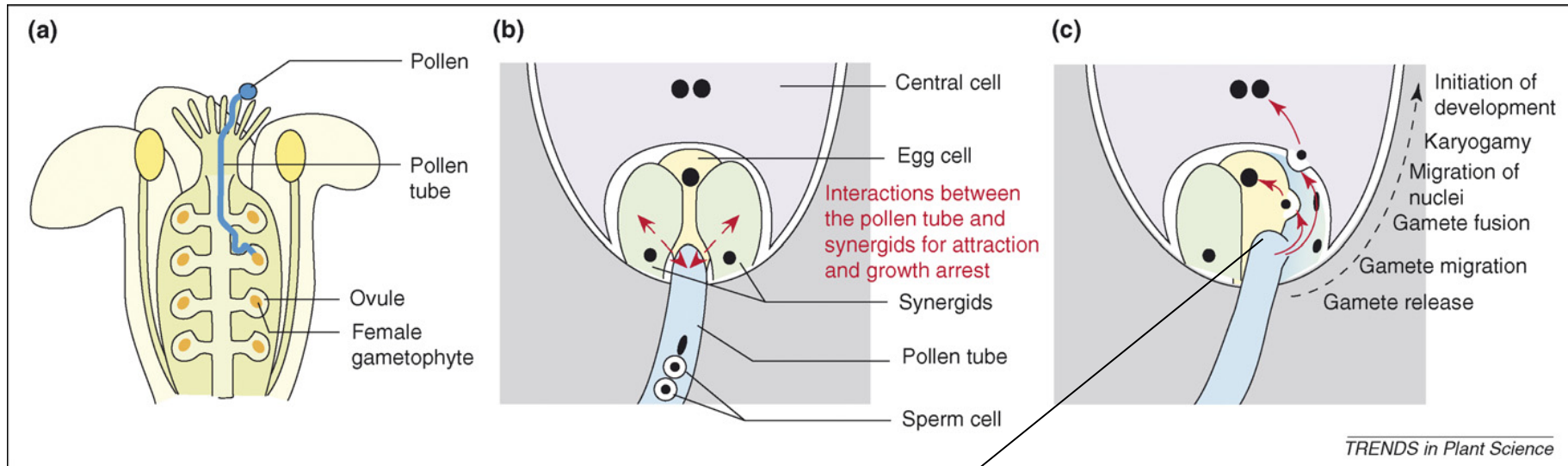
Marton et al., *Science* (2005)

# Pollen Tube Guidance



Marton et al., *Science* (2005)

# Fertilization

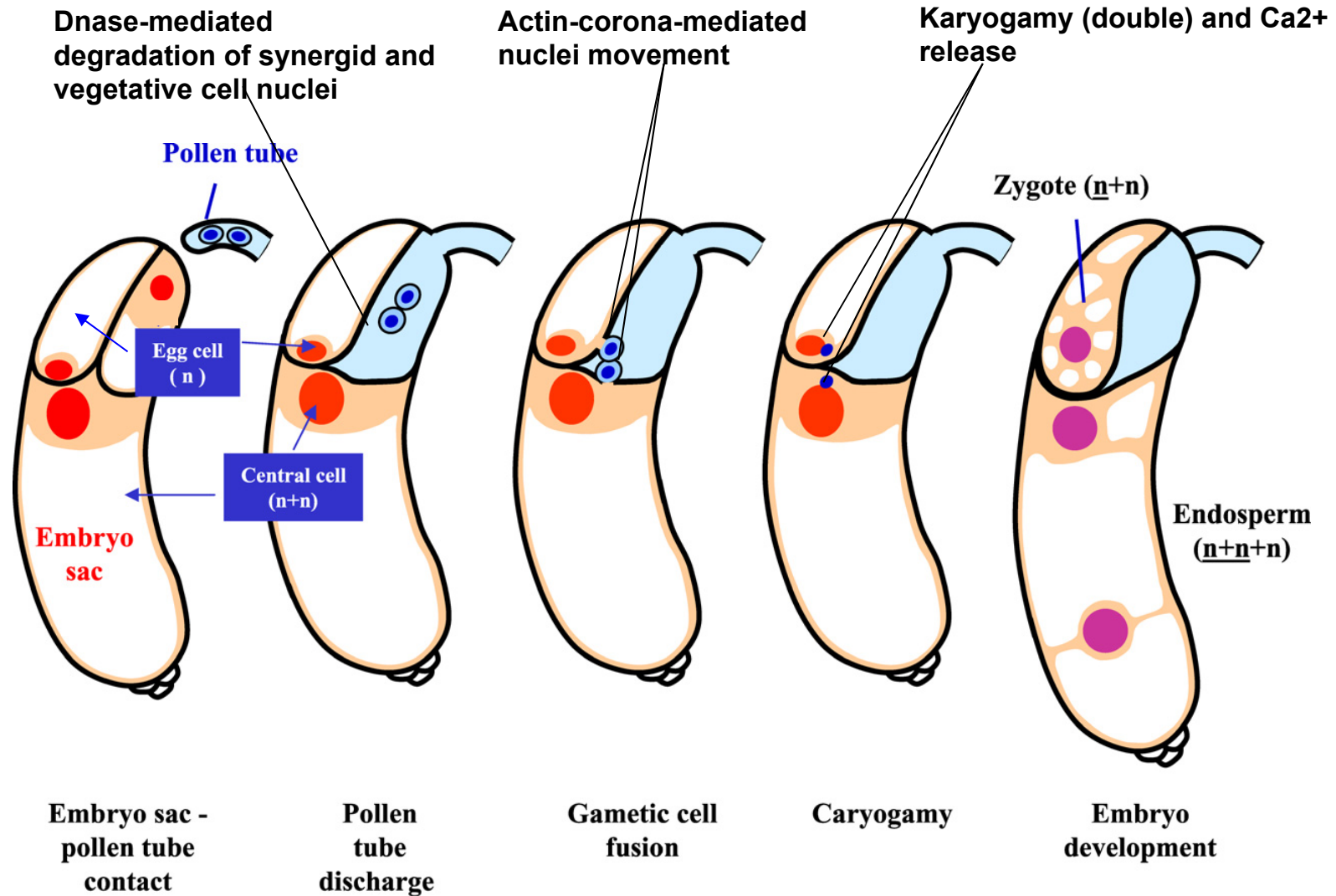


## Receptive synergid

- cytoskeleton reorganization
- Ca<sup>2+</sup> accumulation
- Organelles and plasmamembrane degeneration

Berger et al., *Trends in Plant Science* (2008)

# Fertilization



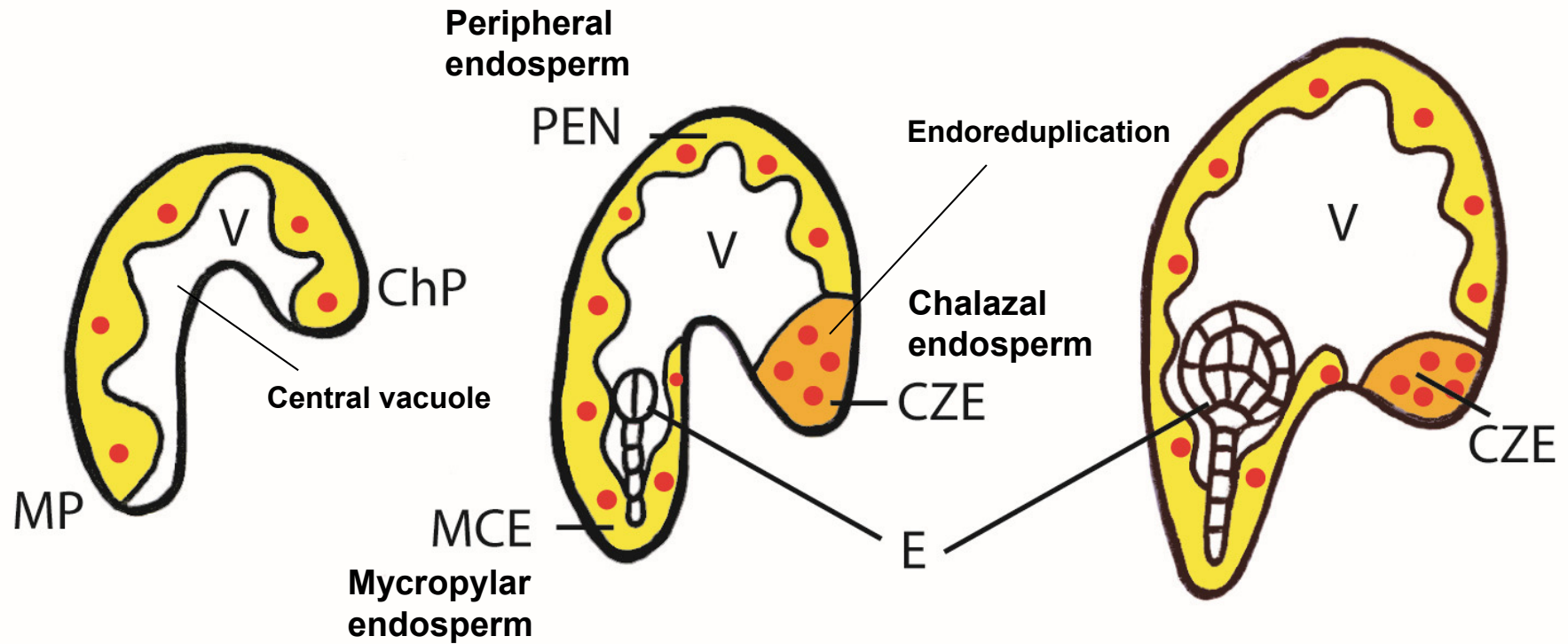
Dumas and Rogowsky., *C. R. Biologies* (2008)

# Outline

- Sexual and asexual plant reproduction
- Plant life cycle
- Initiation of flowering
- Determination of floral organ identity
- Microgametogenesis
- Megagametogenesis
  - Female gametophyte patterning
- Pollen tube growth, guidance and fertilization
- Endosperm and seed formation

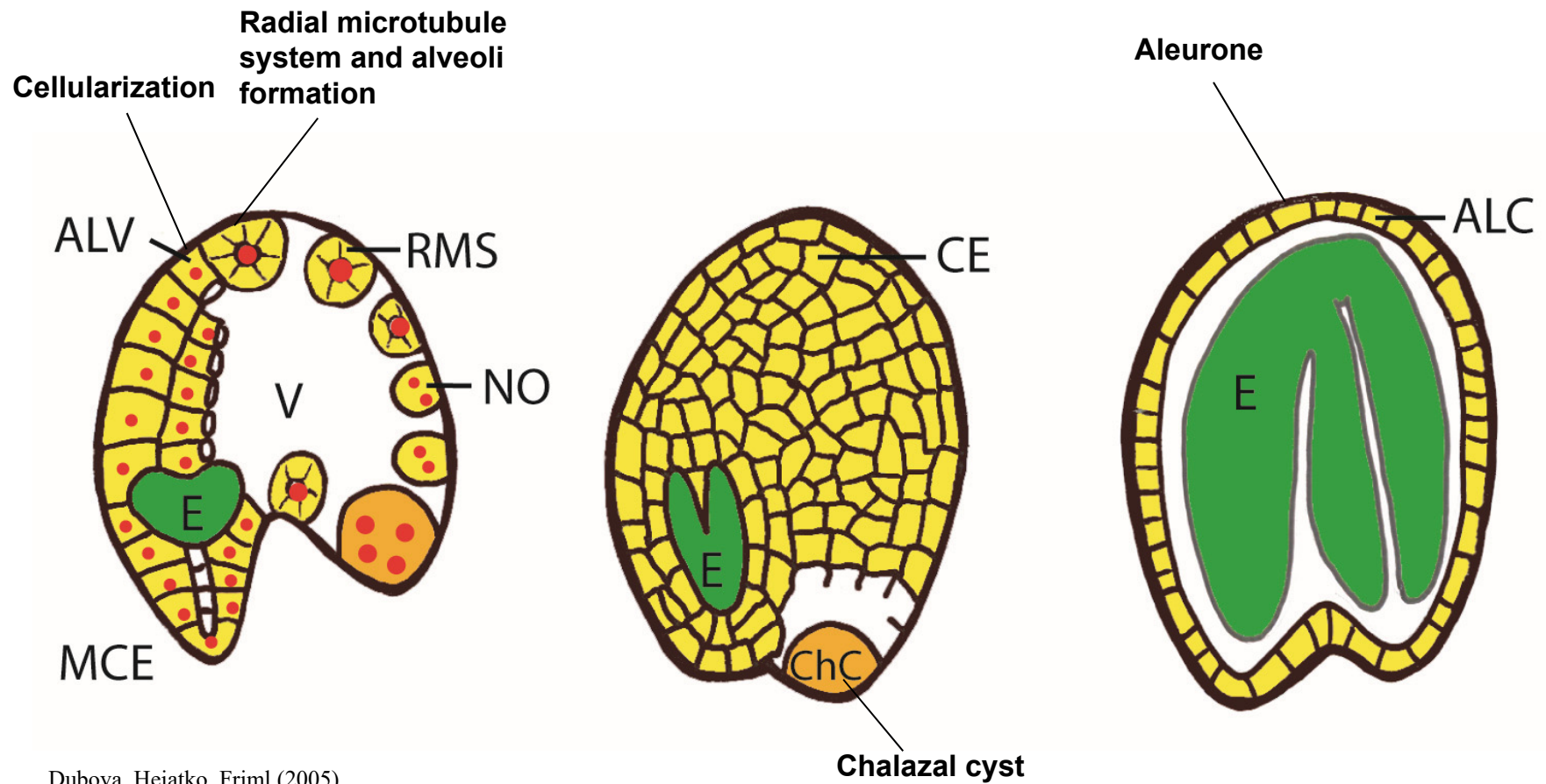


# Endosperm Formation



Dubova, Hejatko, Friml (2005)

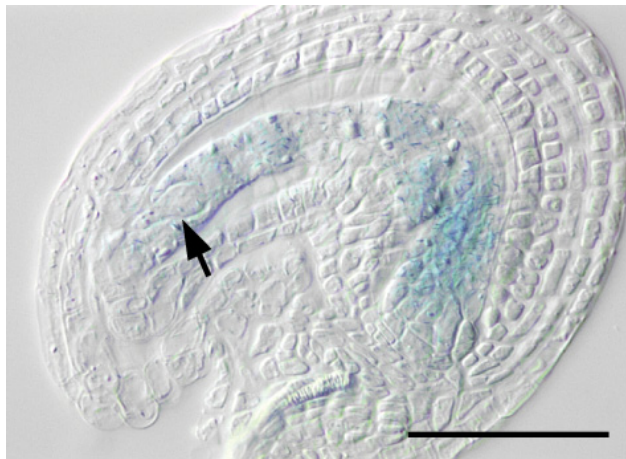
# Endosperm Formation



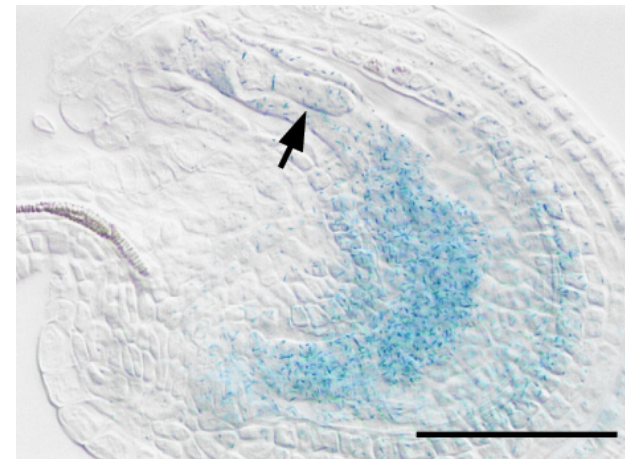
Dubova, Hejatko, Friml (2005)

# CKI1 Activity in Endosperm

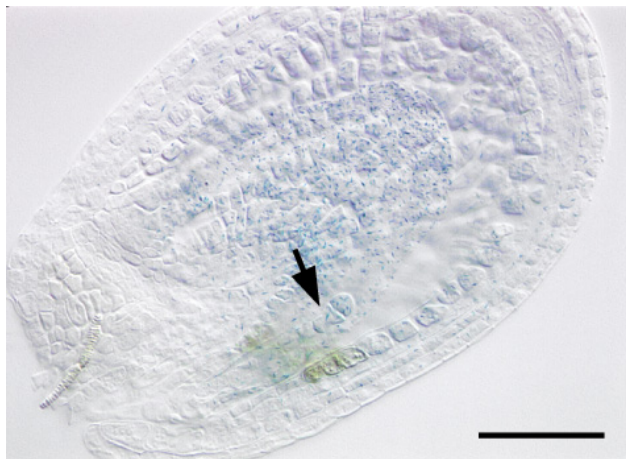
♀ wt x ♂ *CKI1prom::uidA*



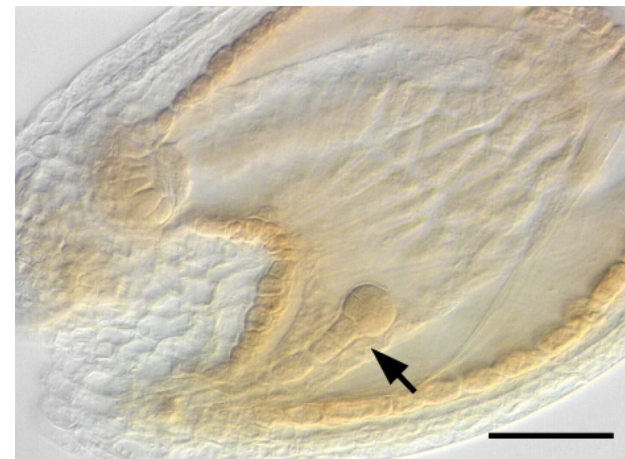
12 HAP



24 HAP



48 HAP



72 HAP

Hejátko et al., *Mol Genet Genomics* (2003)

# Key Concepts

- In plants, **gametophytic** and **sporophytic portion** (“generation”) of the life cycle could be distinguished
- **Initiation of flowering** integrates **multiple inputs** (light quality/photoperiod, vernalization, autonomous and hormonal signals)
- **Several developmental switches** resulting into **acquisition of floral meristem** and **floral organ identity** take place during onset of flowering. These **switches** are under control of **specific genes** that mutually interact
- In angiosperms, the gametophyte is reduced to **three-celled pollen tube** (male gametophyte) and mostly **seven-celled female gametophyte** (embryo sac). **Auxin gradient** determines **acquisition of cell identity** during embryo sac development
- Pollen tube growth is complex process associated with large amount of cell material deposition. **Pollen tube guidance is mediated by specific molecules** allowing **synergid-cell mediated chemotaxis**.
- **Expression of maternal** and **paternal genes** is **tightly regulated** during seed development.

# Discussion