CEITEC

Central European Institute of Technology

BRNO | CZECH REPUBLIC

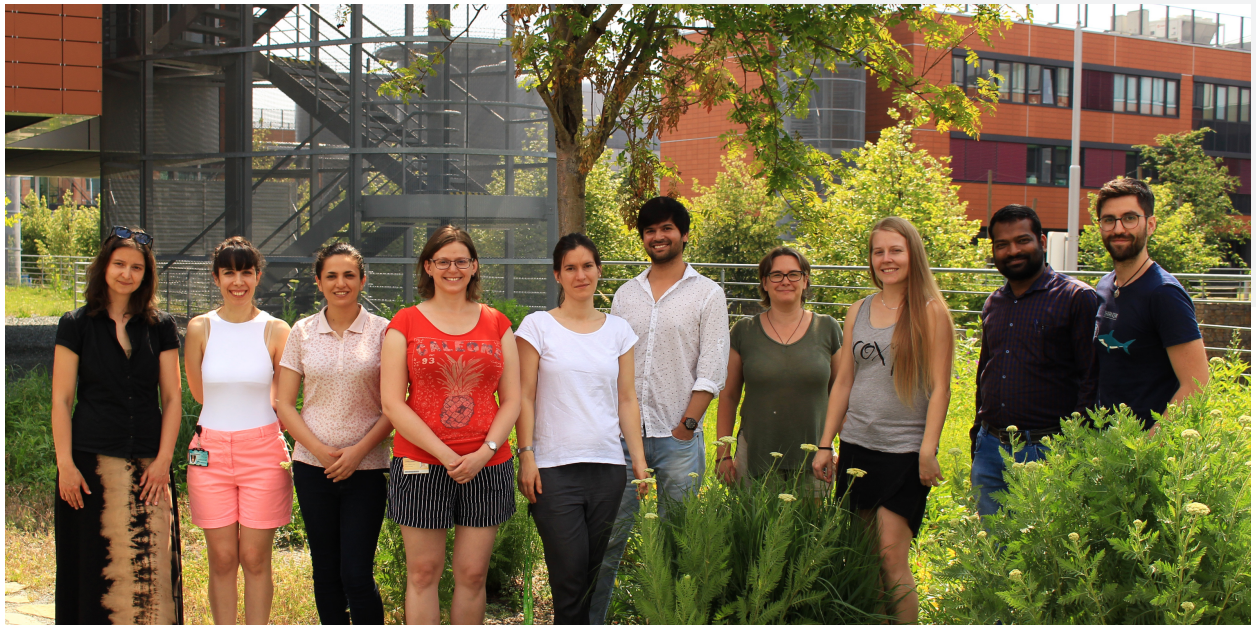
MUNI

Helene Robert Boisivon

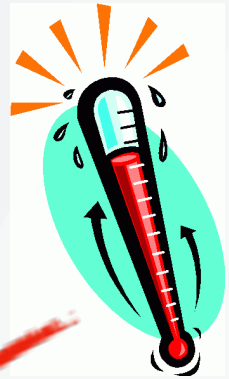
CORE019 Pokroky a výzvy v moderní biologii
Such a beautiful fruit!

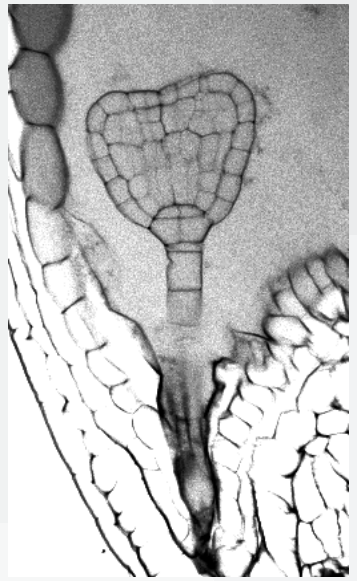
First, who are we?

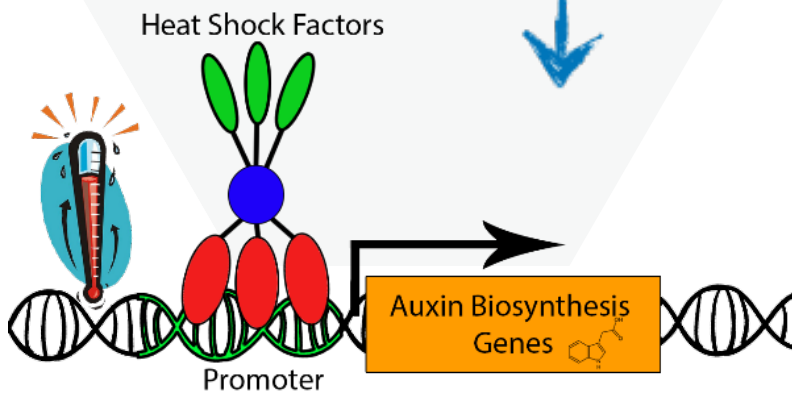
- Plant Biologists
- CEITEC Masaryk University, Brno
- Since 2016
- Team of 12 members:
- Seed development in *A. thaliana* and rapeseed
- Effects of high temperatures



Our main research interests







Basic facts from Food and Agriculture Organization (FAO)



“Plants are the primary basis for human sustenance, used directly for food, clothing and shelter…”

“Seeds and Plant Genetic Resources: A basis for life”

Conservation and Diversity of seed stocks and varieties

Sustainability, Quality of seeds

Food security, Crop productivity



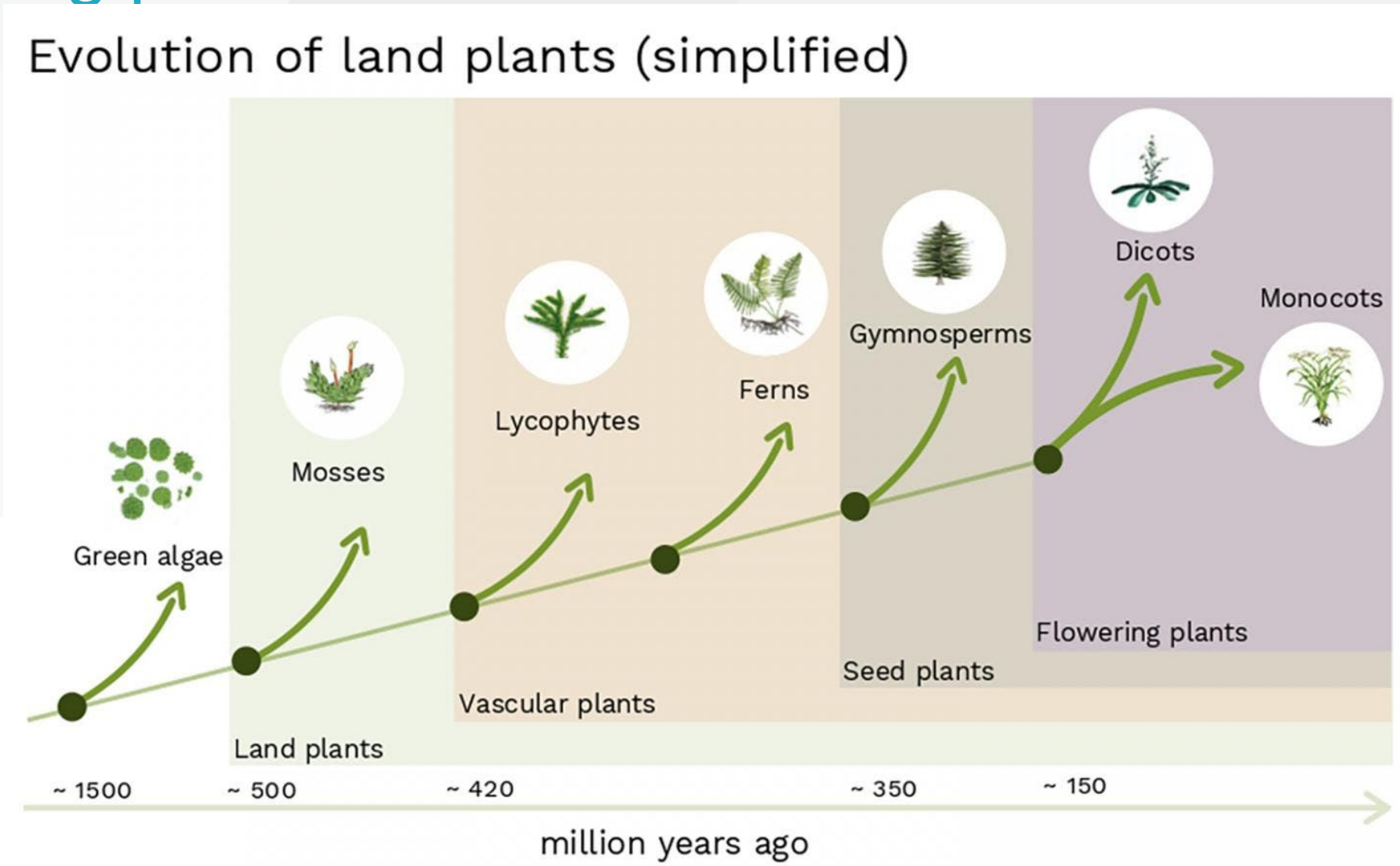

The importance of seeds in our daily life

Who are you?

Go to https://www.menti.com/

Voting code 7351 1510

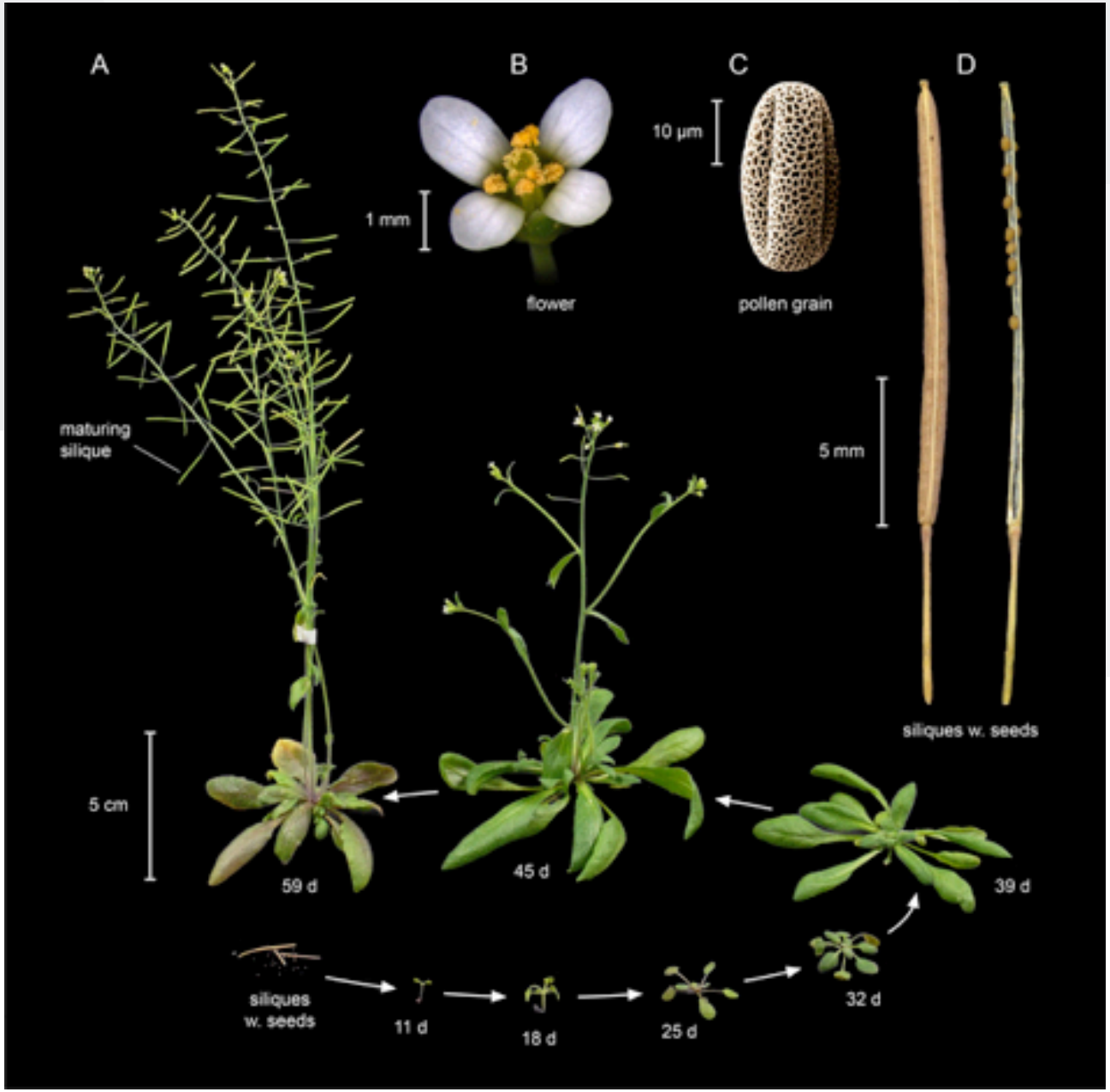
Flowering plants



Plant life cycle

- Seed germination
- Vegetative growth
- Flowering
- Fruit and seed development

Arabidopsis thaliana



Induction of flowering

Environmental cues:

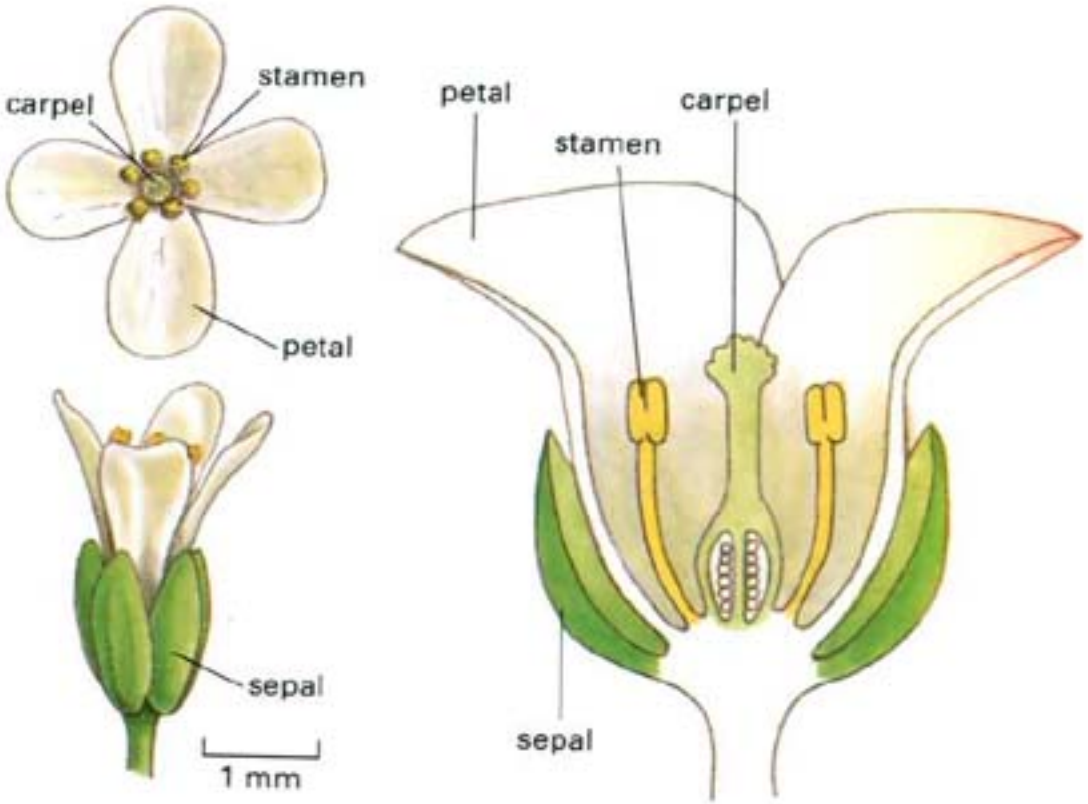
- Temperatures
- Day length

Kramer, eLife, 2015

The flower

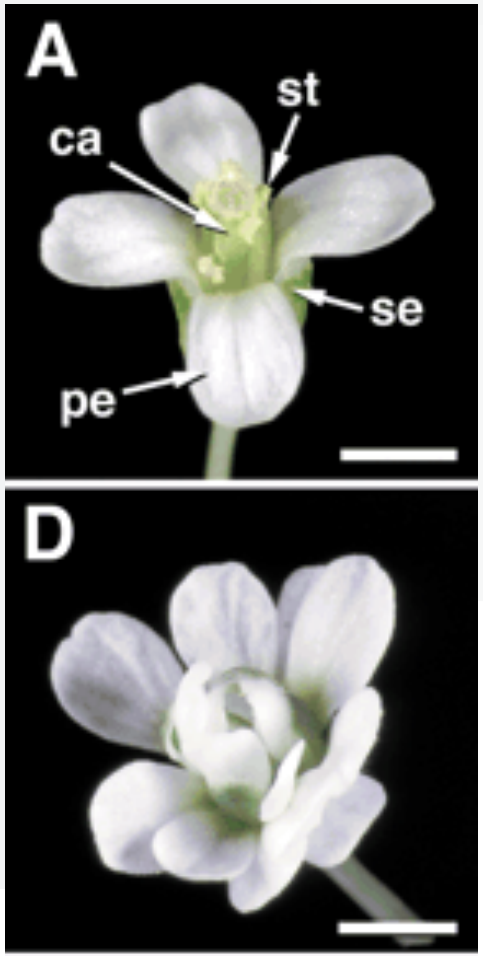
Most plants have whorls of floral organs arranged in concentric circles

- The outer two whorls (**sepal** and **petal**) form the **perianth**, the non-reproductive structures.
- The inner two whorls (**stamen** and **carpel**) represent the male and female **reproductive organs**.

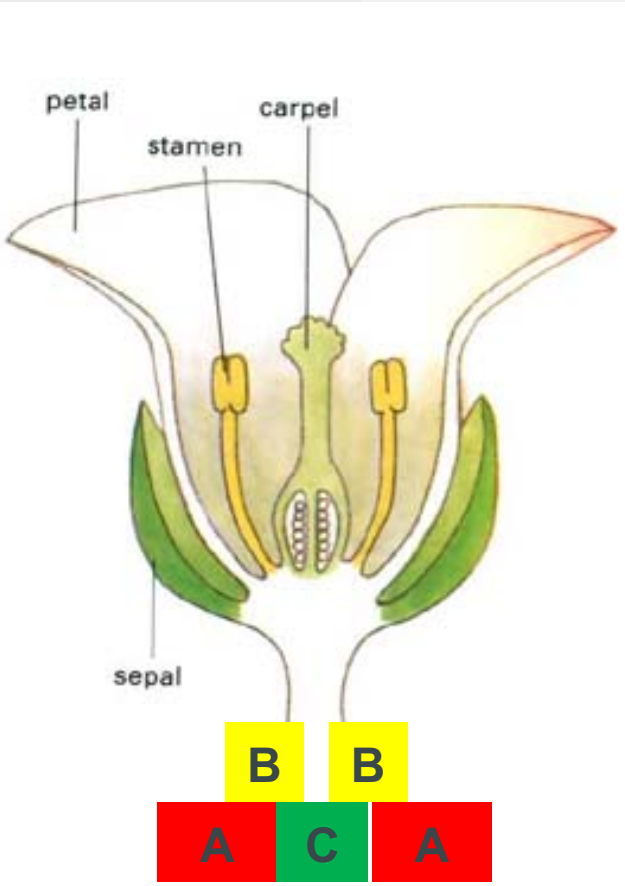


The flower

In the classic ABC model, key transcription factors promote identity of floral organs

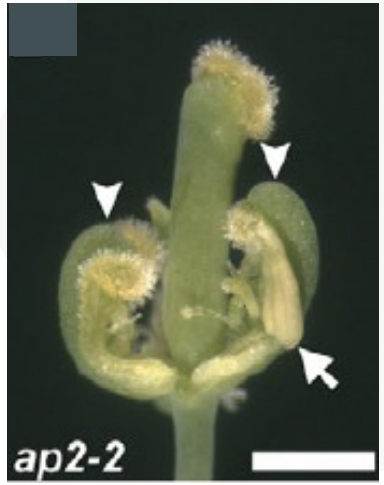


agamous
C gene



Whorl 1=sepal, **A** genes
Whorl 2=petal, **A**+**B** genes
Whorl 3=stamen, **B**+**C** genes
Whorl 4=carpel, **C** genes

pistillata
B gene



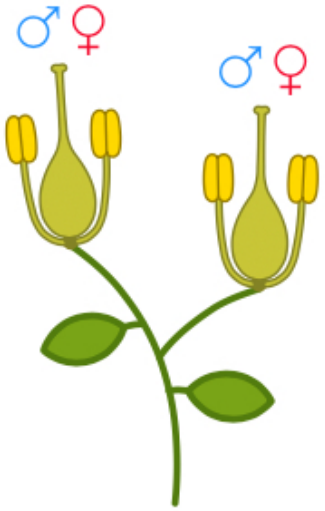
apetala2
A gene

Dornelas, M. C. and Dornelas, O. (2005). From leaf to flower: revisiting Goethe's concepts on the ¨metamorphosis¨ of plants. Braz. J. Plant Physiol. 17: 335-344 CC-BY.
Parcy, F., Bomblies, K., and Weigel, D. (2002). Interaction of LEAFY, AGAMOUS and TERMINAL FLOWER1 in maintaining floral meristem identity in Arabidopsis. Development 129: 2519–2527.
Bowman, J.L., Smyth, D.R., and Meyerowitz, E.M. (1991). Genetic interactions among floral homeotic genes of Arabidopsis. Development 112: 1–20
Krogan, N.T., Hogan, K., and Long, J.A. (2012). APETALA2 negatively regulates multiple floral organ identity genes in Arabidopsis by recruiting the co-repressor TOPLESS and the histone deacetylase HDA19. Development 139: 4180–4190

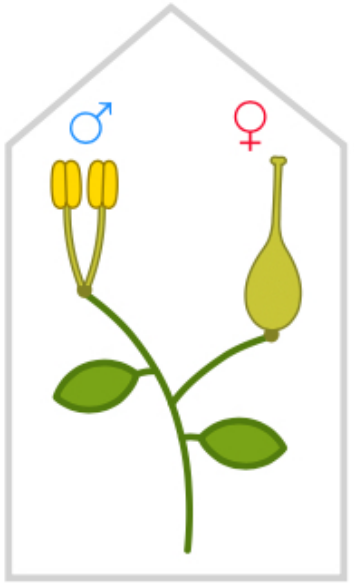
Flowers are diverse in shape and colour

Flowering plants are defined by their flowers

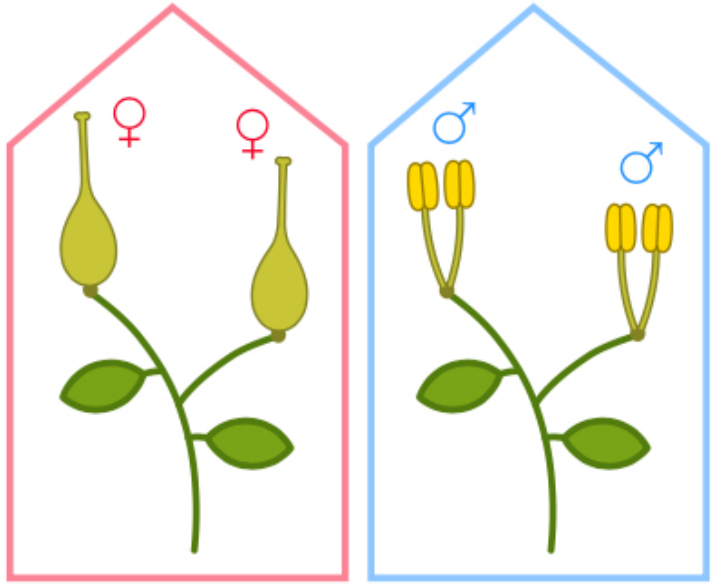
Maize



plant with hermaphrodite flowers



monoecious plant

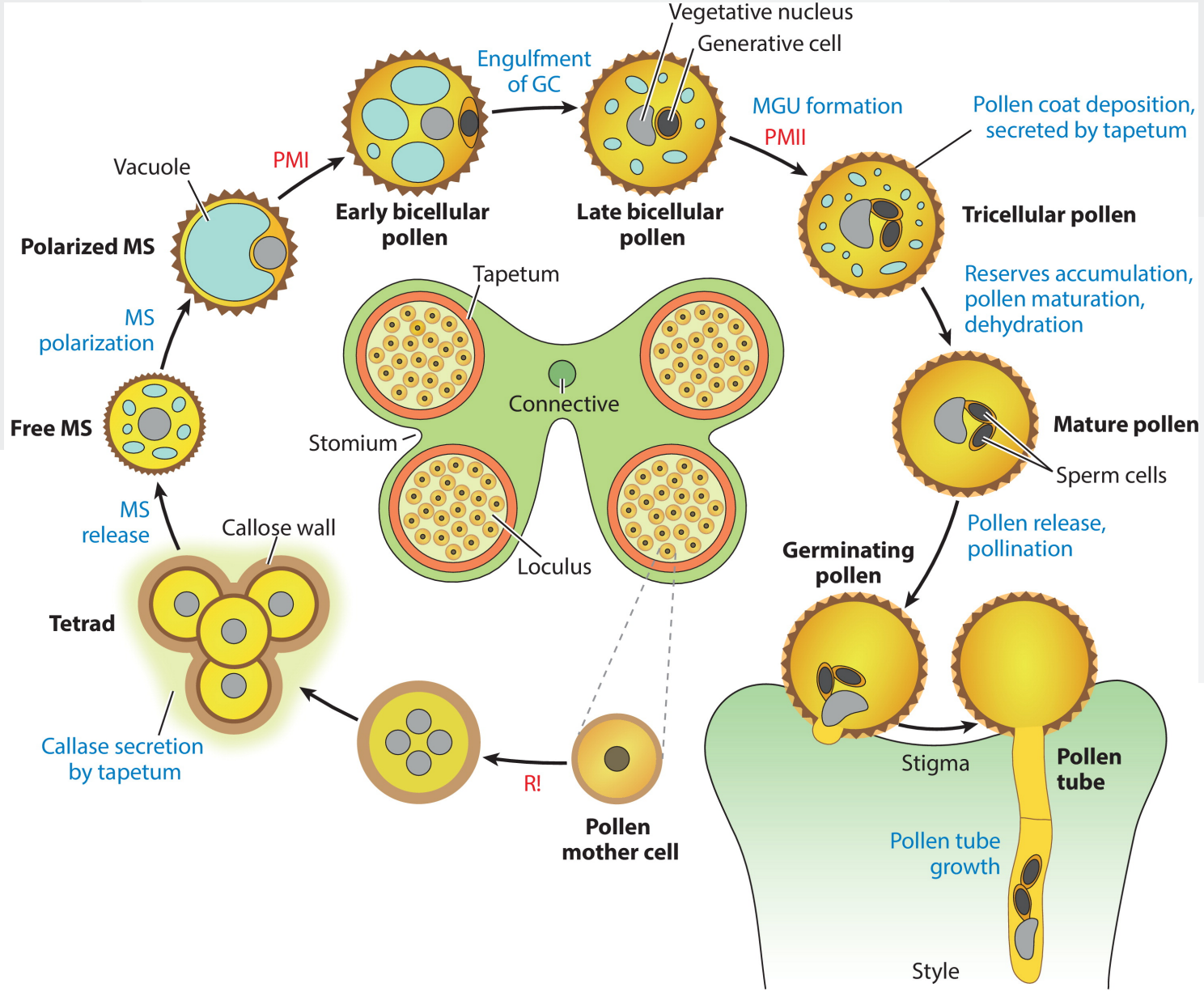


dioecious plant

Kiwi

Reproductive organs: male

The **androecium** (from the Greek “ andros oikia”, the man’s house) is composed of the **stamens**.
The stamens are made of a stalk, the filament, and the anther at its top. The anthers are containing the pollen.
The mature pollen grain contains **two sperm cells** and **one vegetative cell**.

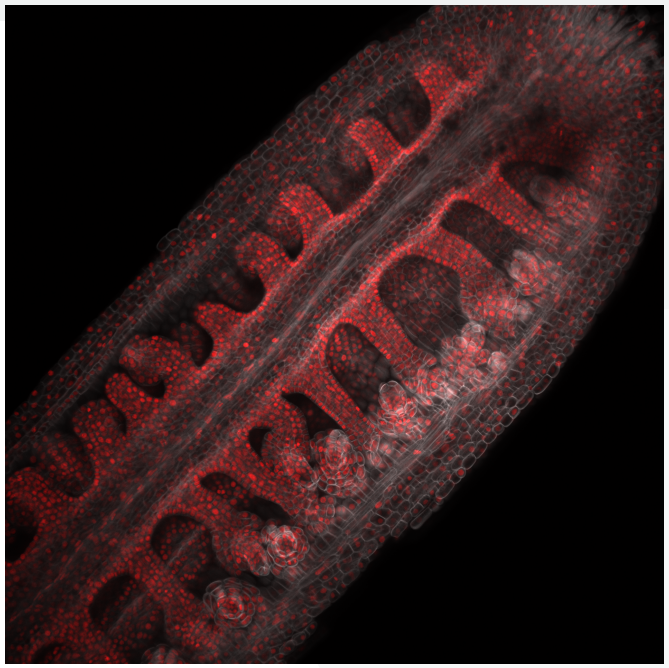


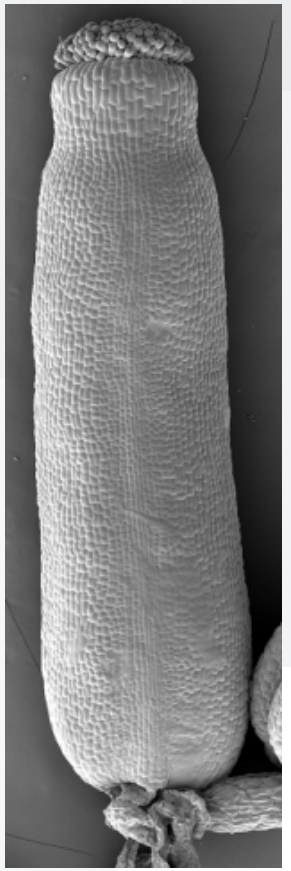
Hafidh S, Honys D. 2021
Annu. Rev. Plant Biol. 72:581–614

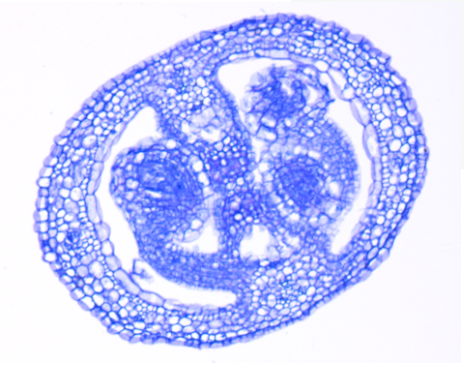
Reproductive organs: Female – The pistil

The **gynoecium** (from the Greek “gynaikos oikia”, the woman’s house) at the centre of the flower. It is also called **pistil**. It consists of three parts.

- At the top, there is the stigma where the pollen grains land to start the pollination of the female flower.
- Then there is the style, a stalk supporting the stigma through which the pollen tubes are growing towards the ovules.
- At the bottom, there is the ovary made of one or more (fused) carpels. The carpel forms a hollow structure containing the ovules.

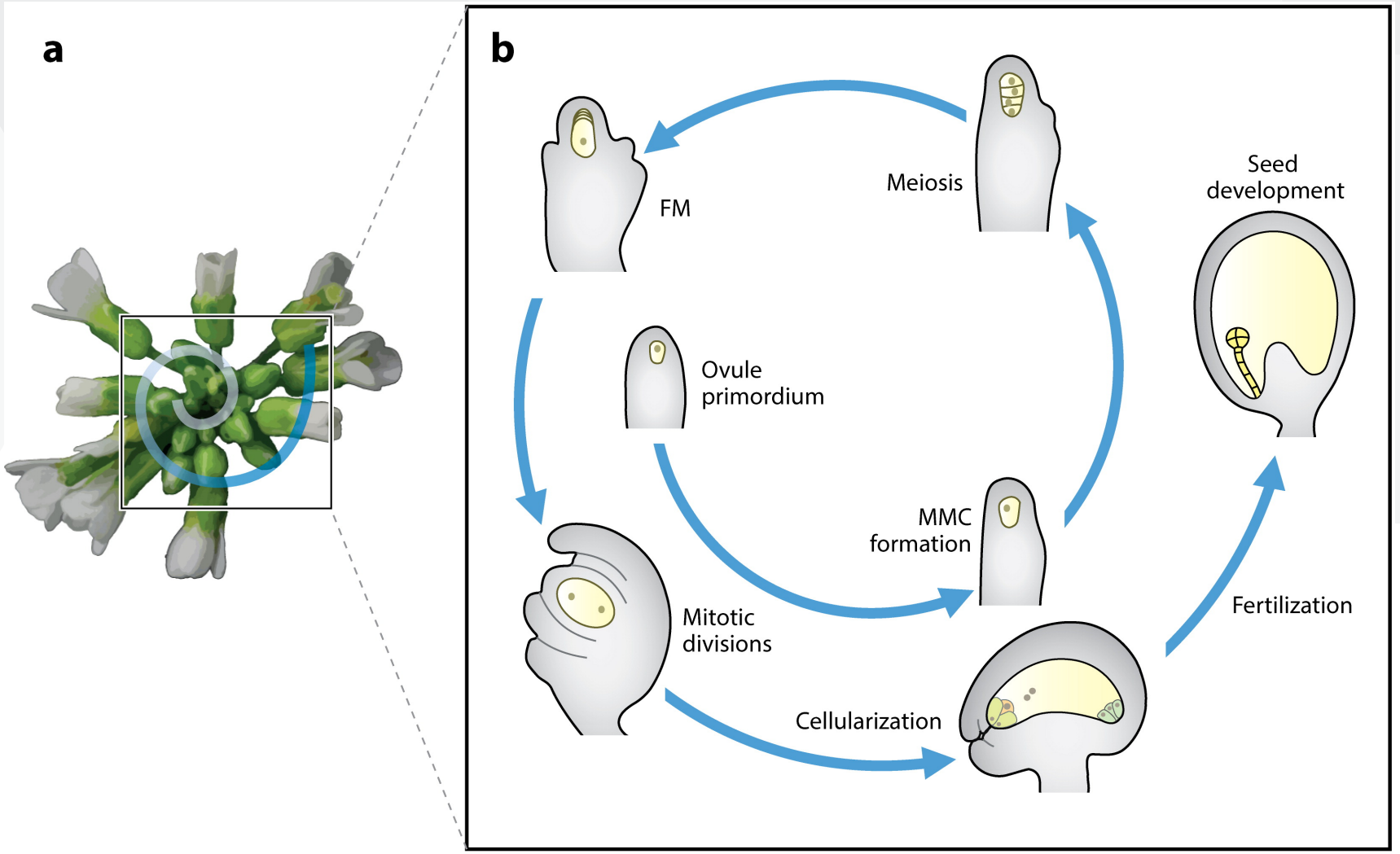






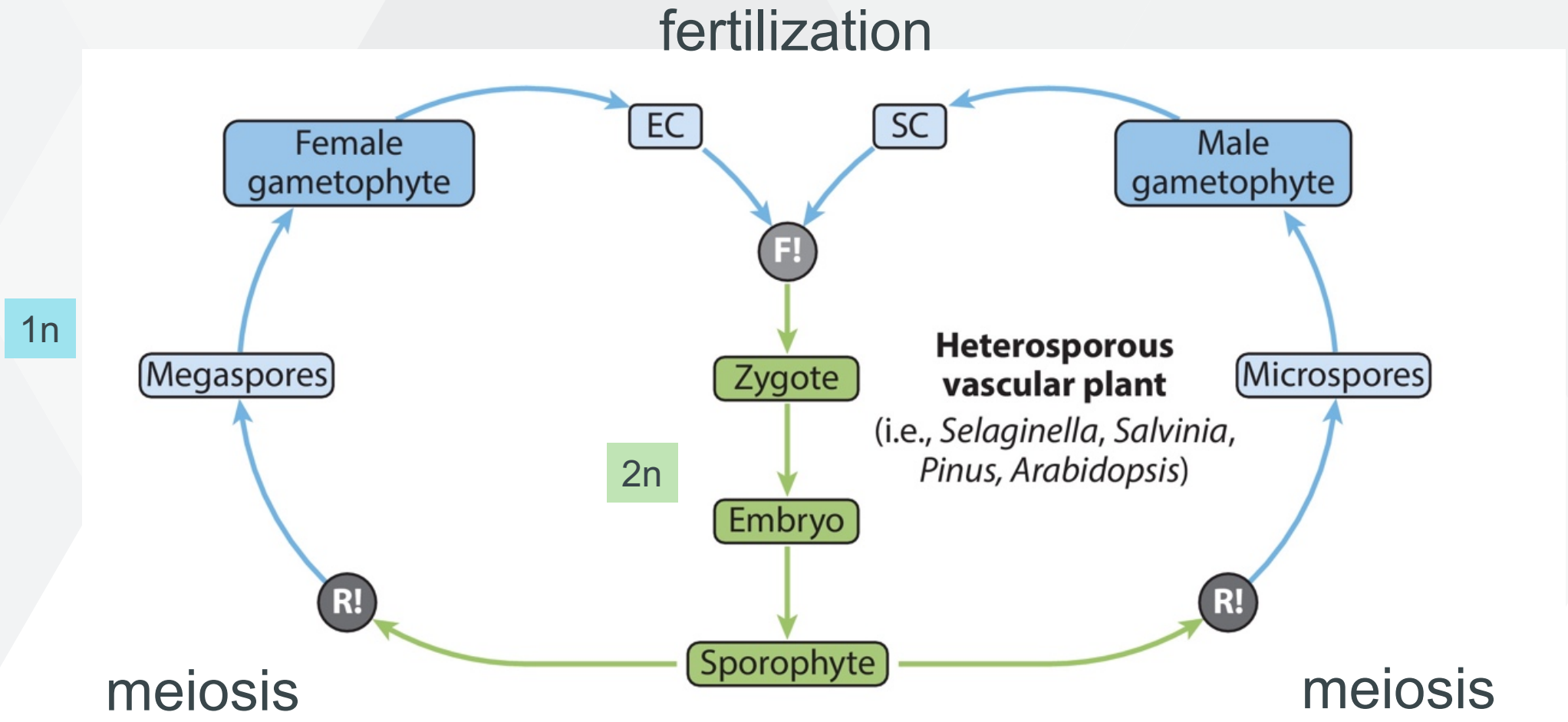
Reproductive organs: Female – The ovule

The ovules carry the female gametophyte, produced by meiosis.



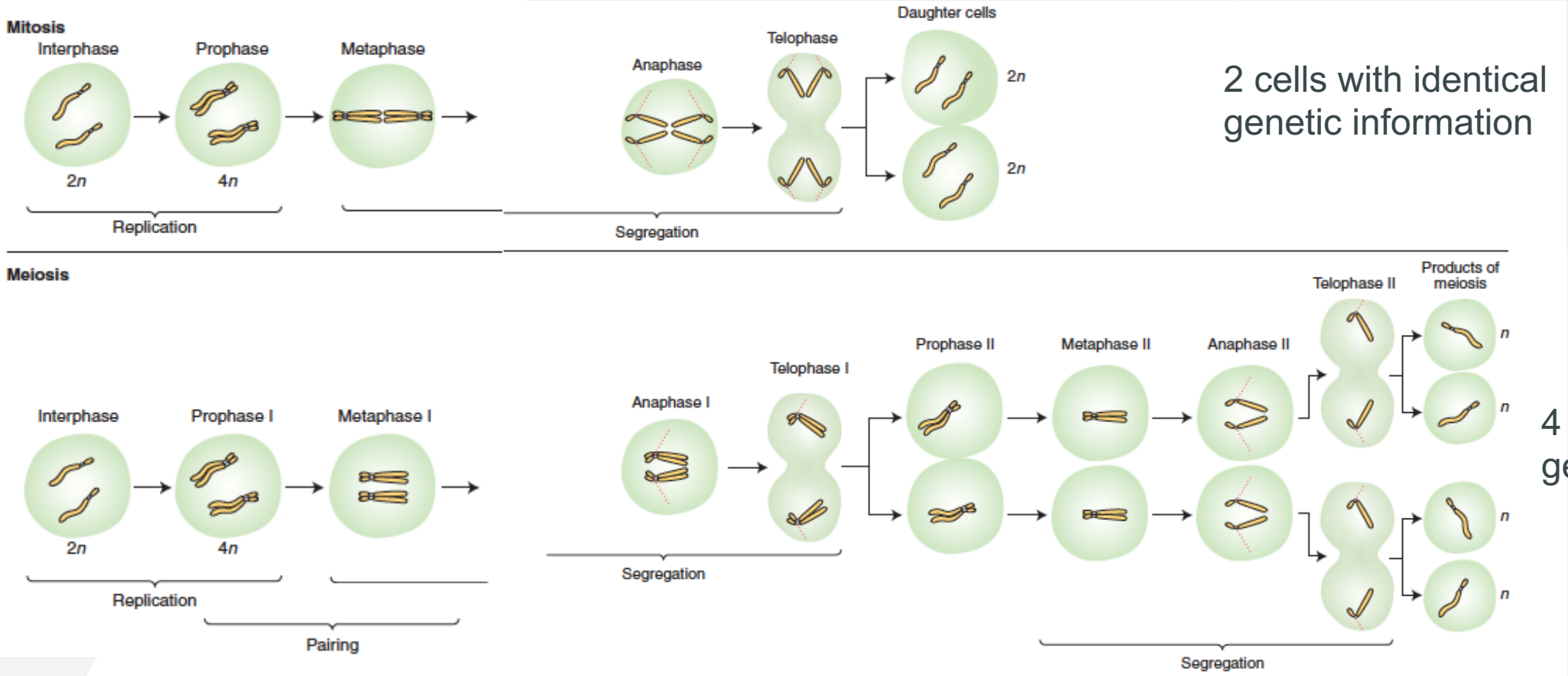
Hater F, et al. 2020.
Annu. Rev. Plant Biol. 71:517–46

Haploid – Diploid cycle



Meiosis

Cellular division - Mitosis

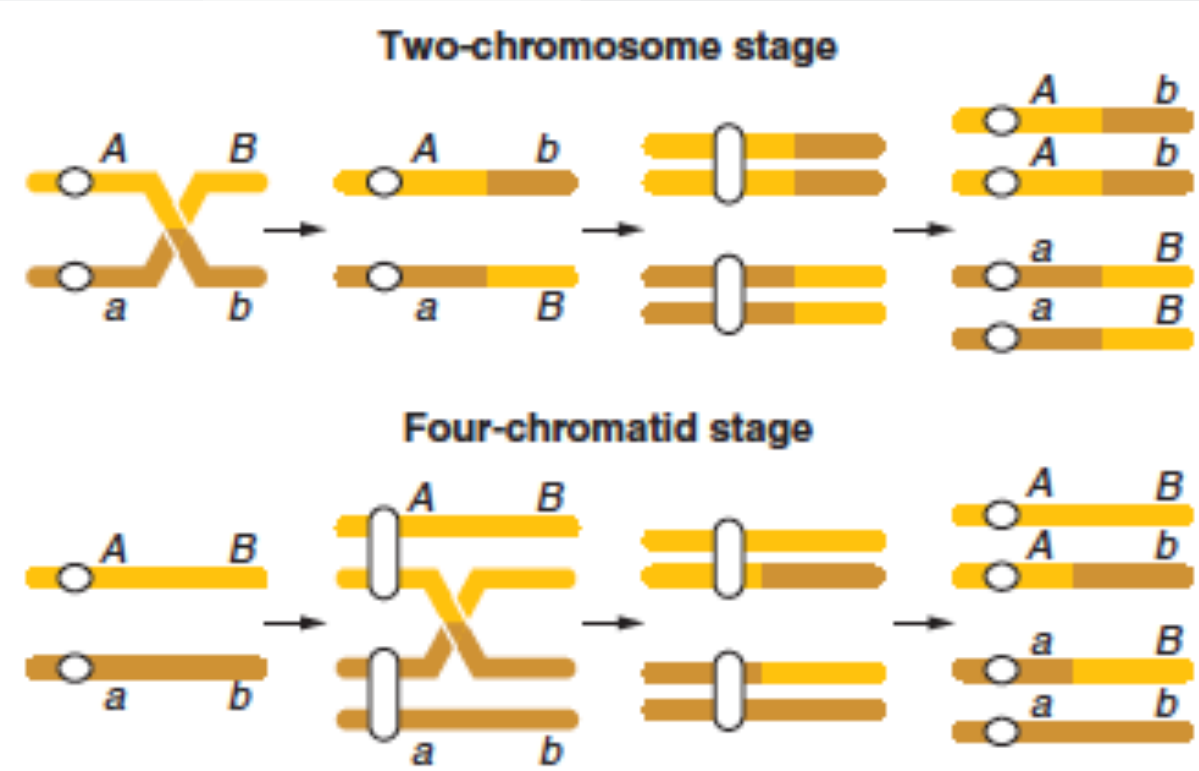


2 cells with identical genetic information

4 cells with different genetic information

Reductive cellular division - Meiosis

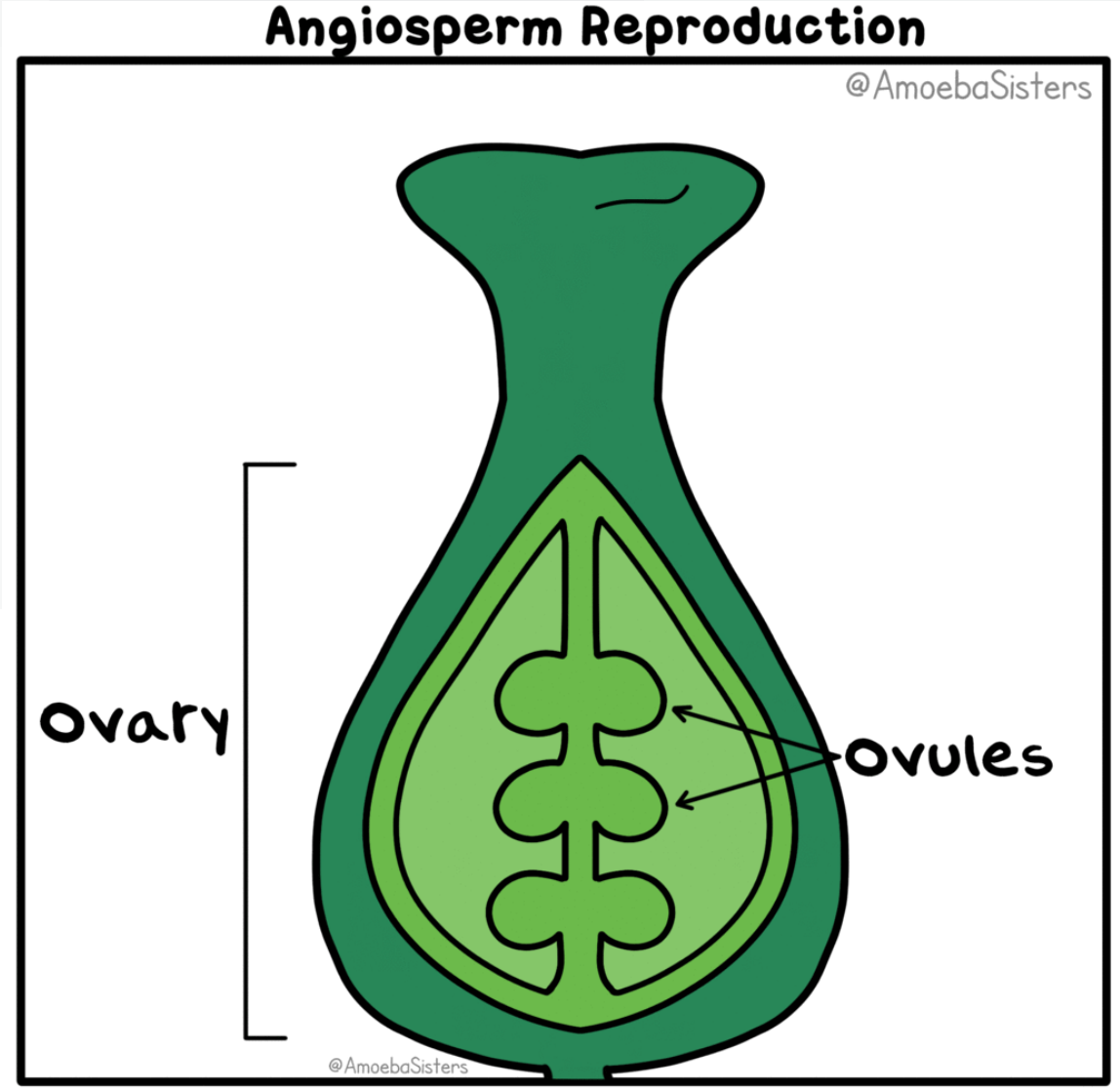
Meiosis – recombination and cross-over



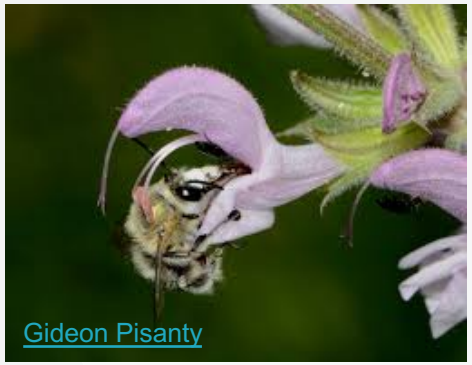
Exchange of DNA between sister chromatids results in genetic information reshuffling between the homologous chromosome

Source of variations for evolution of traits

From flower to fruit: pollination and fertilization



Why floral structure matters



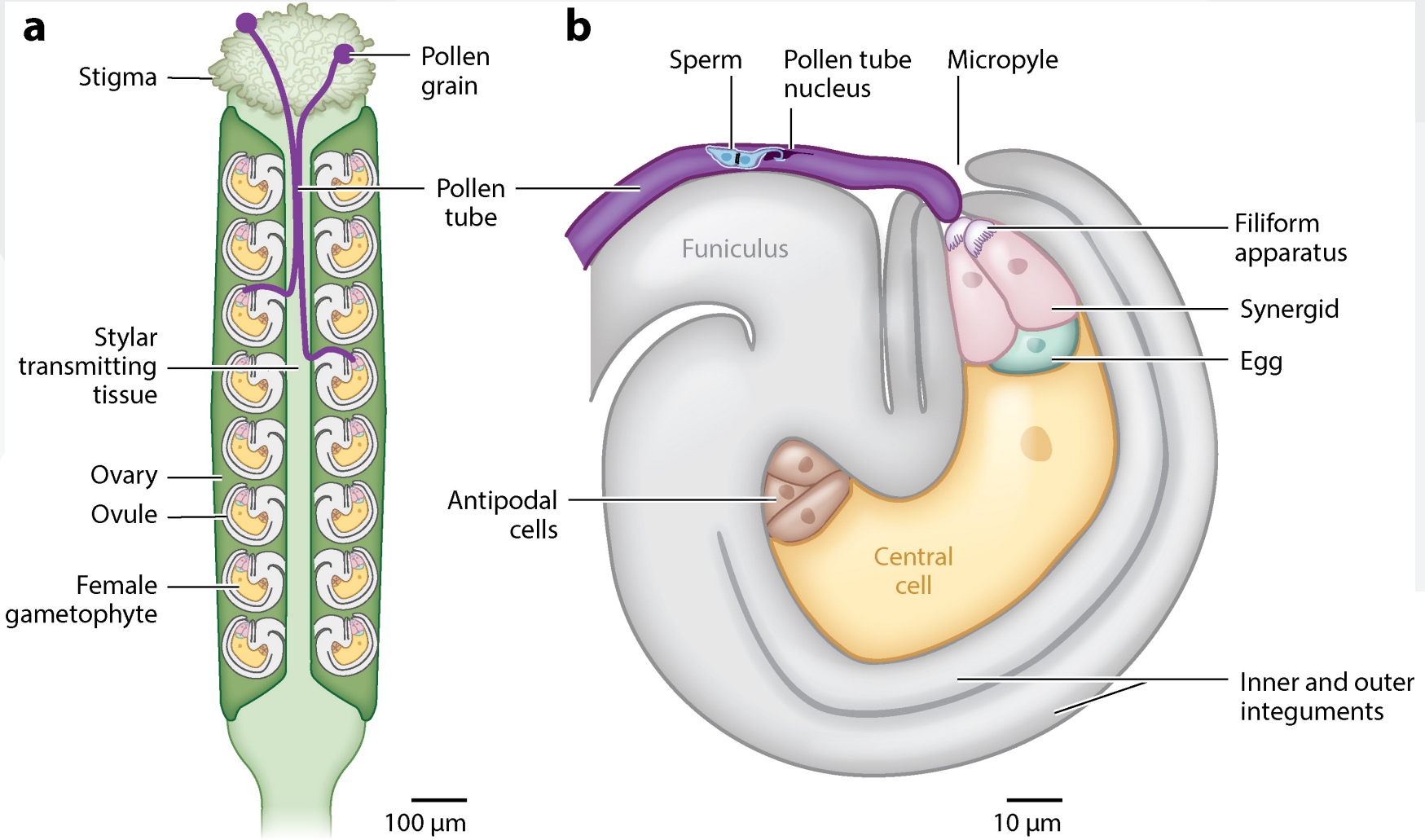
- Plant reproductive strategy and genetic diversity
  - Pollen dispersal
  - Pollinator interactions
  - Reproductive isolation
- Benefits to people
  - Food crops for human consumption
  - Aesthetics

https://youtu.be/LiczM-w3V-U

See Hileman, L.C. (2014). Trends in flower symmetry evolution revealed through phylogenetic and developmental genetic advances. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 369: 20130348..

Journey of the pollen

Intensive communication between male and female organs



Johnson MA, et al. 2019.
Annu. Rev. Plant Biol. 70:809–37

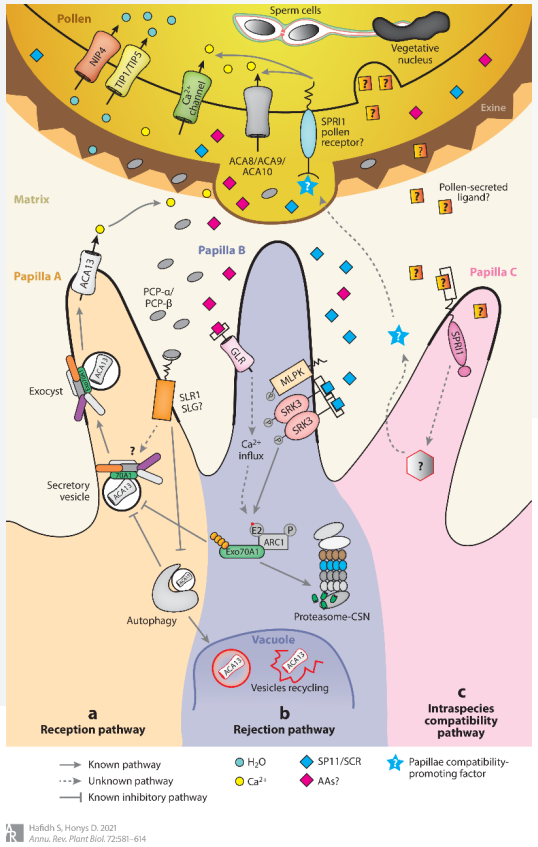
Communication male - female

At the stigma:
Compatibility
Pollen grain germination

In the style:
Compatibility
Pollen tube growth

At the ovule
Attraction and guidance
Polyspermy block

Between gametes
Double fertilization



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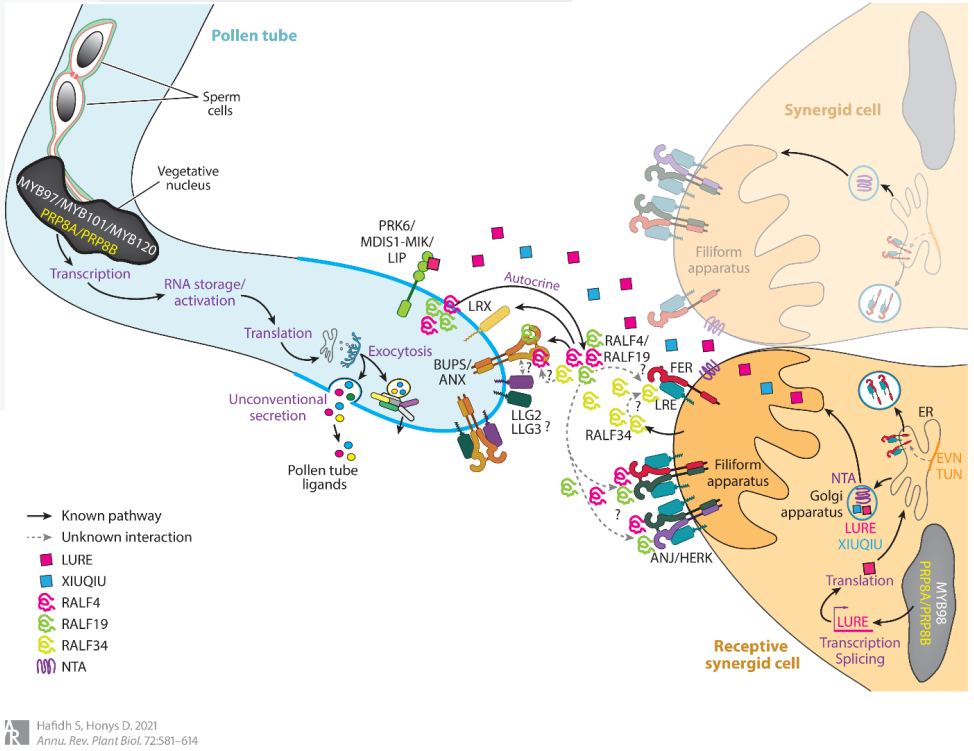

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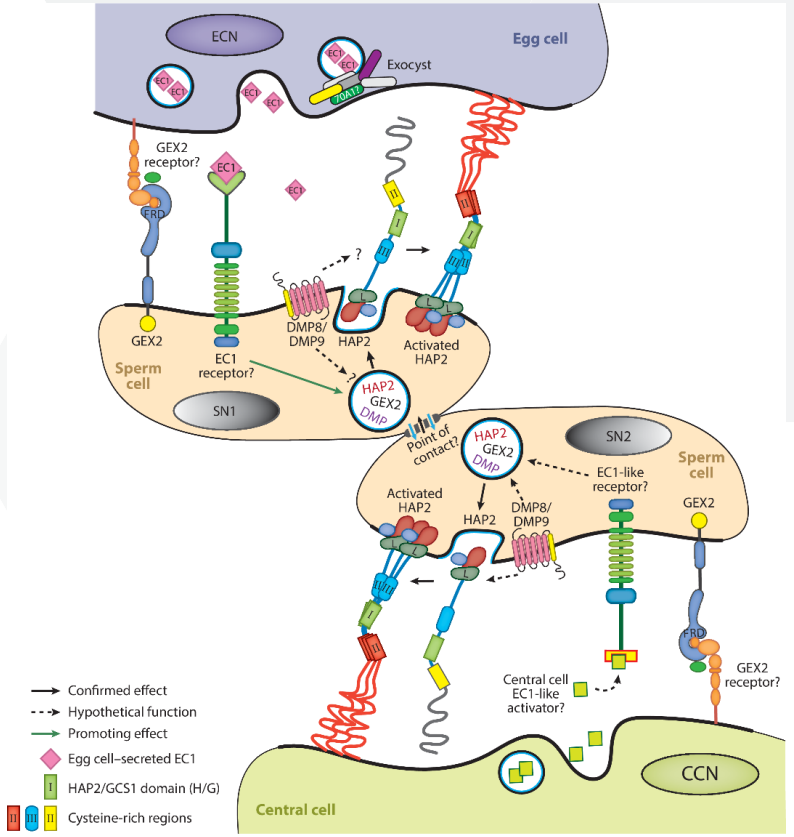


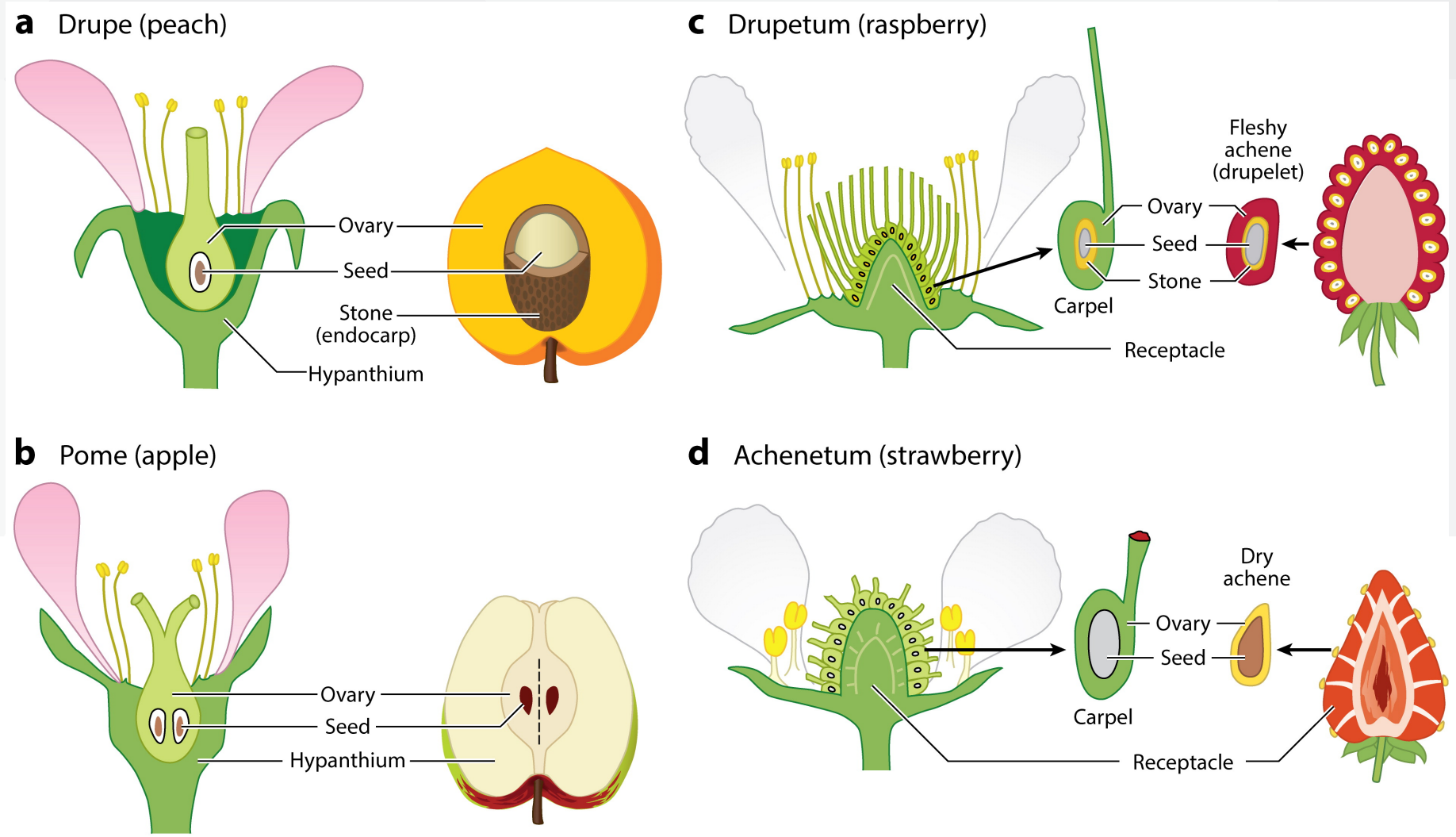
Hafidh S, Honys D. 2021
Annu. Rev. Plant Biol. 72:581–614

Fruit and seeds

Example of the Rosaceae family

Pistil > Fruit
Ovary >> Seed

The number of seeds is determined by the number of ovules

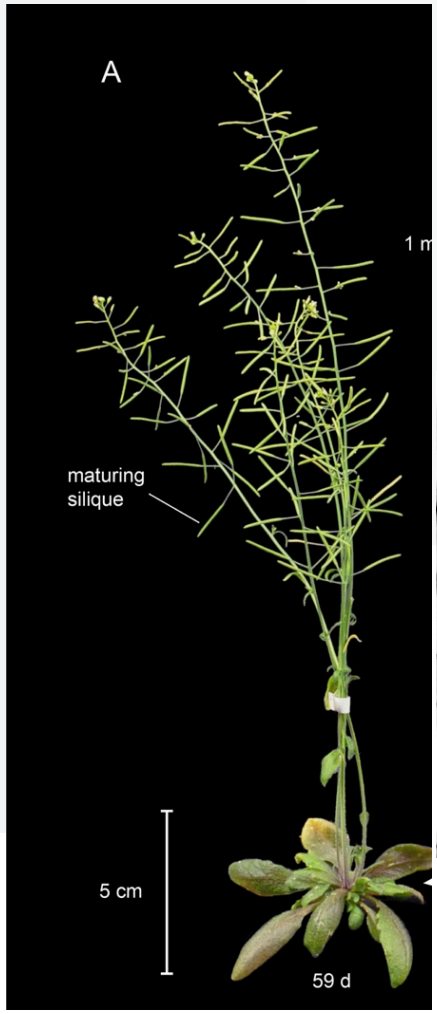


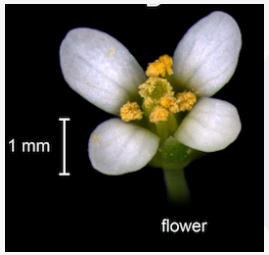
Liu Z, et al. 2020.
Annu. Rev. Plant Biol. 71:547–73

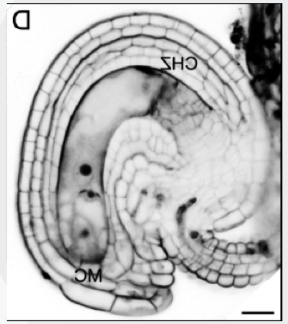
Menti

- Name some fruits and seeds you eat

Embryo development in Arabidopsis

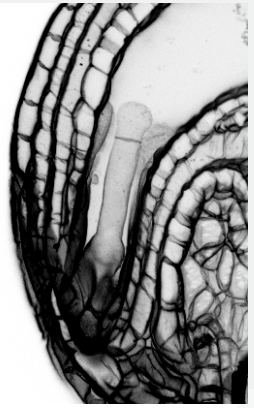






gametophyte

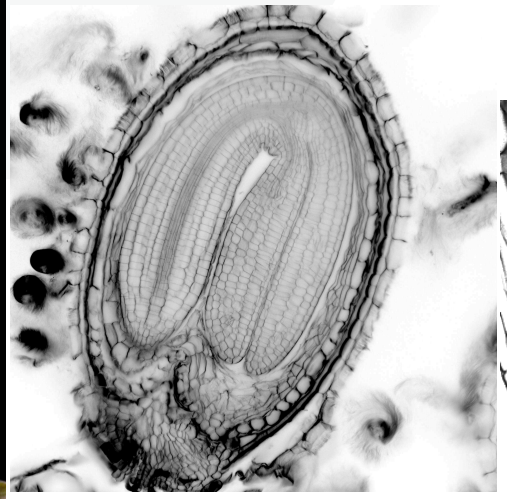
zygote



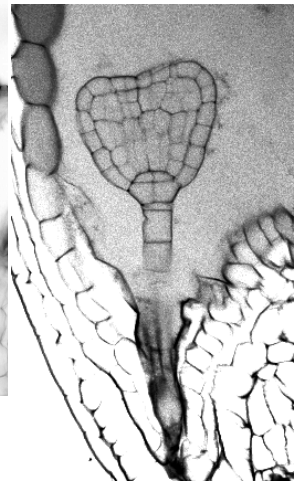
1-cell

2/4-cell

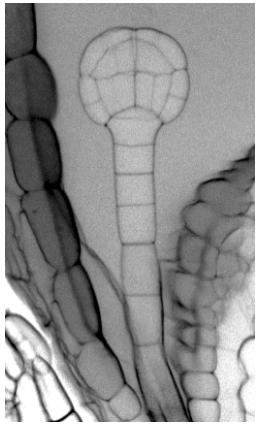
Embryo morphology



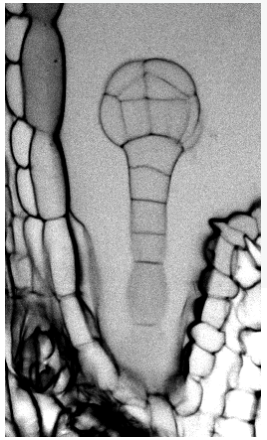
mature



heart

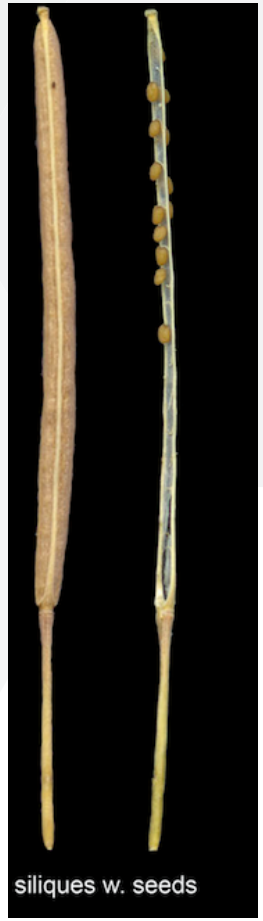


globular



16-cell

8-cell

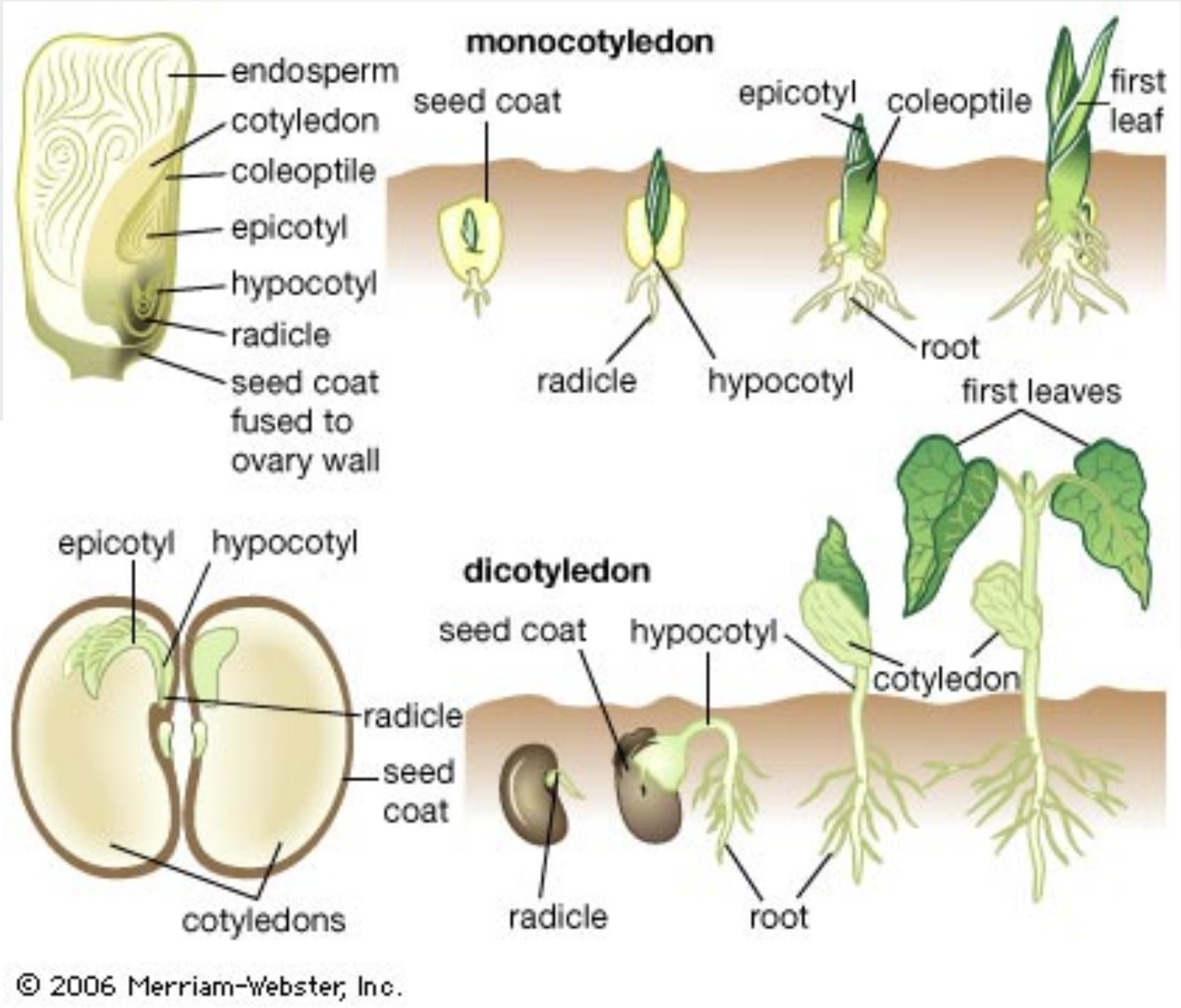


Kramer, eLife, 2015; unpublished

Monocots vs dicots

Monocotyledons or **monocots.** Those are grass and grass-like flowering plants. It also includes cereal grains and crops like rice, maize, wheat, onions, garlic. **When the seed is germinating, only one leaf will appear.**

Dicotyledons or **dicots.** Those are flowering plants like tomatoes, paprika, peas, beans, avocados, sunflowers, and many others, including the Magnolids. **When the seed is germinating, two leaves will appear.**



Dispersal

- menti

Can you cite methods of seed dispersal?

Seed dispersal

Wind

Exploding

https://youtu.be/xY4JFOSuqvY

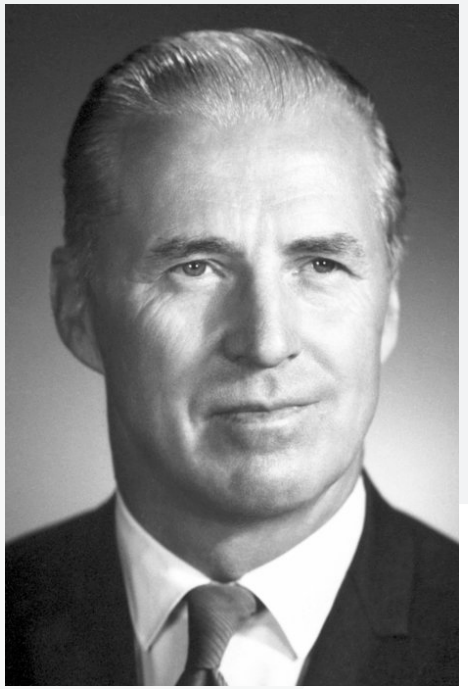
Seed dispersal method is also adapted to the environment where the plants is growing.

Water

Animals

Fruits were/are bred for human consumption

Plant breeding aims to produce plant varieties more useful for human consumption **by increasing yield and quality, improving disease resistance, drought, frost, flood resistance,** etc.
It has been crucial for increasing crop production in response to increased food demand, notably in the 1960s. This has been referred to as the **Green Revolution**.



- **Norman Borlaug**

an American agronomist (1914-2009), received the Nobel Prize for Peace in 1970 for his work on plant breeding to increase agriculture production in the 1950s and 1960s.

semi-dwarf wheat and rice with high yield **saved people from starvation**.

Breeding, some examples

6 vegetables that are the same plant

Over hundreds of years farmers have been breeding one plant – called Brassica Oleracea – into dozens of different varieties. These six vegetables you can find in the grocery store are actually all the same plant.

BRUSSELS SPROUTS
Lateral leaf buds

BROCCOLI
Flower buds/stems

CABBAGE
Terminal leaf bud

CAULIFLOWER
Flower buds

KALE
Leaves

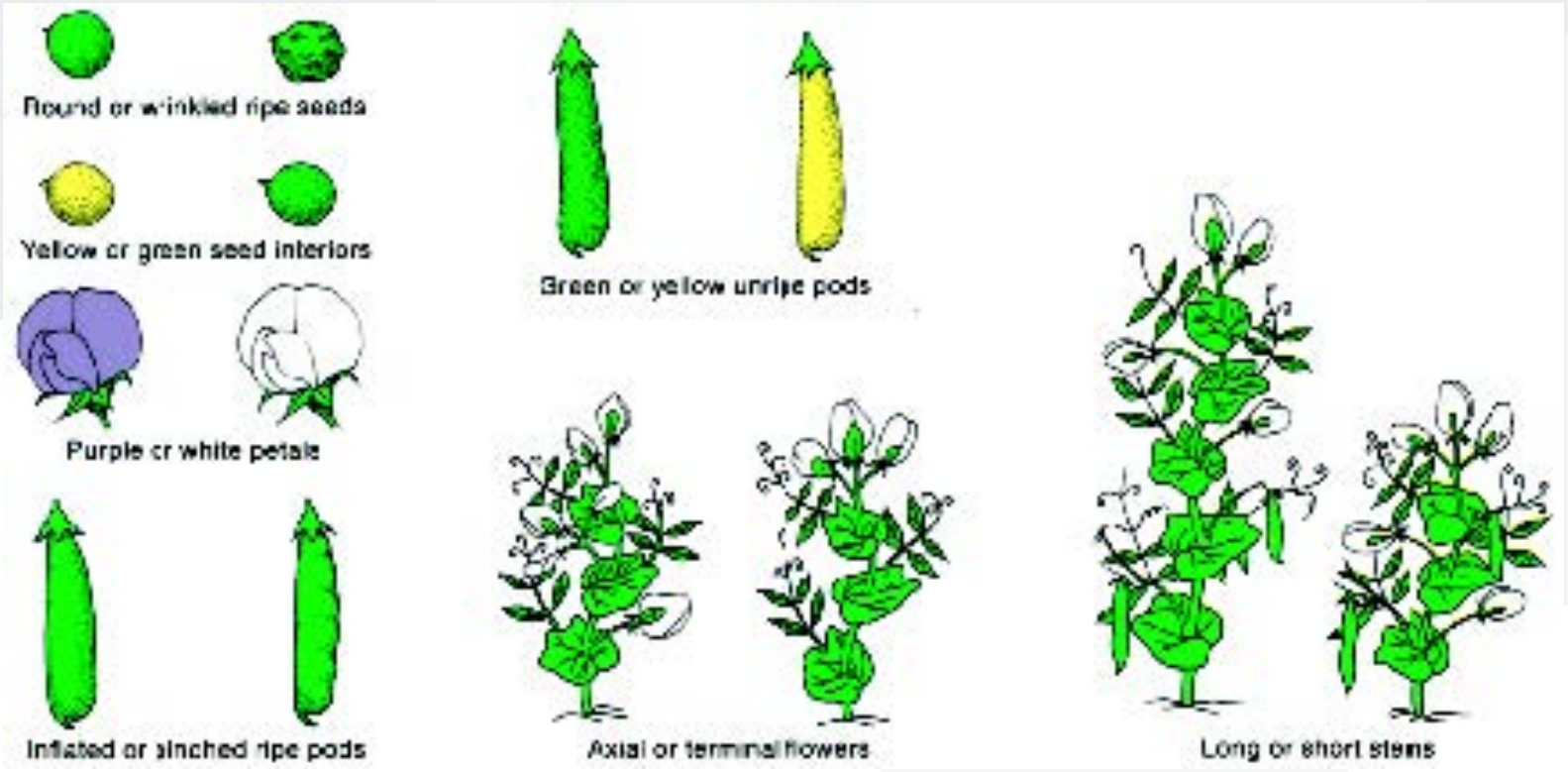
KOHLRABI
Stem

WILD MUSTARD PLANT
(Brassica Oleracea)

SOURCE: Botanist in the Kitchen

TECH INSIDER

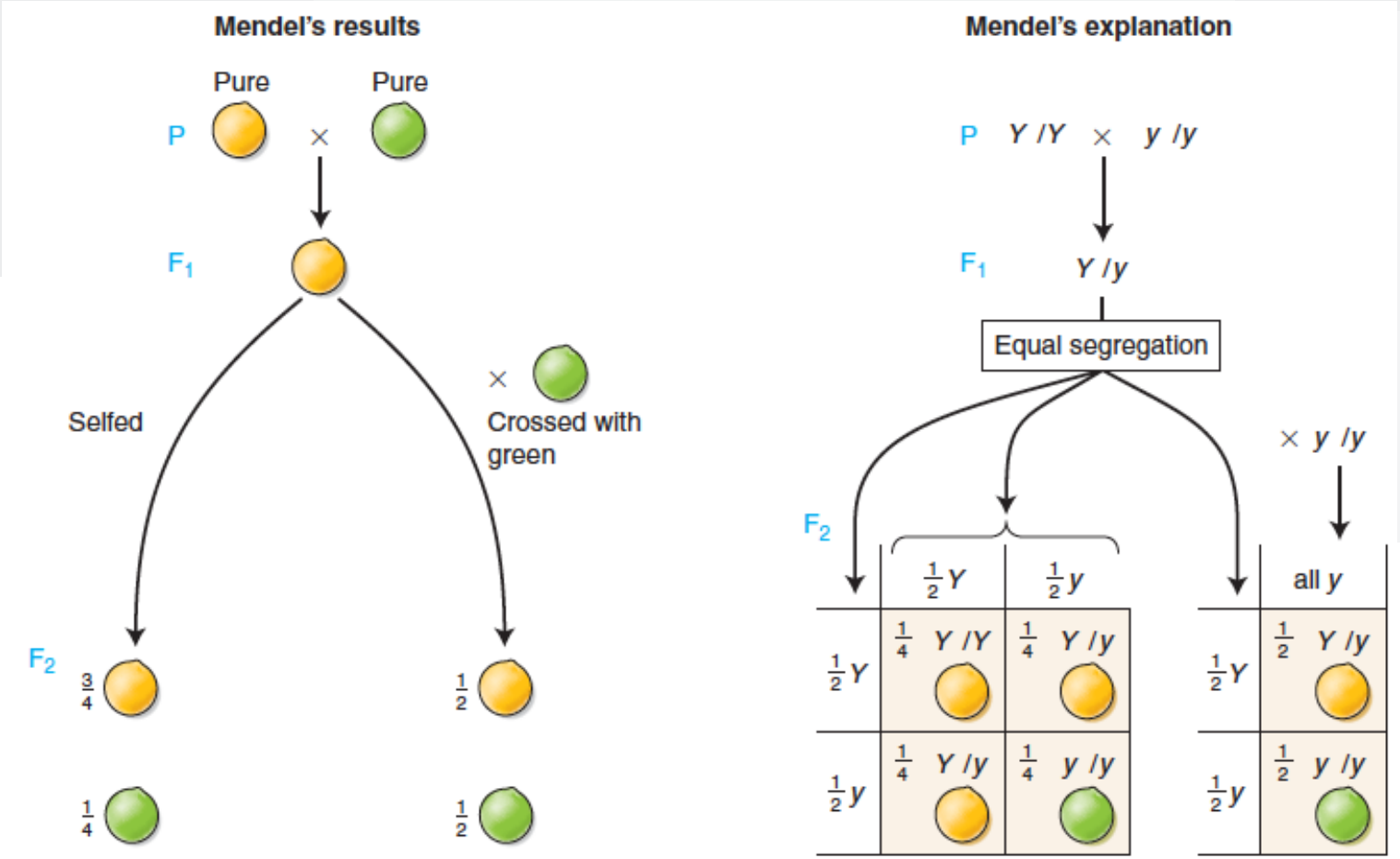
Genetics – Segregation of traits



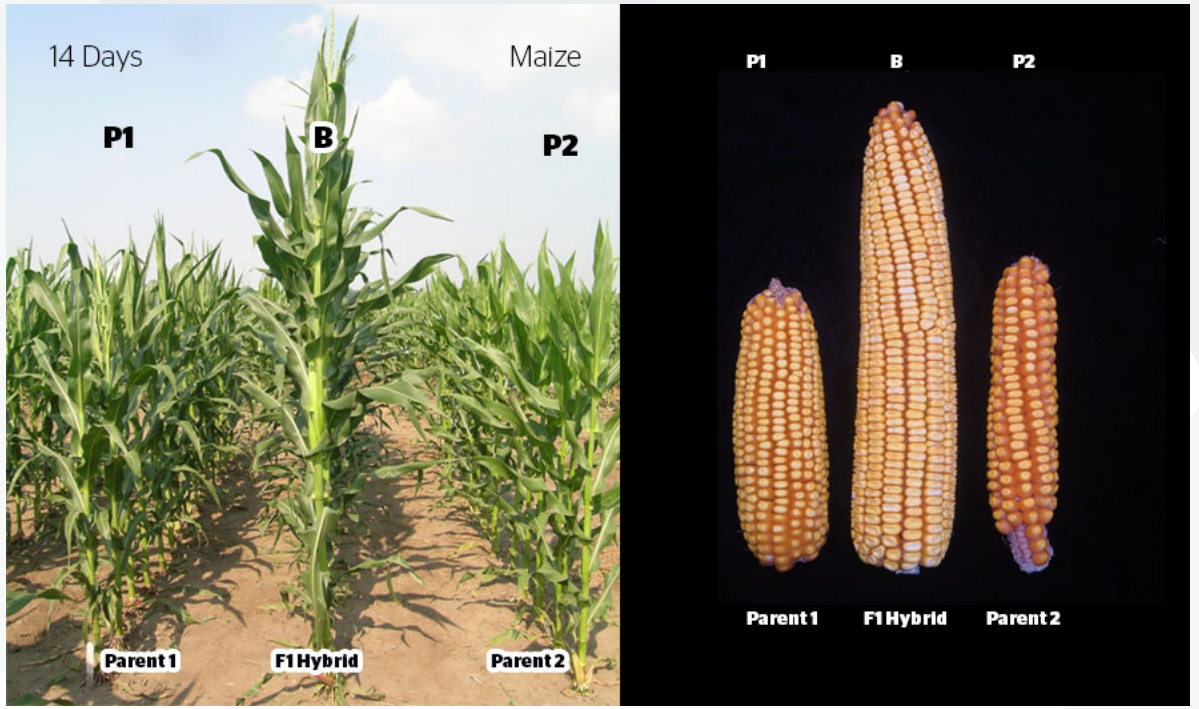
J. G. Mendel discovered the **principles of heredity**, and established the **laws of genetic inheritance**.

Segregation of traits, the genetics

- Traits (**Phenotype**) are carried by genes
- Each gene has two alleles (inherited by mother and by father)
- Composition of alleles: **Genotype**
- One allele is dominant
- One allele is recessive
- The dominant allele is giving the phenotype



Hybrid vigour, F1 hybrid

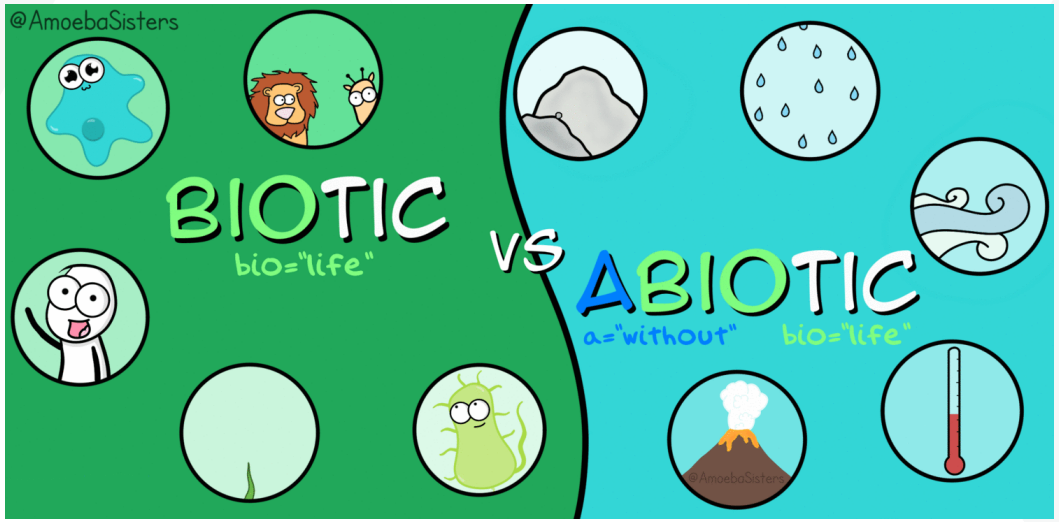


Crop breeding is performed by crossing varieties of the same species **to remove unwanted traits and bring together the traits of interest**.
Some other traits are enhanced in the hybrid offspring because of mixing the genetic information of both parents.
These hybrids tend to be bigger, grow faster and be more fertile than either parent.

Plant hormones

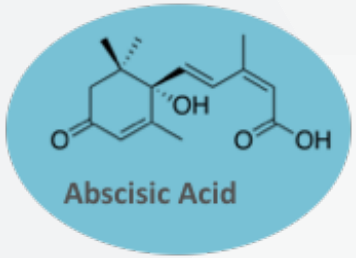
Plant hormones are tiny chemical messengers that help the plant

- grow,
- develop
- protect itself against a stressful environment and attacks from bacteria, fungi, animals.



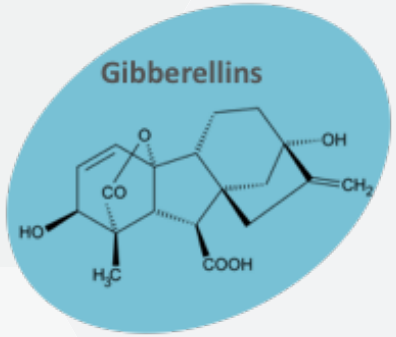
There are five crucial hormones responsible for fruit and seed development **Abscisic acid (ABA), Auxin, Cytokinin, Ethylene, Gibberellins**.

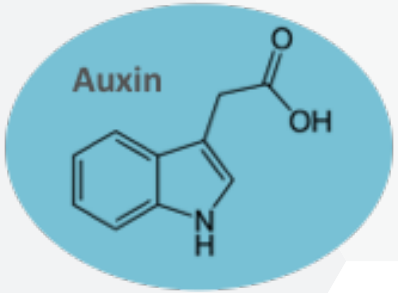
Plant hormones



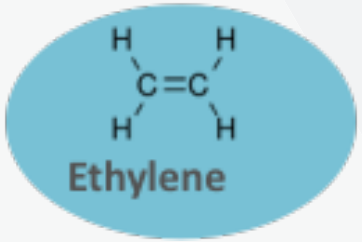
Abscisic acid (ABA), the stress hormone.
It helps fight against drought stress and high temperatures seed dormancy and desiccation

Gibberellins (GA) are essential for growth, seed germination, fruit growth, and sex determination in monoecious species

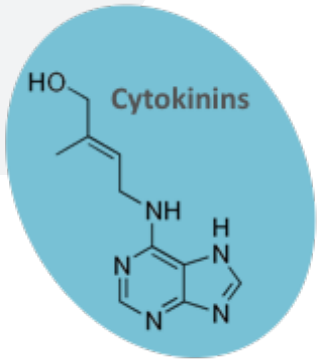




Auxin (IAA, Indole-3-acetic acid), the growth hormone. It affects every aspect of plant development, including morphogenesis



A gaseous hormone.
It controls fruit ripening, flower senescence, and sex determination in some species. It helps the plant to respond to some stresses.



Cytokinins work together with auxin during plant development. Important for senescence (plant aging), for shooting.

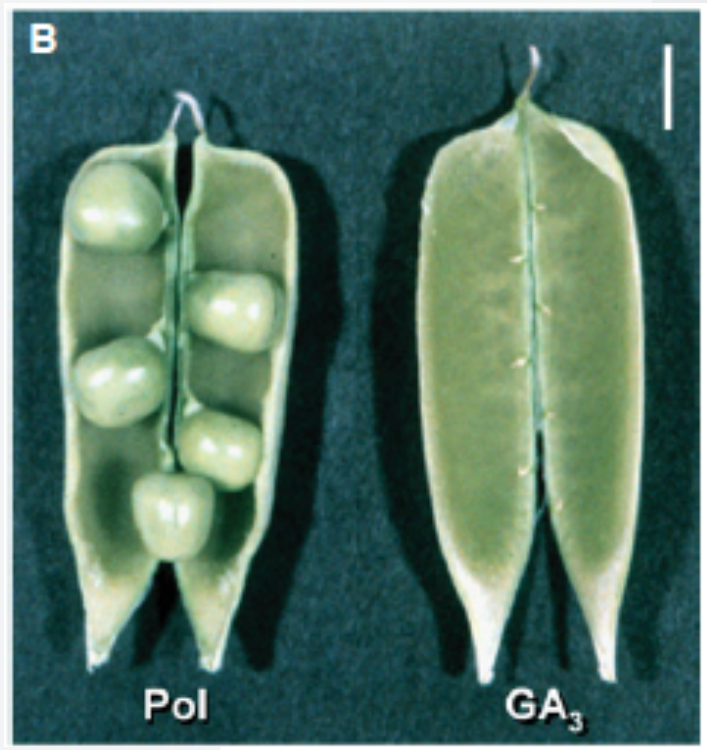
Auxin and GA for fruit growth

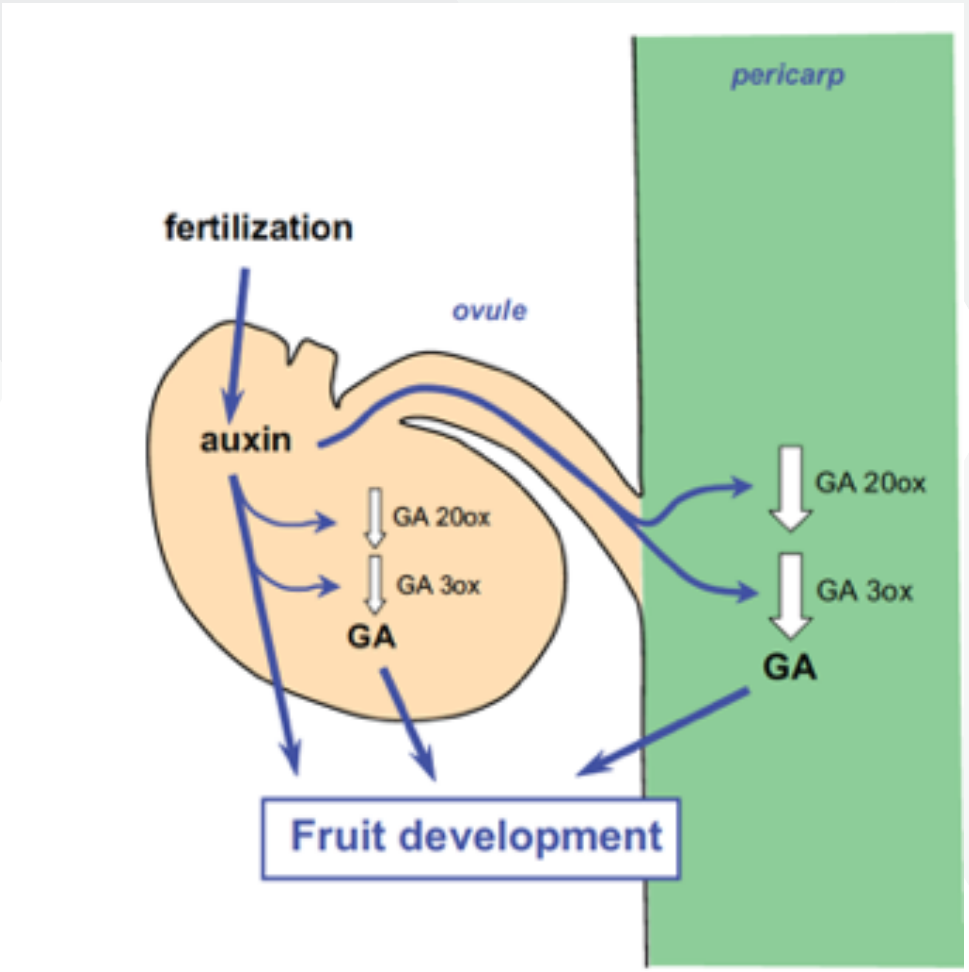
Auxin + GA

GA

Auxin

Auxin and GA for fruit growth



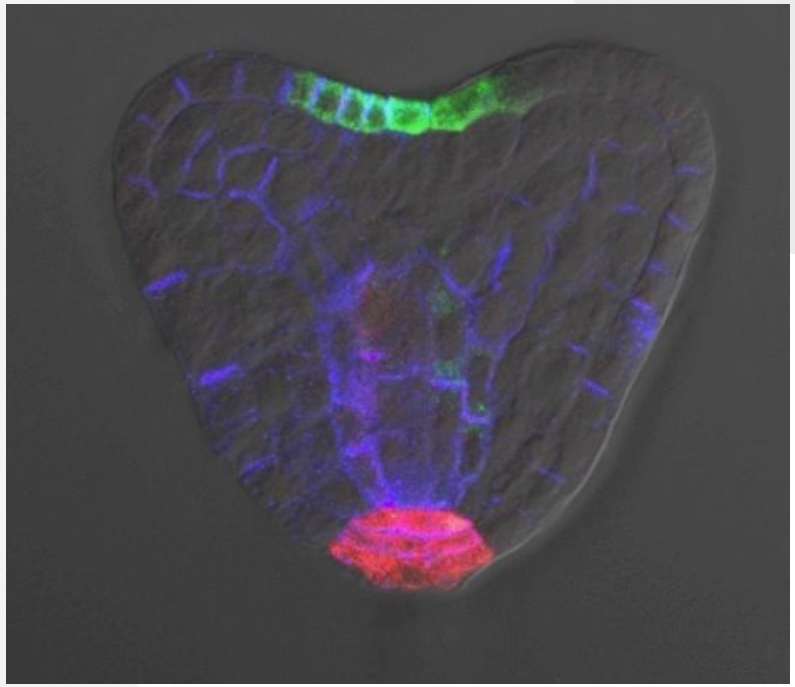


Hormones help to coordinate fruit growth to the number of developing seeds

Fruit without seeds: parthenocarpy

Alabadí D, Blázquez MA, Carbonell J, Ferrándiz C & Perez-Amador MA (2008) Instructive roles for hormones in plant development. *Int. J. Dev. Biol.*

Auxin and cytokinin for embryo morphogenesis

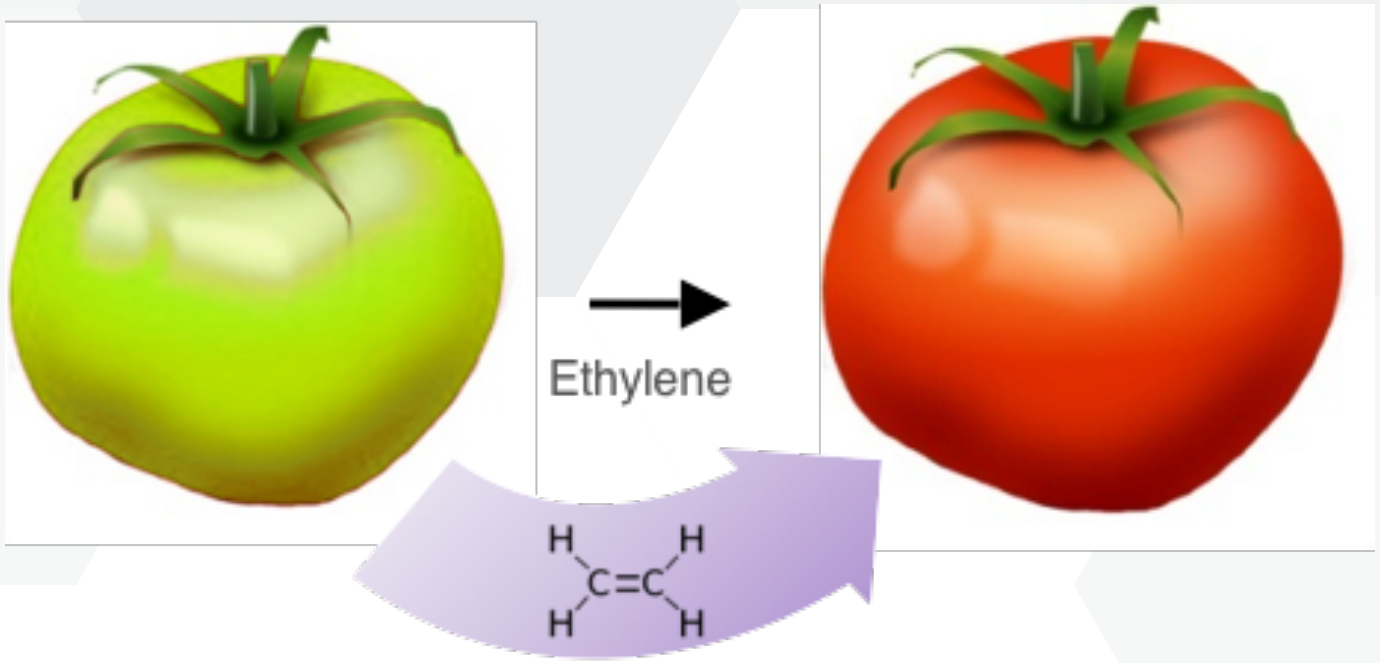


Auxin production >> Shoot apex

Auxin transport + Cytokinin >> Vascular development

Auxin + cytokinin signalling >> Root apex

Ethylene and ABA – Fruit maturation



Ethylene promotes fruit softening and flavour and colour development

But not in every fruits!!

Hormones for fruit maturation

Climacteric Fruit ripe after being harvested. The fruit will become softer and sweeter.

They are transported in controlled-atmosphere storage conditions: low O2, high CO2
These conditions suppress the high production of ethylene by the fruits.

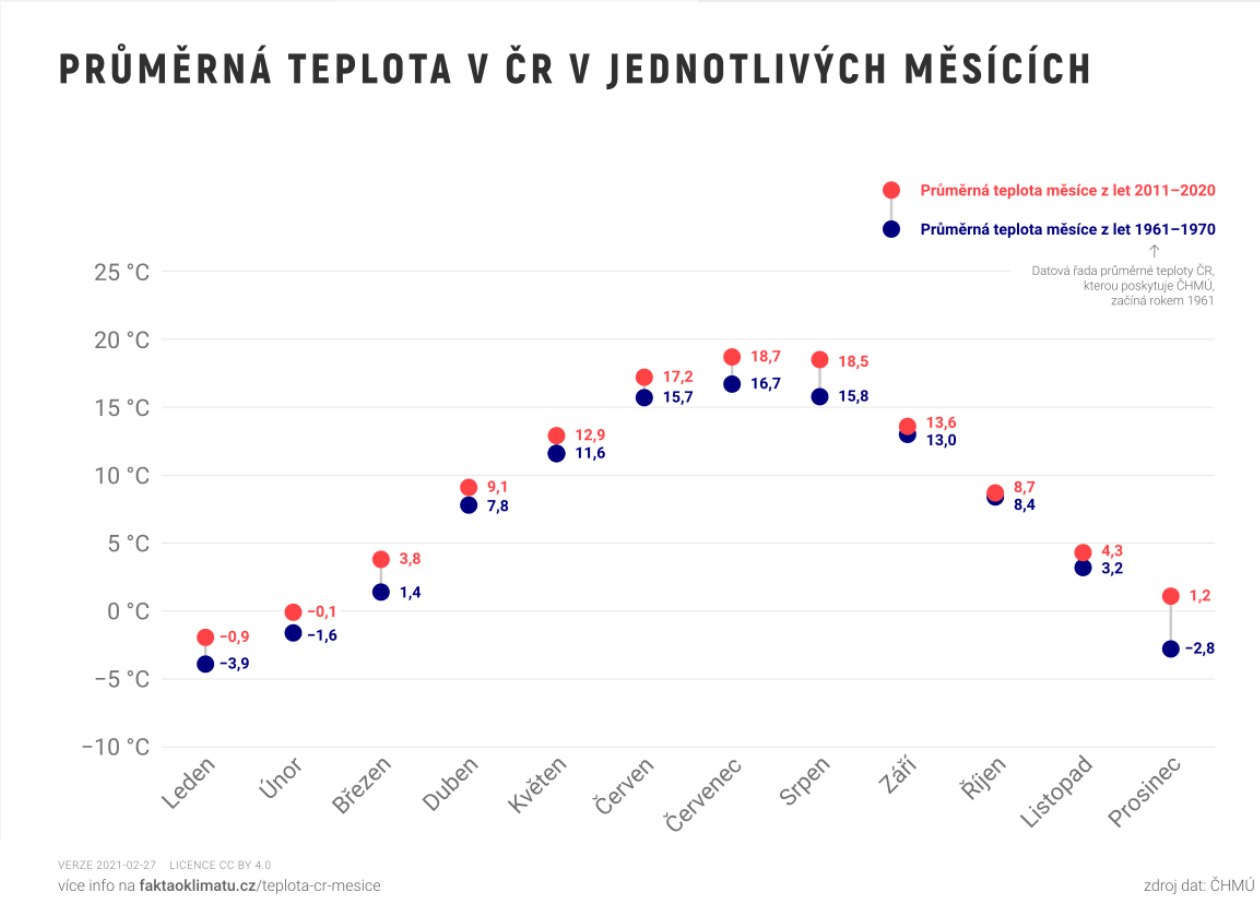
Non-Climacteric Fruit won't mature after harvest.

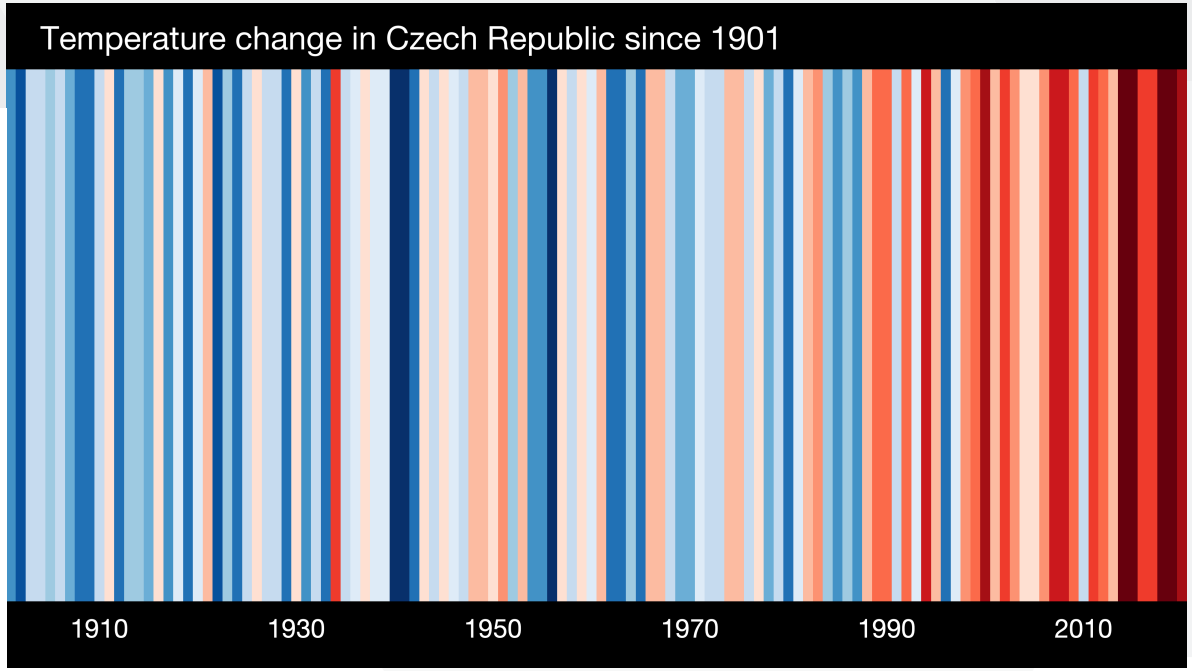
ABA for dormancy; GA for seed germination

At maturation, the seeds accumulate ABA to accumulate reserves of nutrients.
ABA also helps the seed to survive the desiccation process.
Then the seeds become **dormant,** waiting for good growth conditions to germinate.

Reduced ABA and production of GA lead to seed germination.
Lost of dormancy inside the fruit > preharvest sprouting

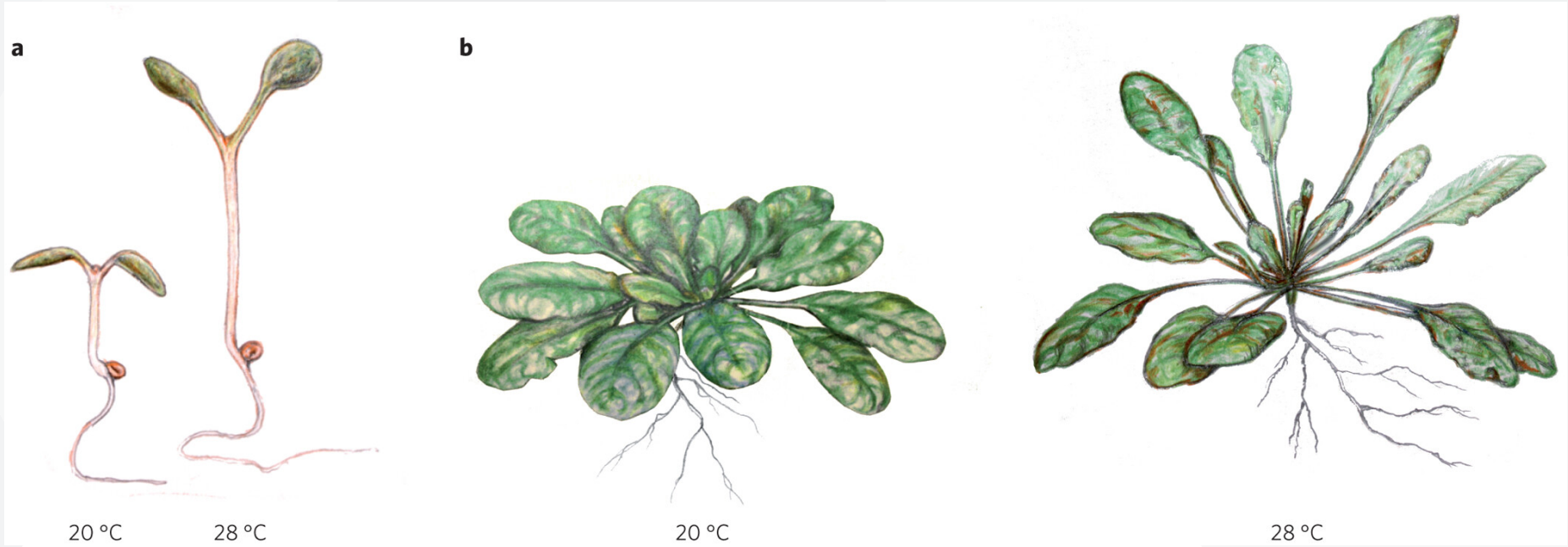
Climate changes – Higher temperatures





https://faktaoklimatu.cz

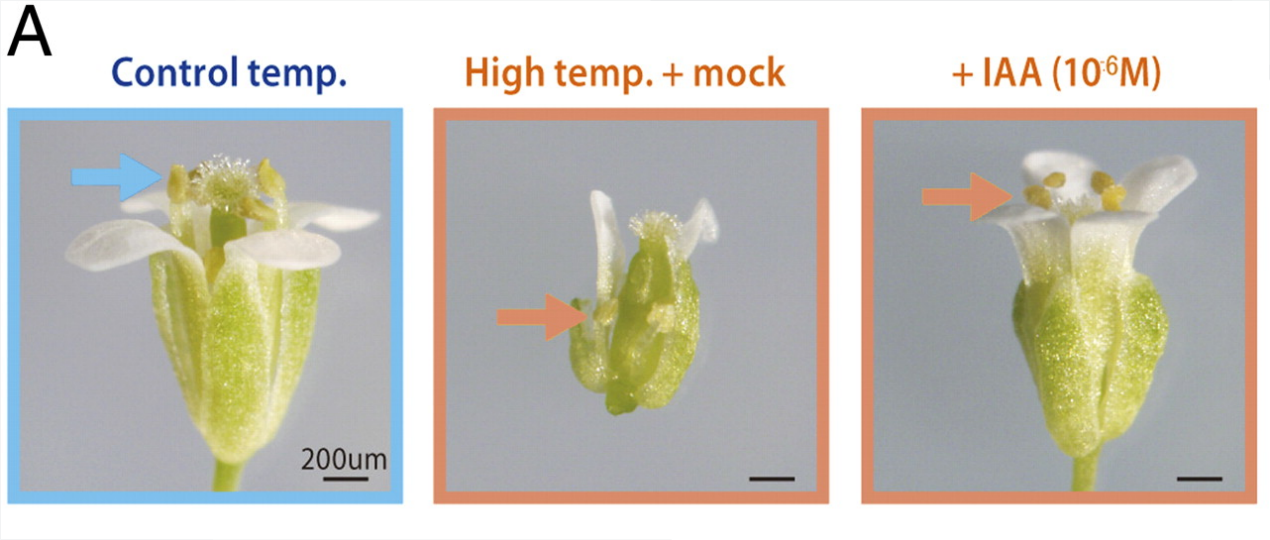
Impact of high temperature on plant development

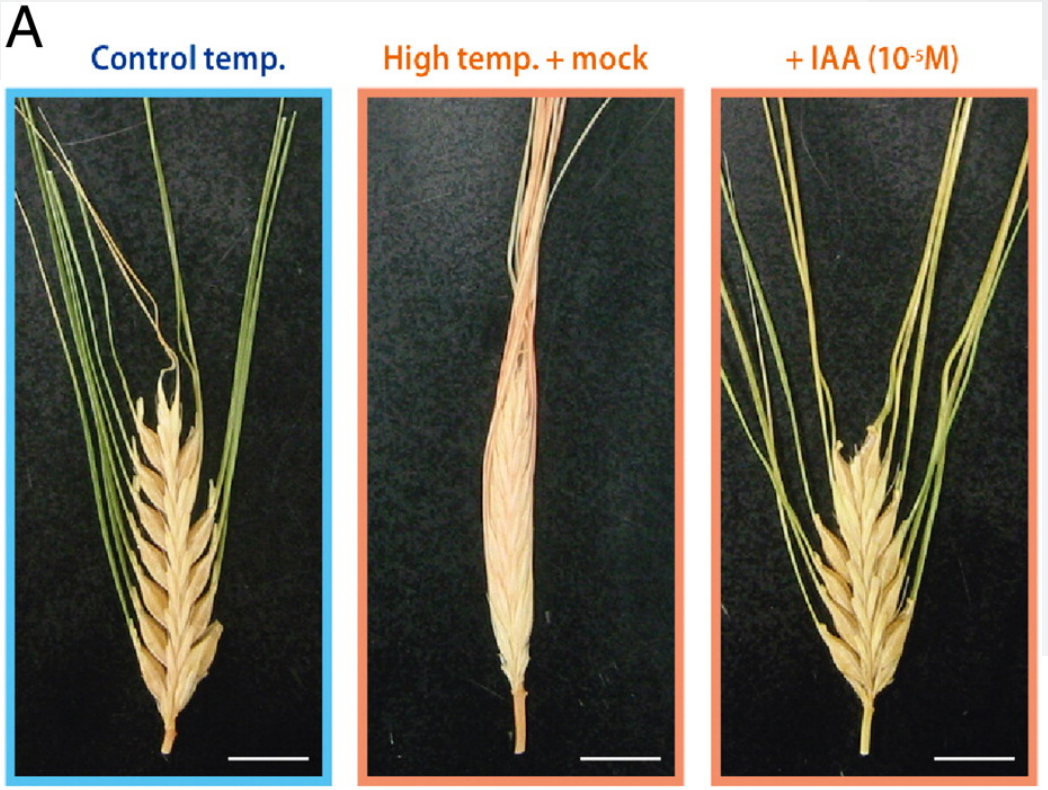


Escape strategy
Accelerated growth

Quint, M., Delker, C., Franklin, K. A., Halliday, K. J. & Zanten, M. van. Molecular and genetic control of plant thermomorphogenesis. *Nature Plants* 2, 15190 (2016).

Impact of high temperature on seed development (auxin)





High temperatures impact pollen development
Thus, fertilization and seed production

Auxin may help to protect against it!

Sakata, T. *et al.* Auxins reverse plant male sterility caused by high temperatures. *PNAS* **107**, 8569–8574 (2010).

Climate change threatens to reduce the quantity of crops, lowering yields and their nutritional value

1°C rise in global mean
temperatures would res
average **reduction of 3**
global production of rice
maize, and soybean.

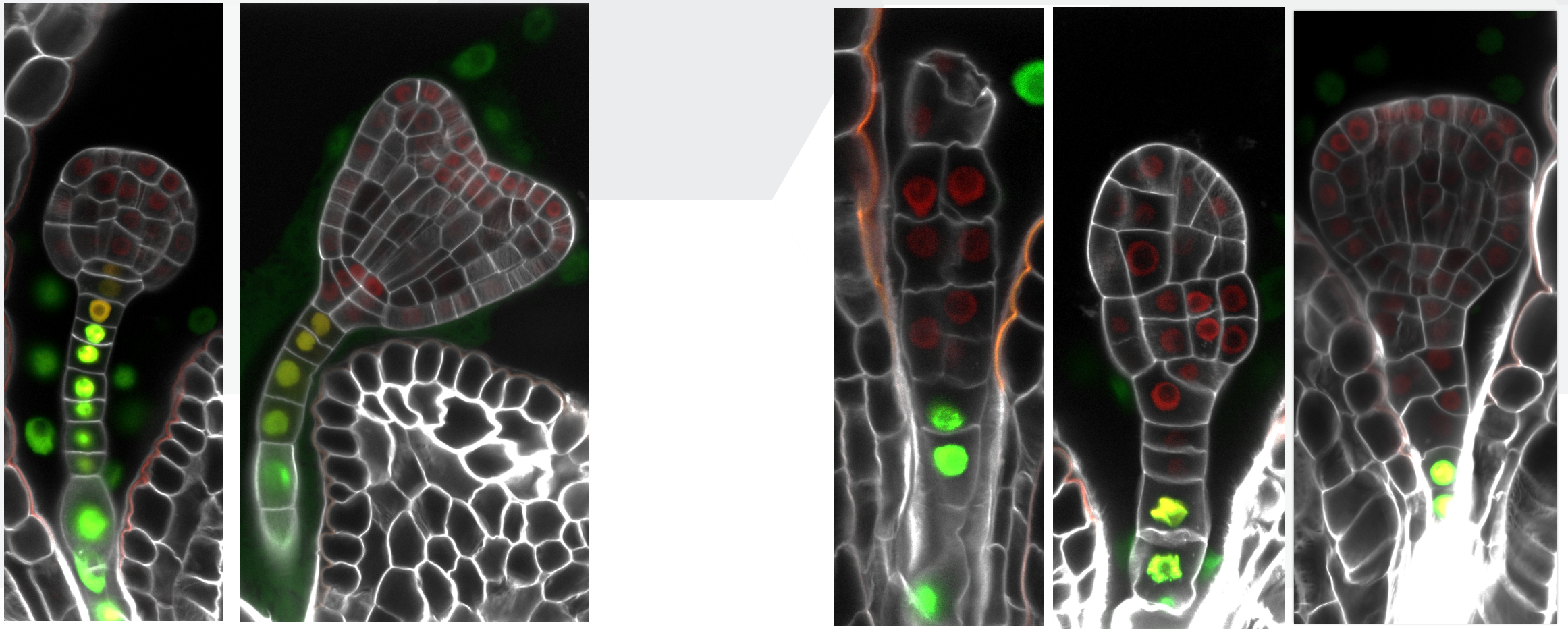
The Intergovernmental Panel on Clim
reported in 2018 that global temperat
by **a further 1.5°C between 2030 ar**

(Zhao et al., 2017)

High temperatures also affect embryo morphogenesis

21ºC

34ºC



WOX2 (embryonic) / WOX8 (suspensor)

Juan Francisco Sanchez Lopez, unpublished

Outlines

- Fruits are produced by flowering plants
- Flowers have various shape, smell and colours to attract pollinators
- To produce a fruit, the flower needs to be pollinated and fertilized
- The pistil becomes the fruit, the ovules become the seeds.
- In the seed, the embryo develops into the next generation offspring
- Meiosis is necessary to maintain the ploidy of the plant.
- Traits of interest were selected for food production, thanks to the work of geneticists like Mendel and Borlaug.
- Plant hormones are crucial for fruit and seed production
- Climate changes may threaten fruit and seed production

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