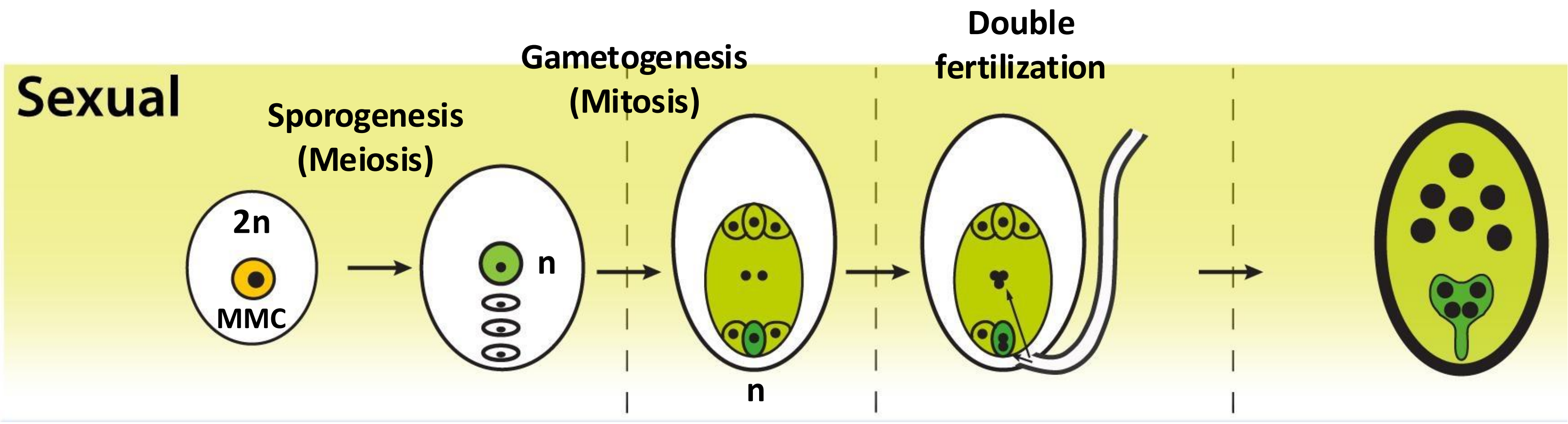
Meiosis: Apomixis

Section IV-F

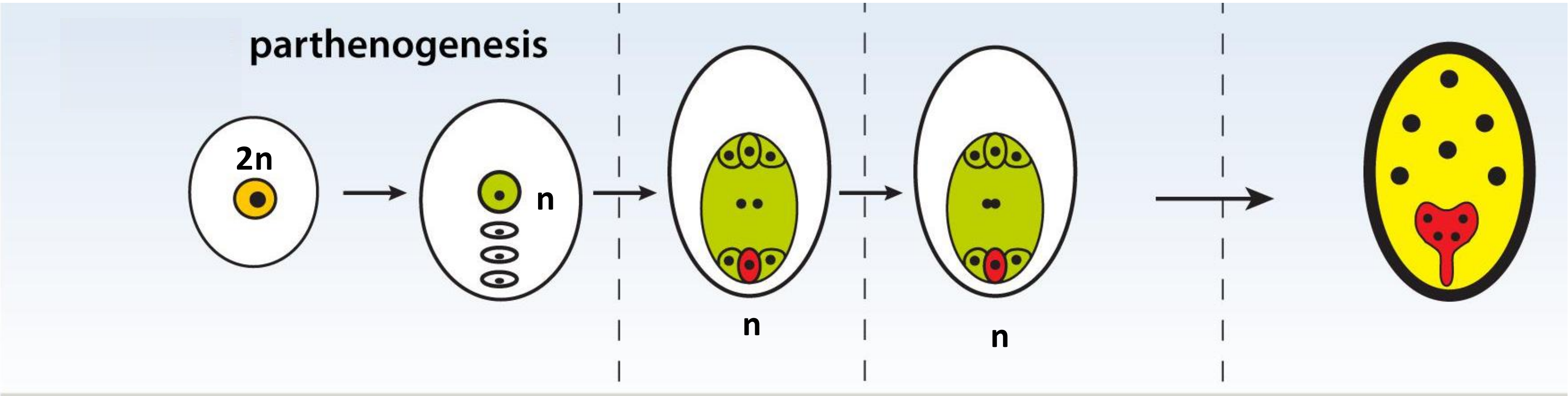
Review

Hojsgaard and Hörandl, 2019



Endosperm: 3C (2m:1p)
Embryo: 2C (1m:1p)

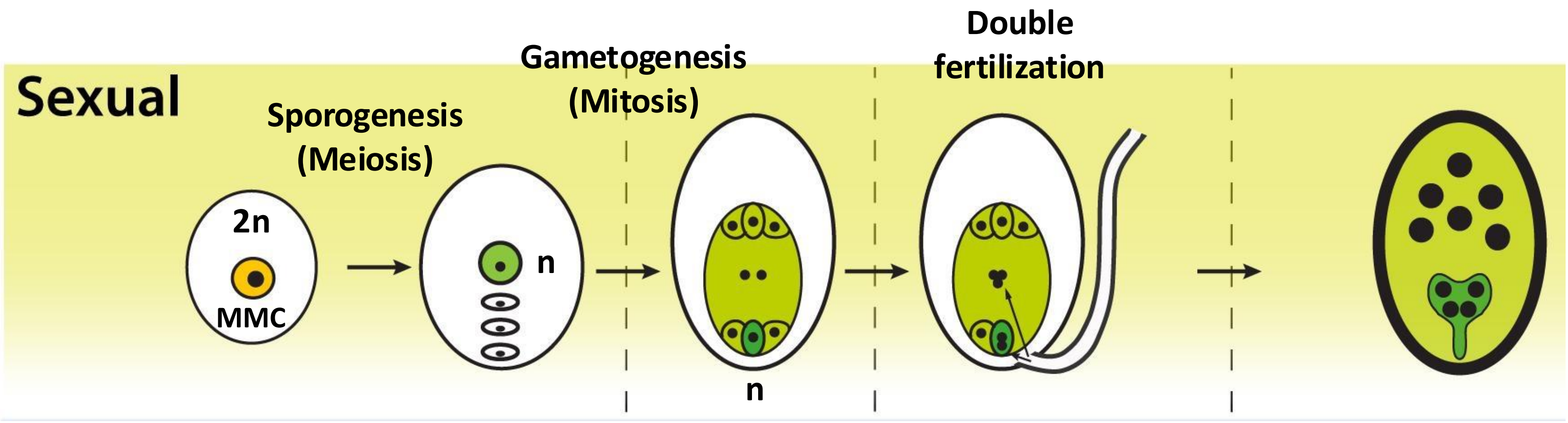
- Parthenogenesis: Embryogenesis without fertilization.



Endosperm: 2C (2m)
Embryo: 1C (1m)

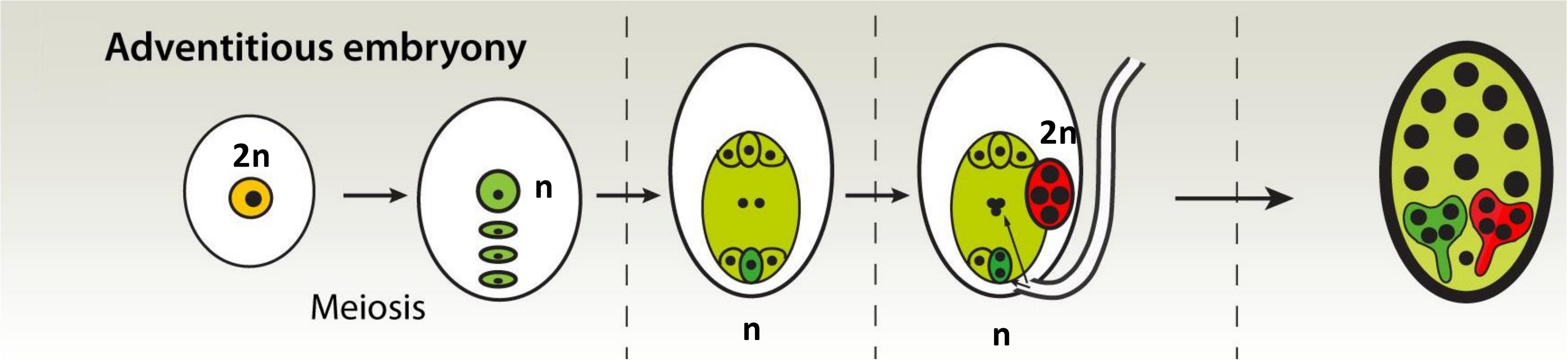
Review

Hojsgaard and Hörandl, 2019



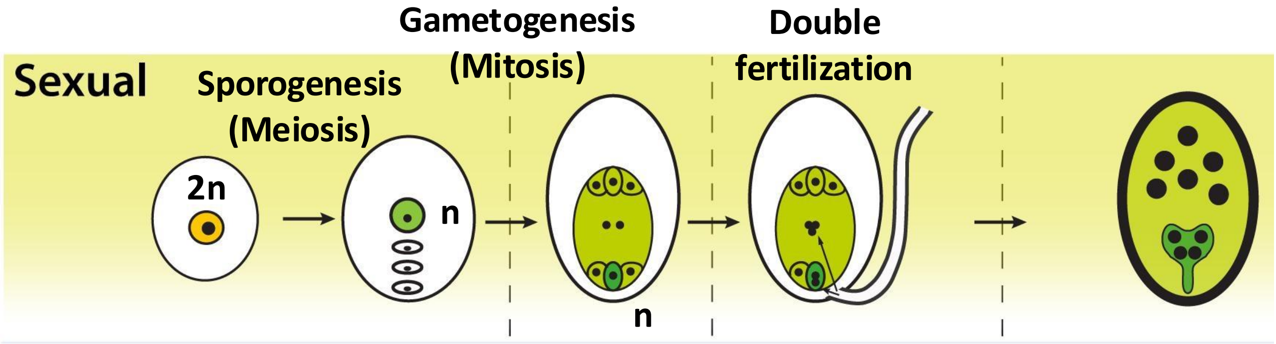
Endosperm: 3C (2m:1p)
Embryo: 2C (1m:1p)

- Adventitious embryony (Sporophytic apomixis).



Endosperm: 3C (2m:1p)
Embryo (sexual): 2C (1m:1p)
Embryo (apomictic): 2C (2m)

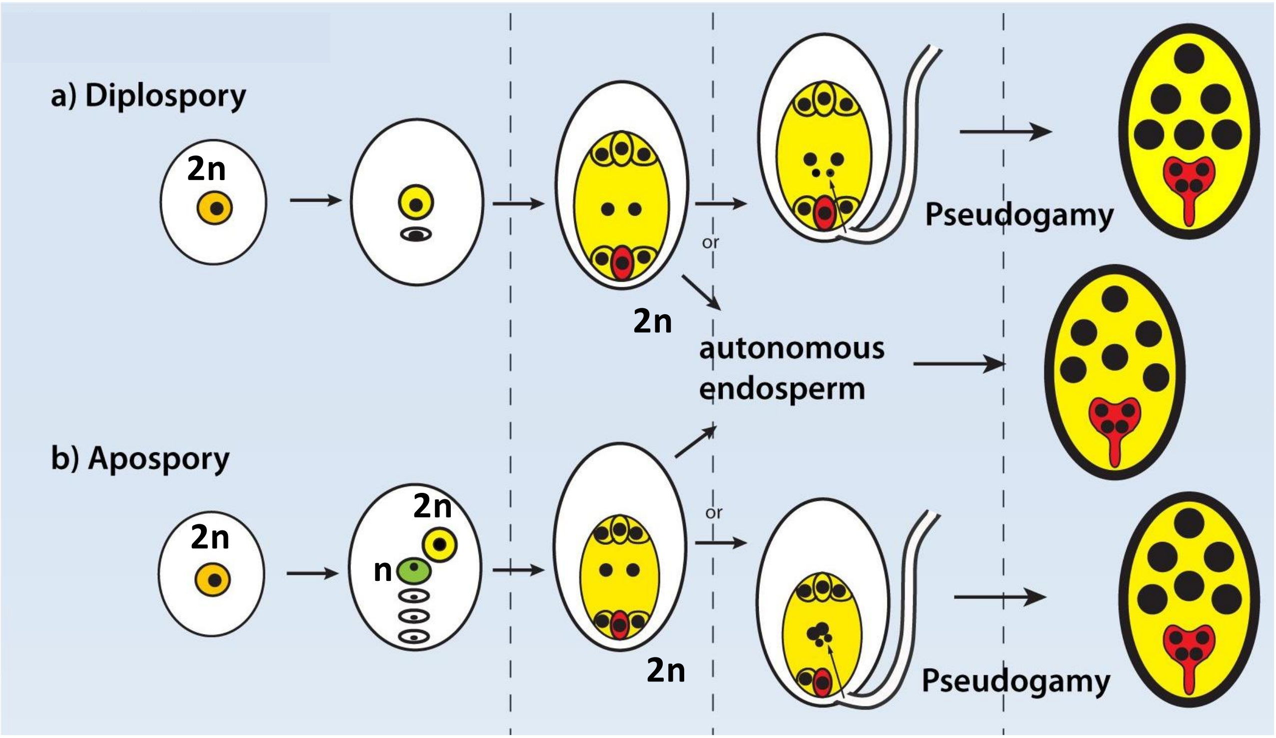
Review



Hojsgaard and Hörandl, 2019

Endosperm: 3C (2m:1p)
Embryo: 2C (1m:1p)

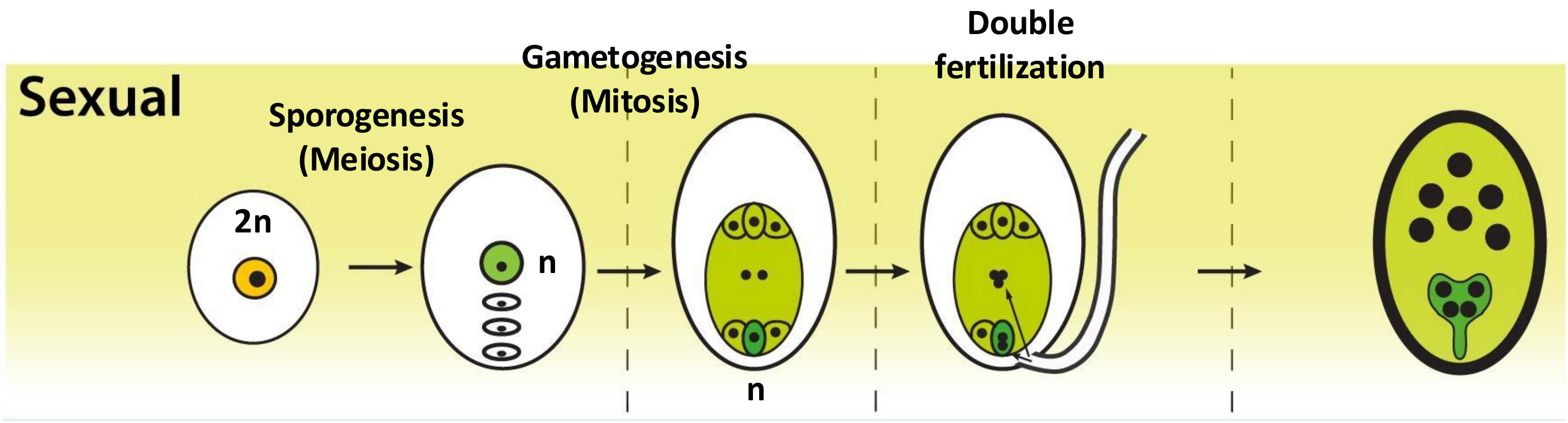
- Gametophytic Apomixis: Apomictic embryo is formed from an unreduced gametophyte (Apomeiosis + parthenogenesis).



Endosperm (pseudogamous): 5C (4m:1p)
OR
Endosperm (autonomous): 4C (4m)
Embryo (apomictic): 2C (2m)

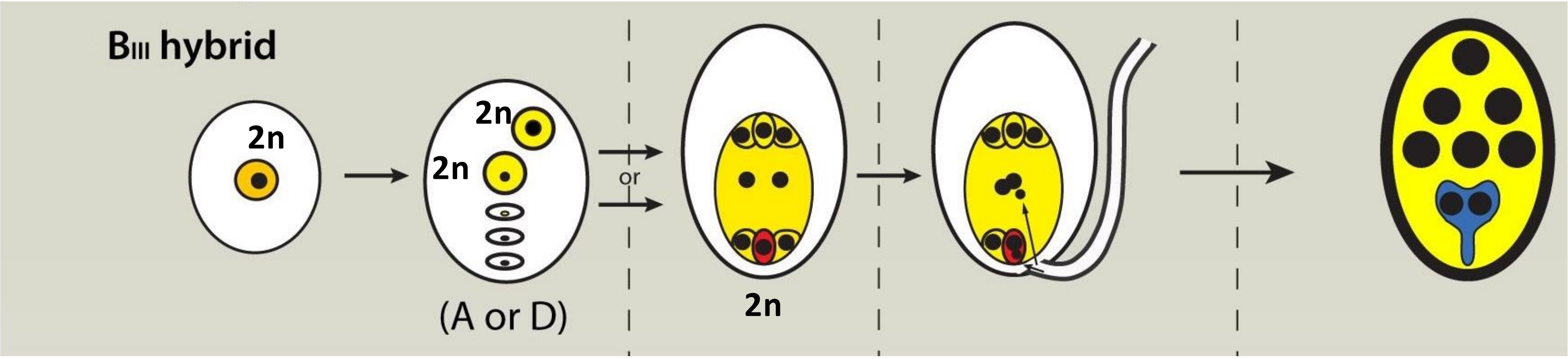
BIII hybrid

Hojsgaard and Hörandl, 2019



Endosperm: 3C (2m:1p)
Embryo: 2C (1m:1p)

- BIII hybrid: Unreduced egg-cell is fertilized by reduced sperm.

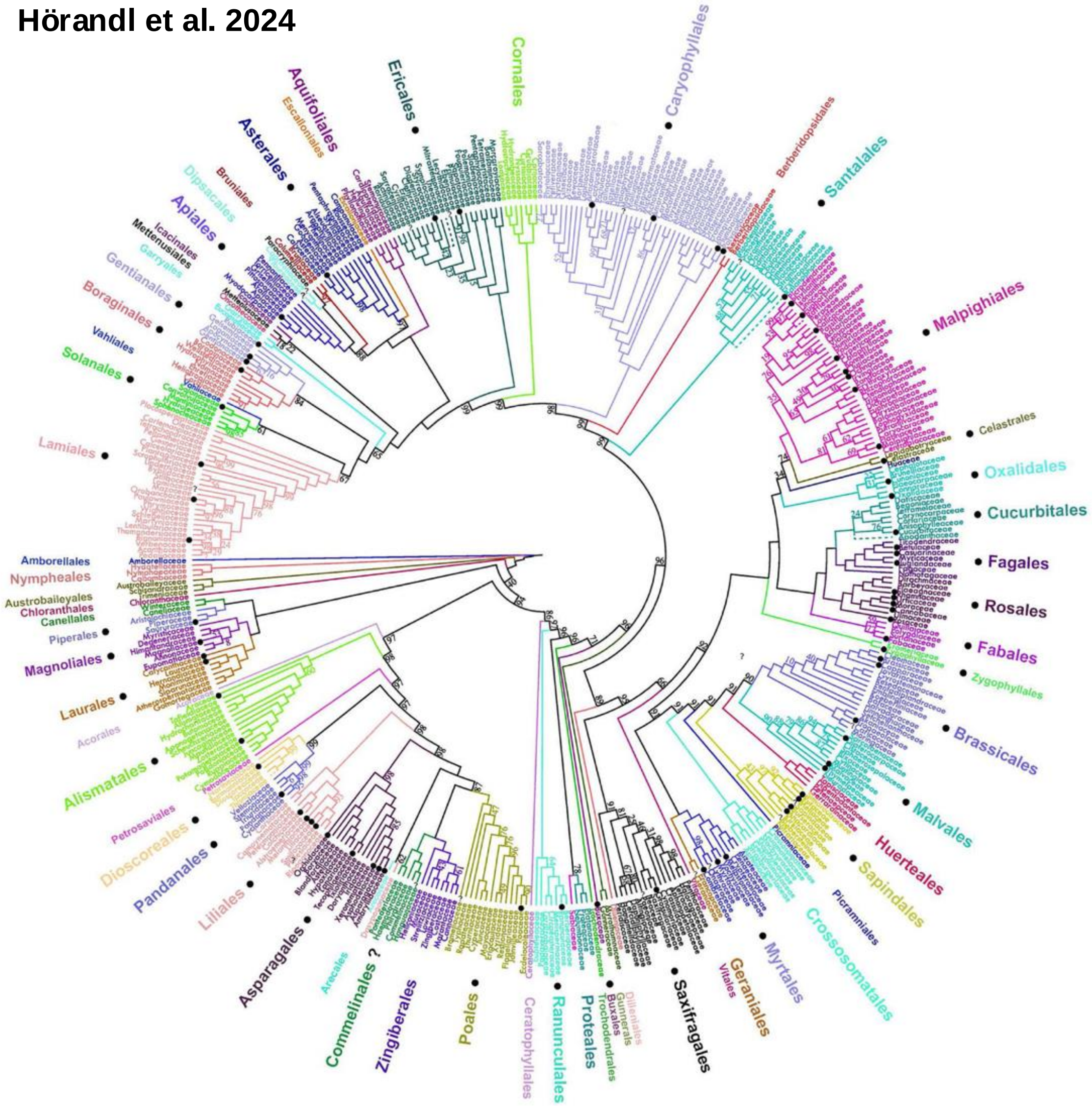


Endosperm: 5C (4m:1p)
Embryo (sexual): 3C (2m:1p)

Apomixis: role in evolution

Occurrence **Carman, 1997; Ozias-Akins & van Dijk, 2007**

Hörandl et al. 2024



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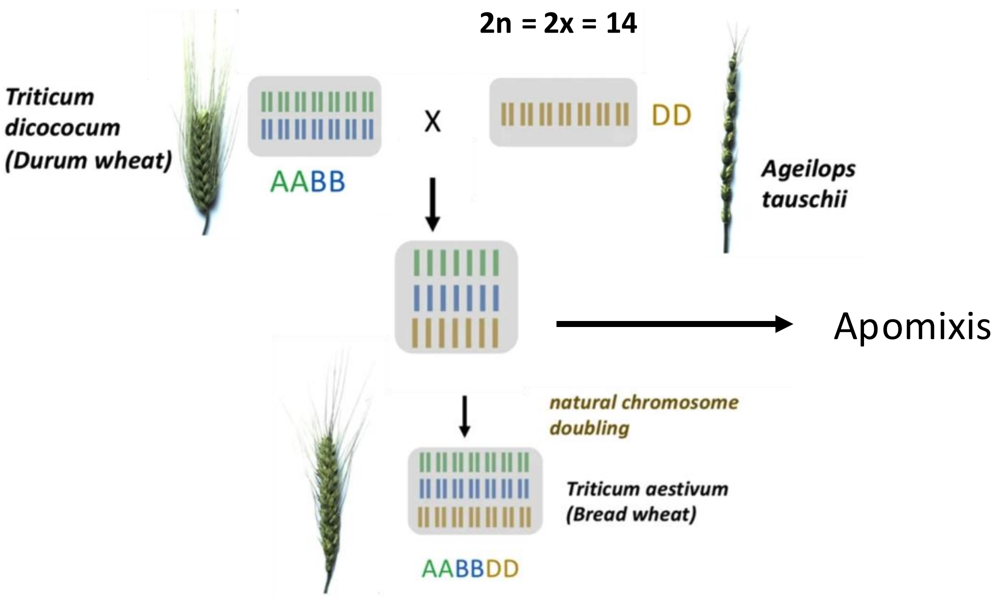


Modified from Rosyara et al. 2019

Apomixis: role in evolution

Occurrence

- **Darlington, 1939**: "Apomixis is an escape from sterility, but an escape into a blind alley of evolution.”
- However, this view has been found to be incorrect:
  -
  -
  -

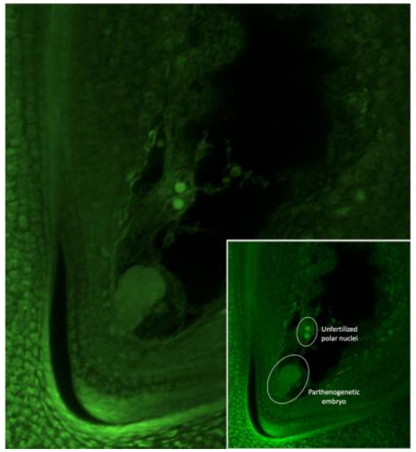
Dandelions (*Taraxacum* spp.)
Insideecology.com

Kentucky bluegrass (*Poa prantensis*)
thespruce.com

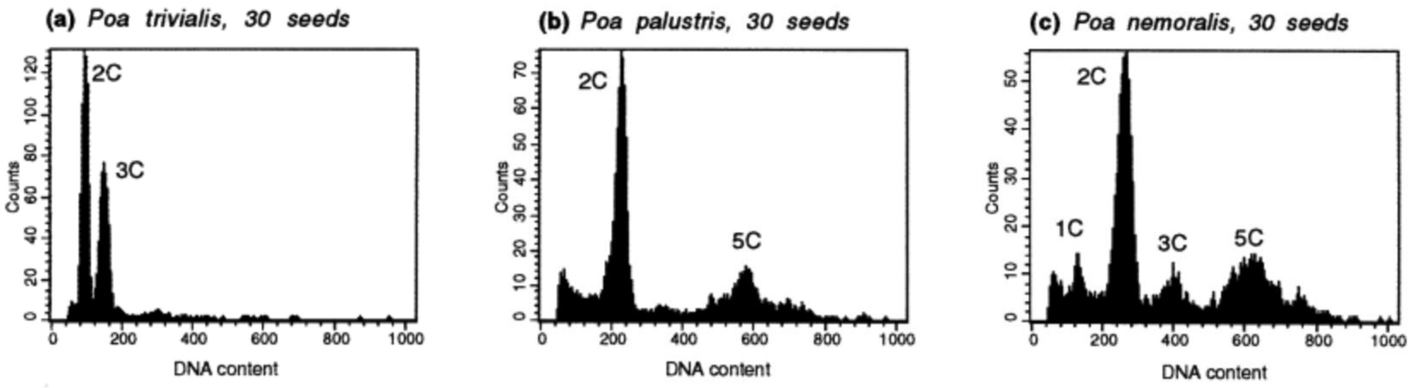
Indicators of Apomixis

Occurrence

Sidhu et al. 2022



Matzk et al, 2001



Genetic control of Apomixis

Ozias-Akins & Van Dijk, 2007

Species	Apomixis type	Loci	Genotype	Suppression of recombination
Brachiaria brizantha	Apospory, pseudogamous endosperm	1	Aaaa	–
Cenchrus ciliaris	Apospory, pseudogamous endosperm	1	Aaaa	+
Erigeron annuus	Diplospory, mitotic, autonomous endosperm	2	D/dd*) Fff	+ –
Hieracium caespitosum	Apospory, autonomous endosperm	2	Aaaa Pppp	– +
Panicum maximum	Apospory	1	Aaaa	+
Paspalum notatum	Apospory, pseudogamous endosperm	1	Aaaa	+
Paspalum simplex	Apospory, pseudogamous endosperm	1	Aaaa	+
Pennisetum squamulatum	Apospory, pseudogamous endosperm	1	Aaaa	+
Poa pratensis	Apospory	2	Aaaa Pppp	–
Ranunculus auricomus	Apospory, pseudogamous endosperm	1	Aaaa	??
Taraxacum officinale	Diplospory, meiotic, autonomous endosperm	3	Ddd Ppp	– +
Tripascum dactyloides	Diplospory, mitotic, pseudogamous endosperm	1?	Dddd	+

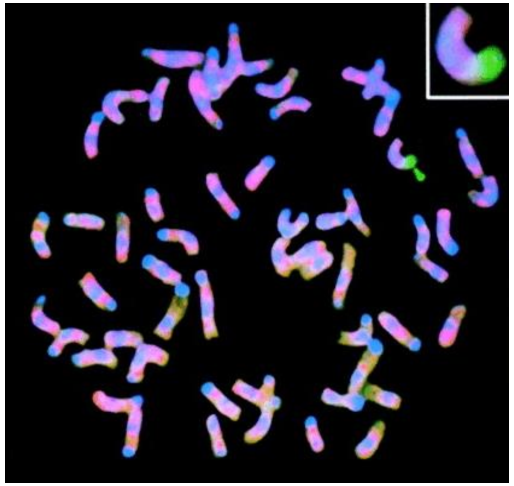
A: apospory, D: diplospory, P: parthenogenesis, F: fertilization factor

Genetic control of Apomixis

- Apomictic loci usually have suppressed recombination.

Simplex genotype → Low recombination → Tight linkage

- Difficulties in genetic mapping and introgression.



Goel et al. 2003. ASGR in *Pennisetum squamulatum* (2n = 8X = 56). Mitotic spread. ASGR is ~50 Mb long (almost ¼ of the chromosome).

Ozias-Akins & Van Dijk, 2007

Species	Apomixis type	Loci	Genotype	Suppression of recombination
Brachiaria brizantha	Apospory, pseudogamous endosperm	1	Aaaa	–
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Erigeron annuus	Diplospory, mitotic, autonomous endosperm	2	D/dd*) Fff	+ –
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Panicum maximum	Apospory	1	Aaaa	+
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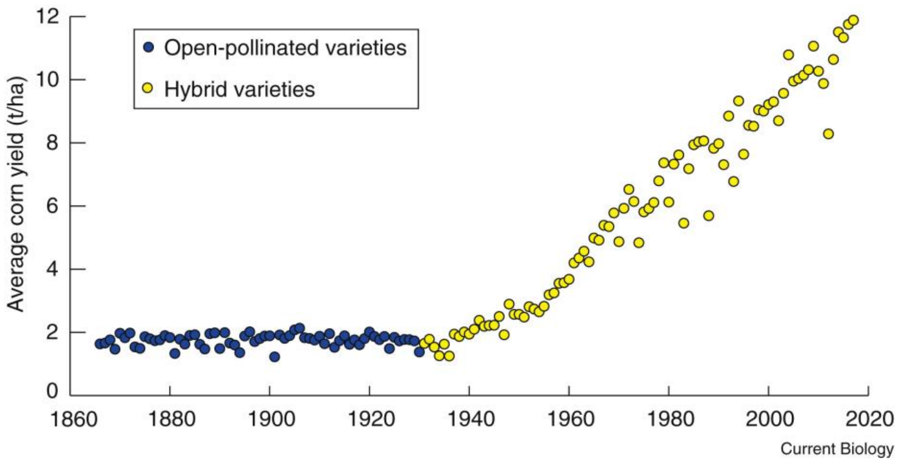
Poa pratensis	Apospory	2	Aaaa Pppp	–
Ranunculus auricomus	Apospory, pseudogamous endosperm	1	Aaaa	??
Taraxacum officinale	Diplospory, meiotic, autonomous endosperm	3	Ddd Ppp	– +
Tripascum dactyloides	Diplospory, mitotic, pseudogamous endosperm	1?	Dddd	+

A: apospory, D: diplospory, P: parthenogenesis, F: fertilization factor

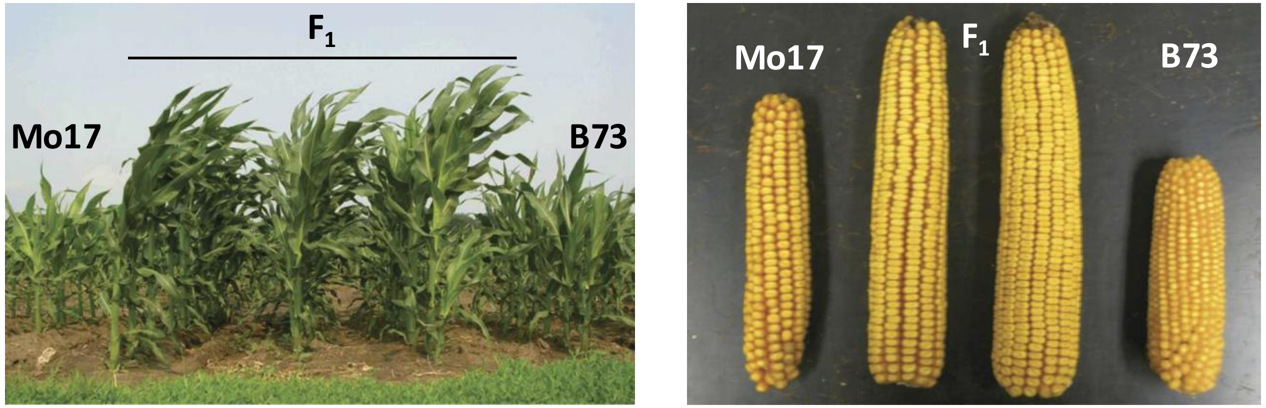
Why we care about Apomixis?

Hybrids

Hochholdinger and Baldauf, 2018

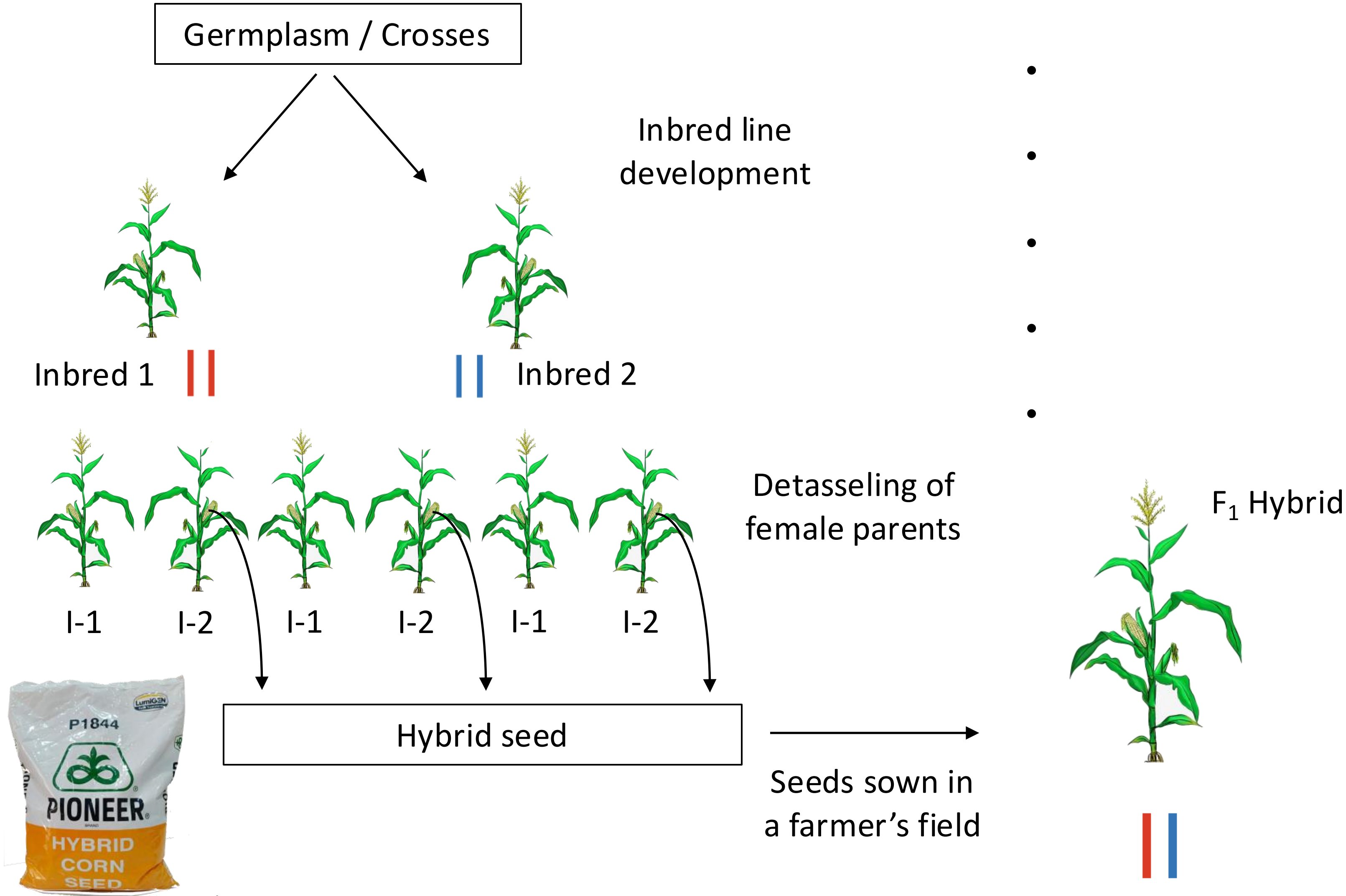


Springer and Stupar, 2007



Why we care about Apomixis?

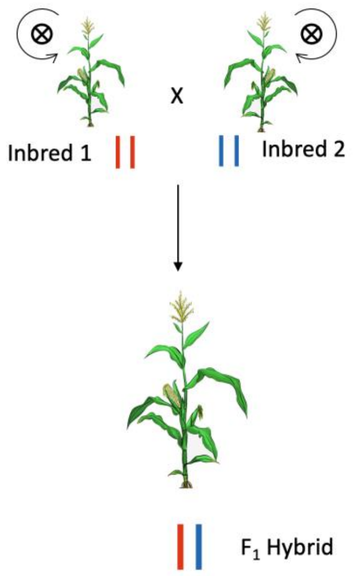
Hybrid seeds are expensive!

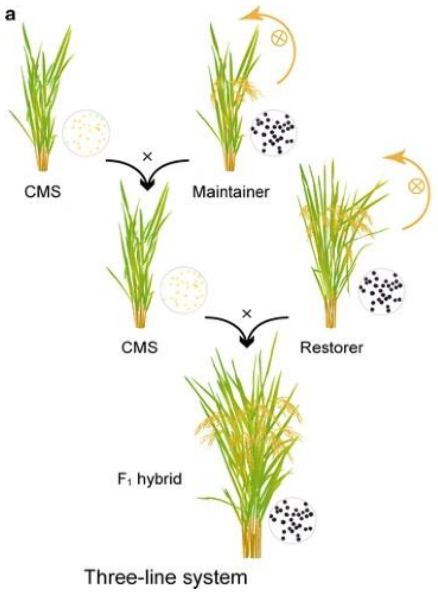


indiamart.com

Why we care about Apomixis?

Benefits **Hanna, 1987**





Fan and Zhang, 2017

Country ->	China	India
Total area under rice cultivation	30 m ha	45 m ha
Rice production (2020 – 21)	210 m tons	120 m tons
%age Hybrid rice	> 50 %	< 10 %

Data source: National Food Security Mission, India & National Bureau of Statistics, China

Breeding for Apomixis

Introgression from related species

Savidan, 2000; Sokolov and Khatyapova, 2001

Tripsacum dactyloides X *Zea mays*

Carman et al. 1985

Elymus rectisetus X *Triticum*

Wayne Hanna

Hanna, 1987; Dujardin & Hanna, 1983 – 1989, Kaushal et al. 2010

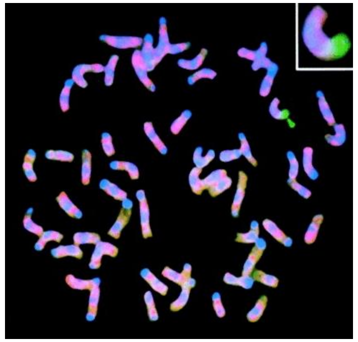
Pennisetum squamulatum X *Pennisetum glaucum*

Morgan et al. 1998

Slide adapted from Lovepreet Chahal

P. glaucum (2n = 14) ✖ *P. purpureum* (2n = 28)
⬇
F_1 (2n = 3x = 21)
⬇ Chromosome doubling
F_1 (2n = 6x = 42)

P. glaucum (2n = 2x = 14) ✖ *P. squamulatum* (2n = 8x = 56)
⬇
F1 (2n = 41 - 42) ✖ F_1 (2n = 6x = 42)
⬇
P. glaucum (2n = 4x = 28) ✖ Double cross (2n = 42)
⬇
P. glaucum (2n = 2x = 14) ✖ BC1 (2n = 32-39)
⬇
P. glaucum (2n = 2x = 14) ✖ BC2 (2n = 32-39)
⬇
P. glaucum (2n = 2x = 14) ✖ BC3 (2n = 29) → continue to …. BCx



tifton.caes.uga.edu, clearview-farm.com, sellomarket.com, istockphoto.com

Engineering Apomixis.

Requirements

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-
-

1. Engineering Apomeiosis

Meiosis vs mitosis

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-
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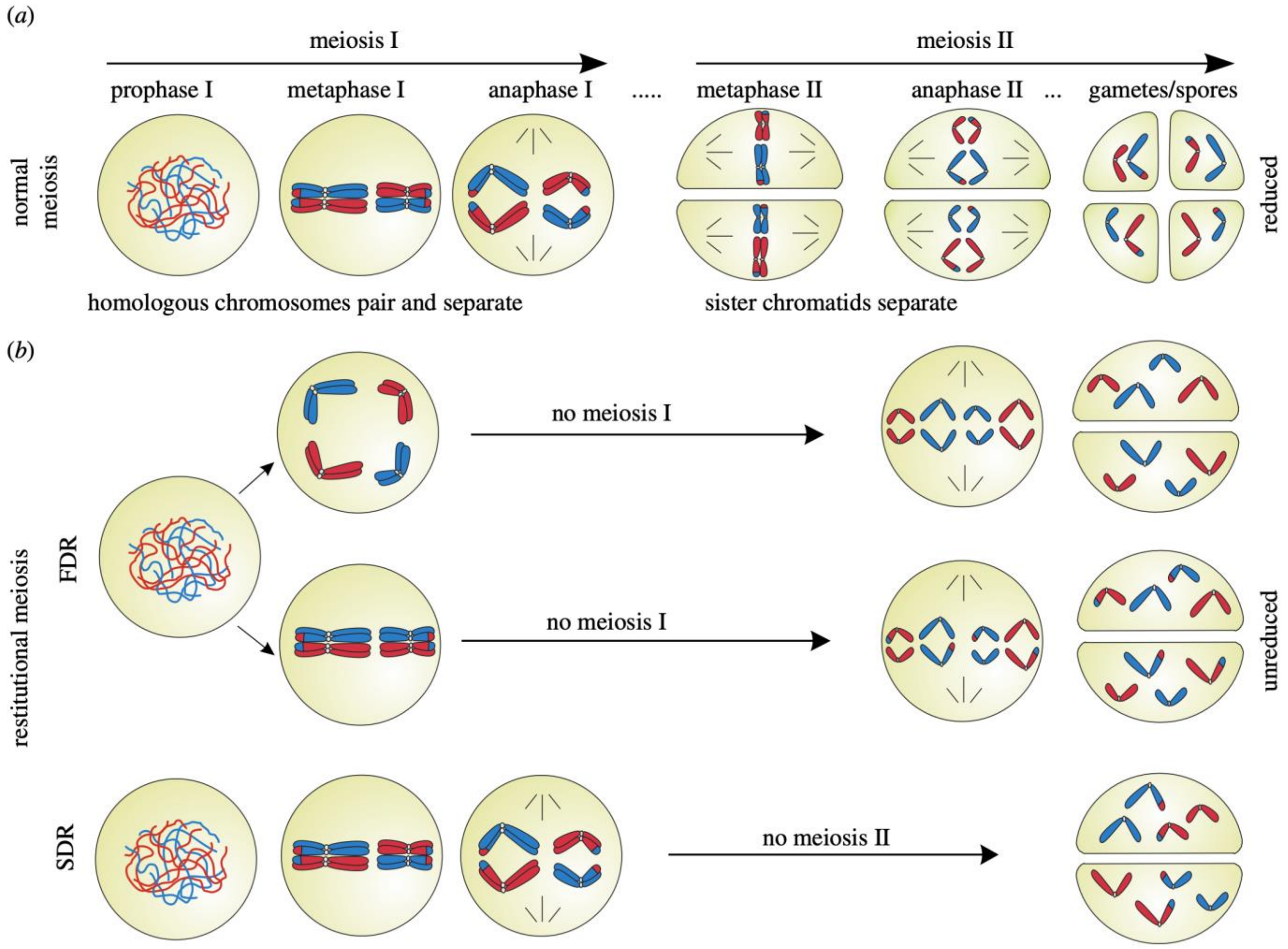
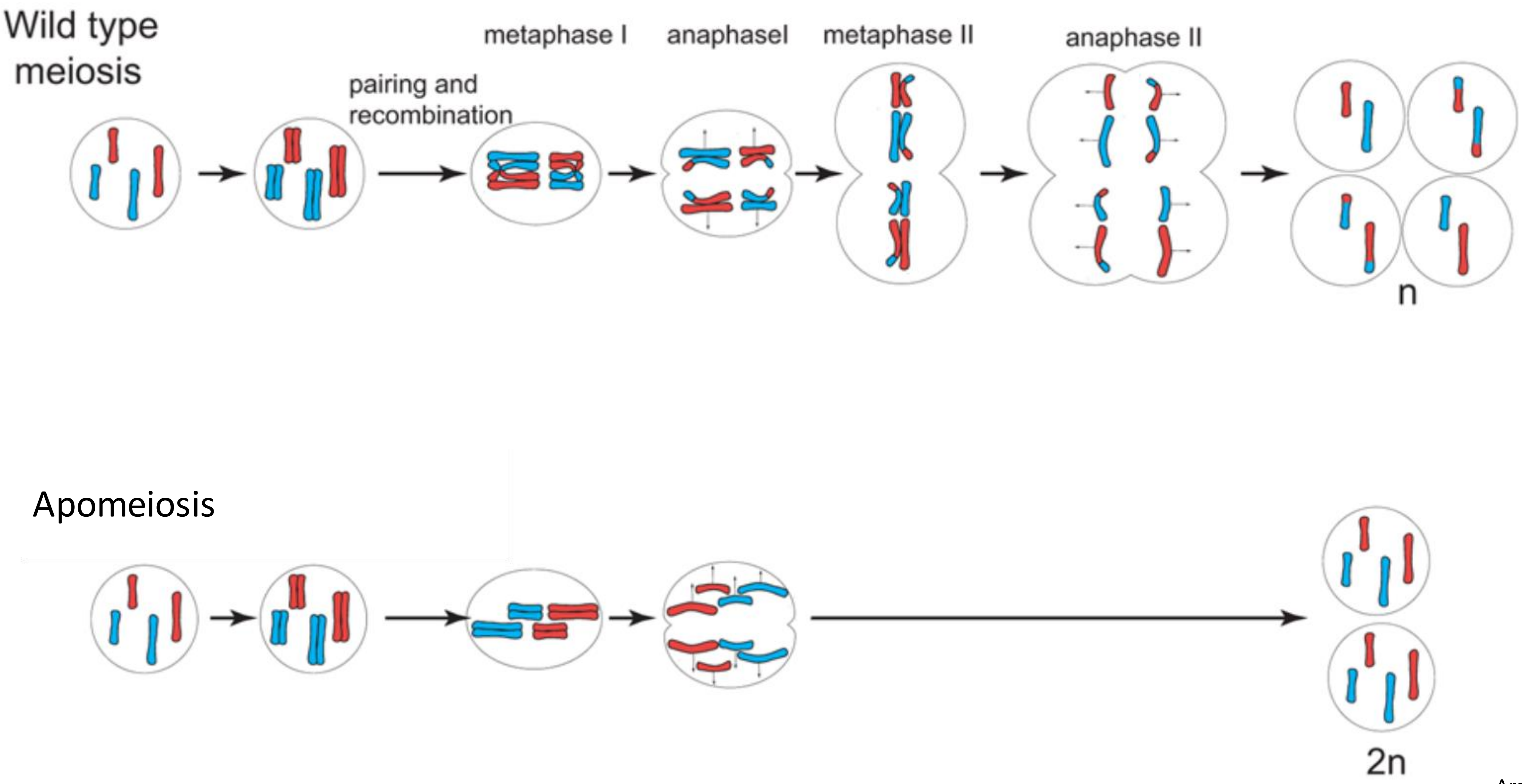
Mirzaghaderi and Horandl. 2016



Engineering Apomeiosis.

d'Erfurth et al. 2009

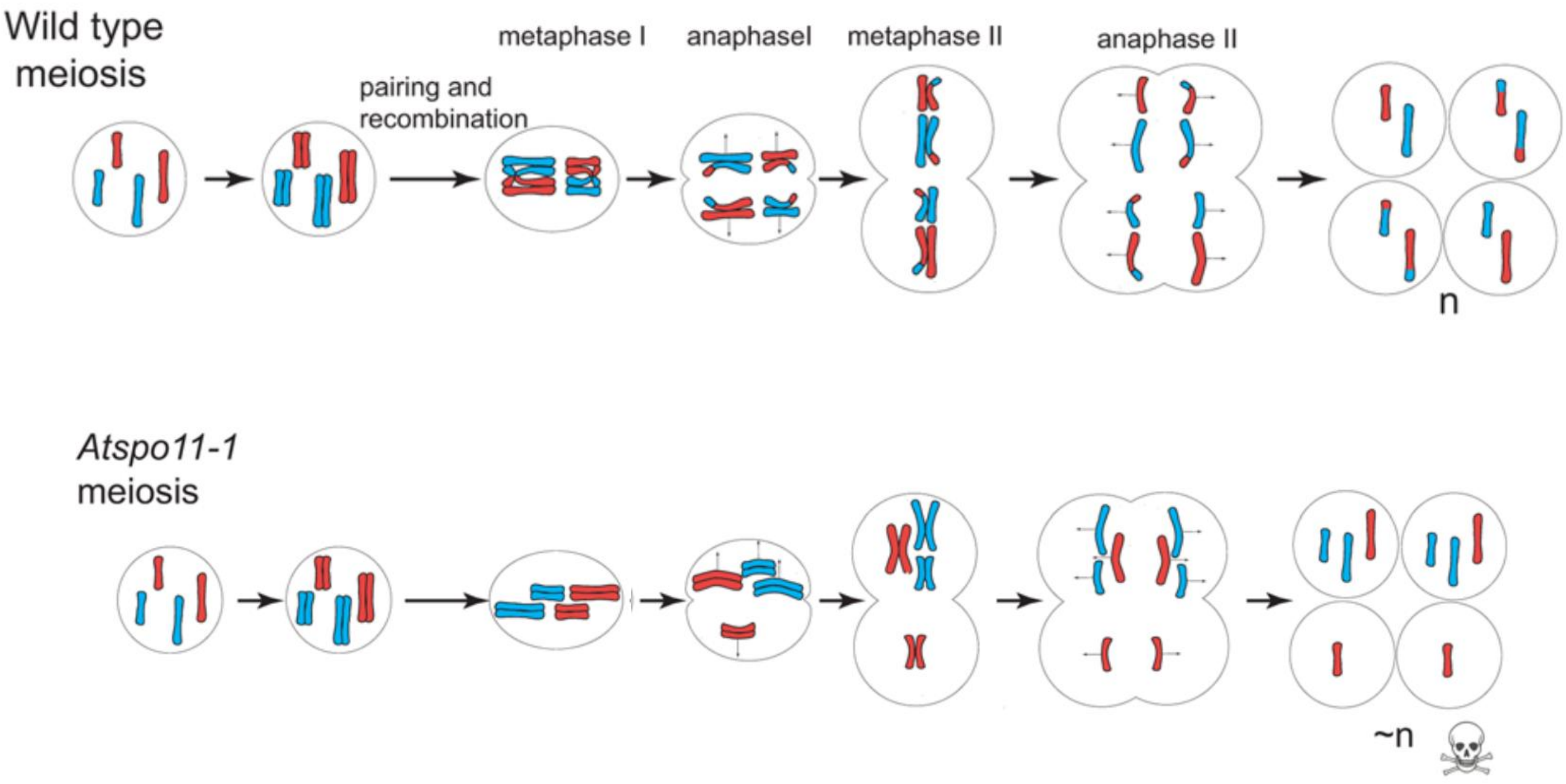


Raphaël Mercier

Arabidopsis: botanic.cam.ac.uk

Engineering Apomeiosis.

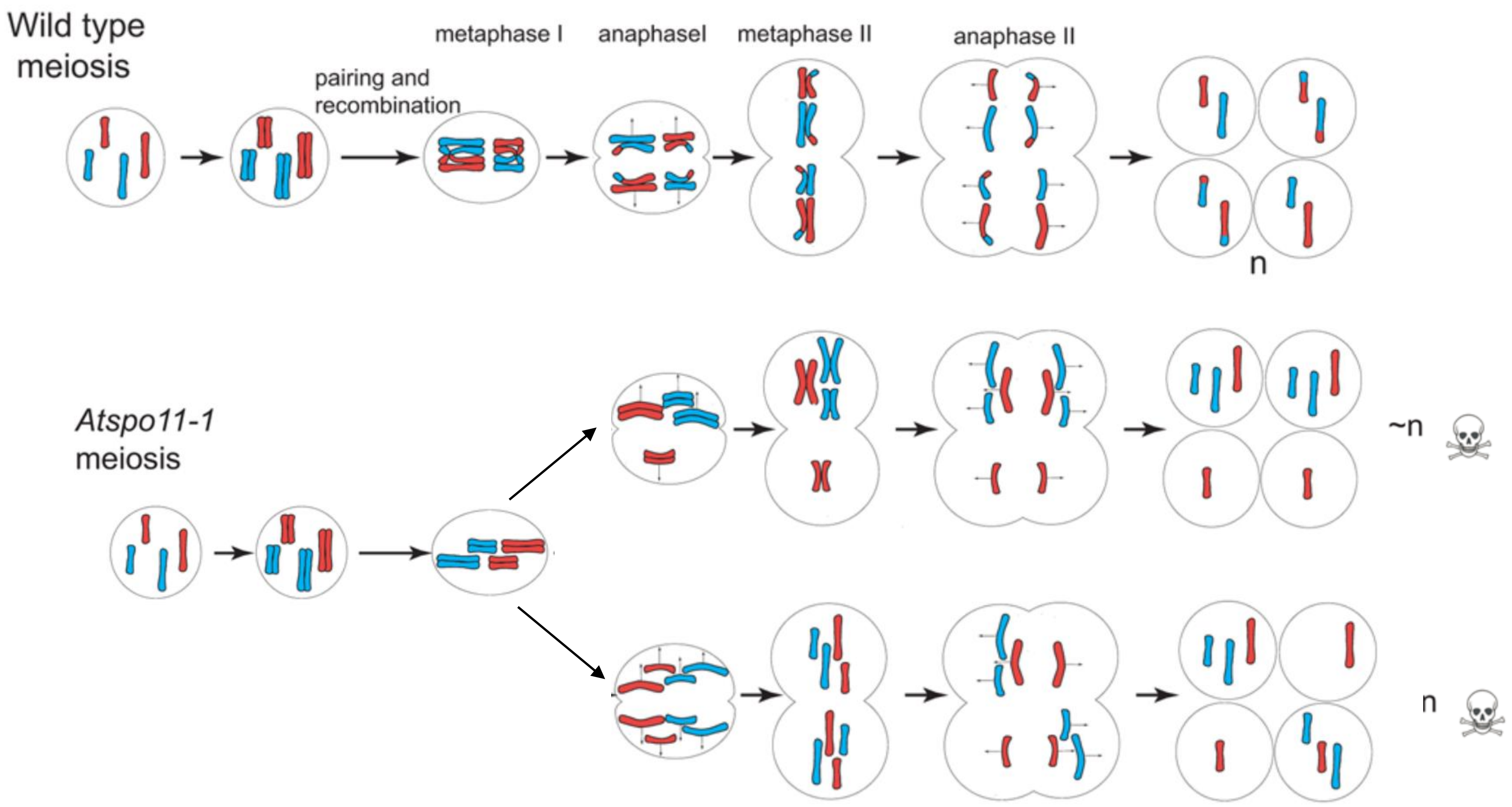
1.



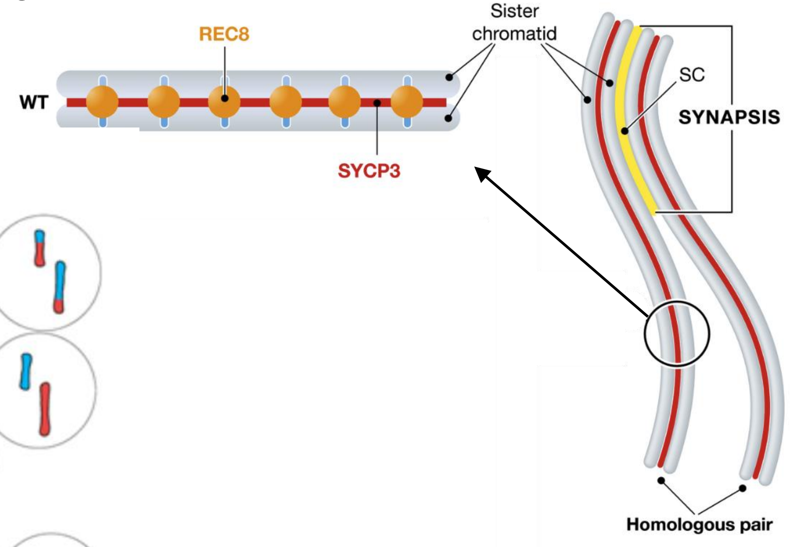
d'Erfurth et al. 2009

Engineering Apomeiosis.

2.



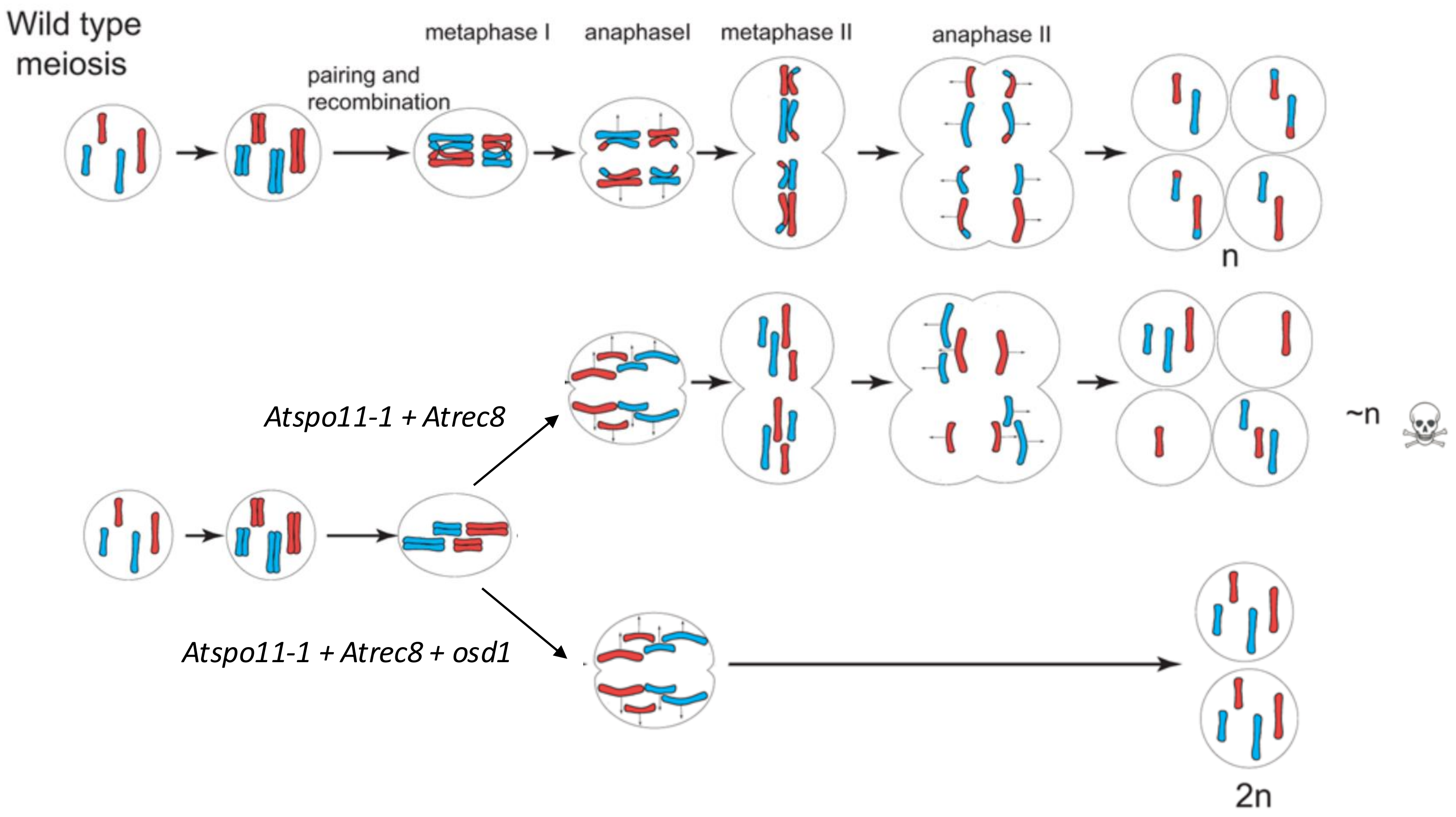
Ishiguro & Watanabe. 2016



d'Erfurth et al. 2009

Engineering Apomeiosis.

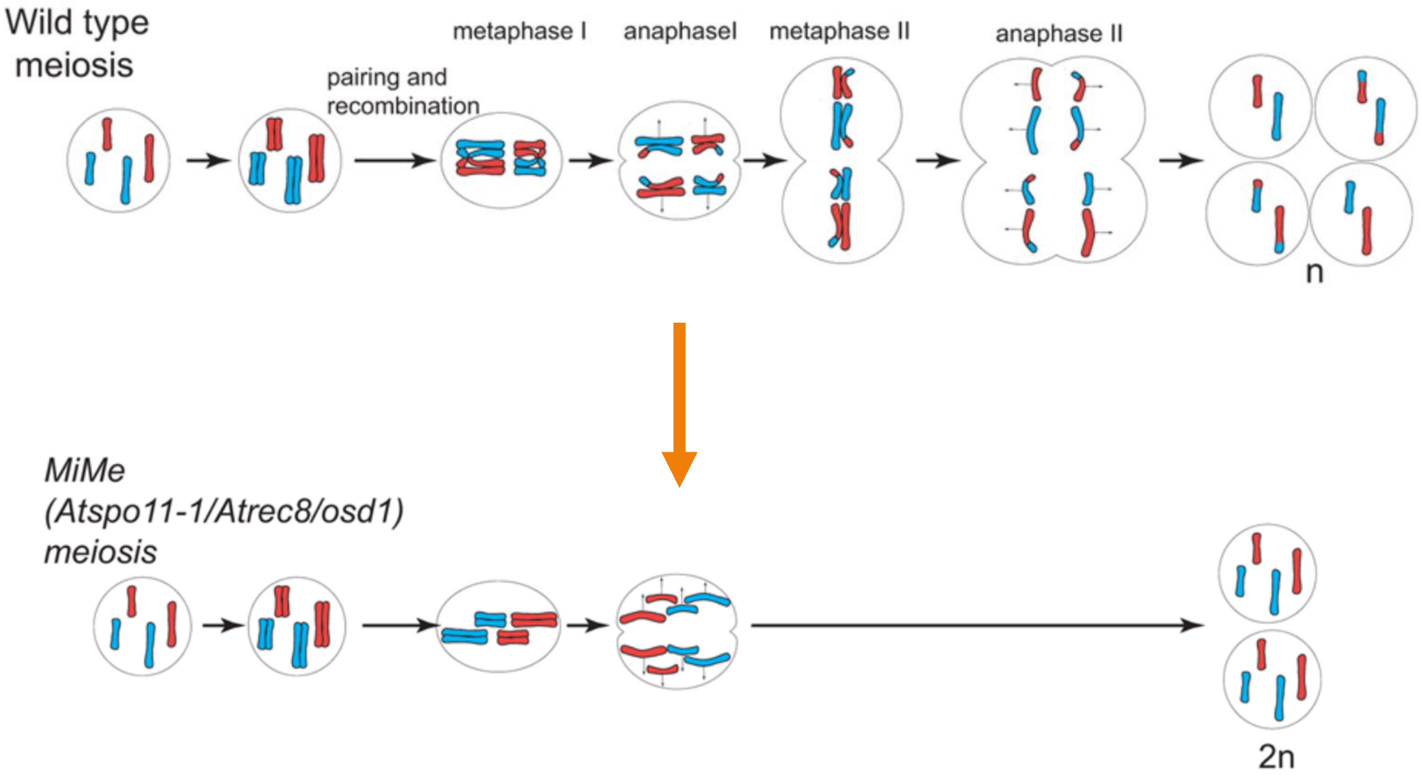
3.



d'Erfurth et al. 2009

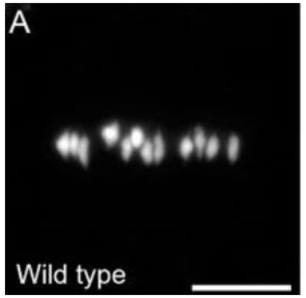
Engineering Apomeiosis.

d'Erfurth et al. 2009



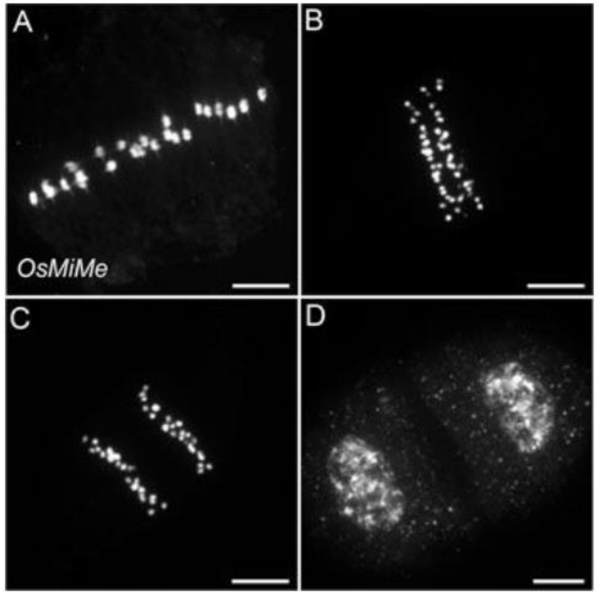
Mieulet et al., 2016

- Engineering *MiMe* in rice with CRISPR.



Wild type rice (2n = 2X = 24)

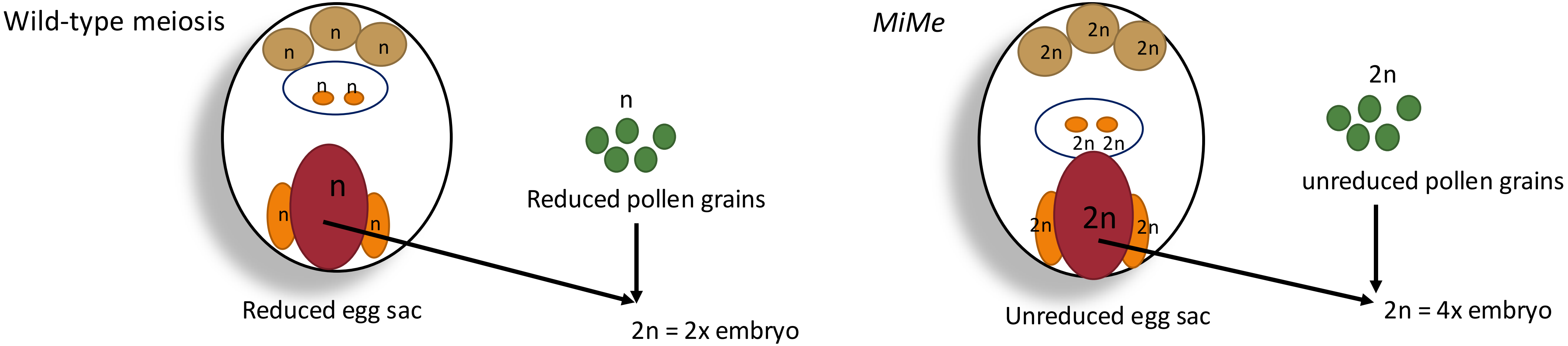
MiMe rice



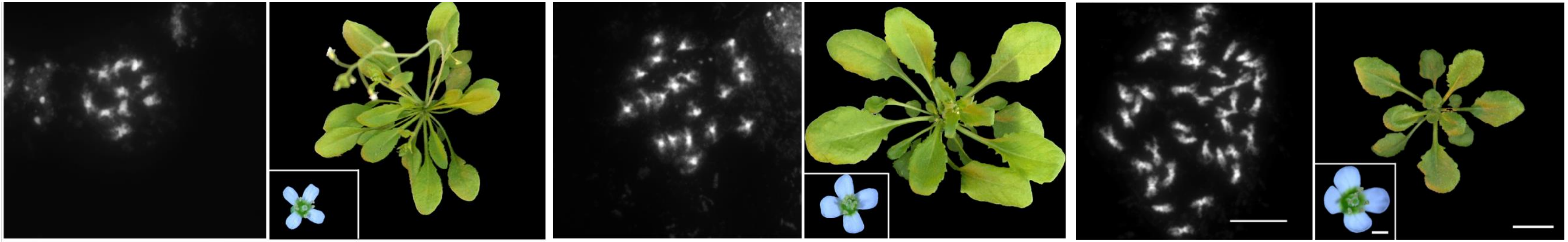
MiMe alone ?

Graphics by Lovepreet Chahal

d'Erfurth et al. 2009

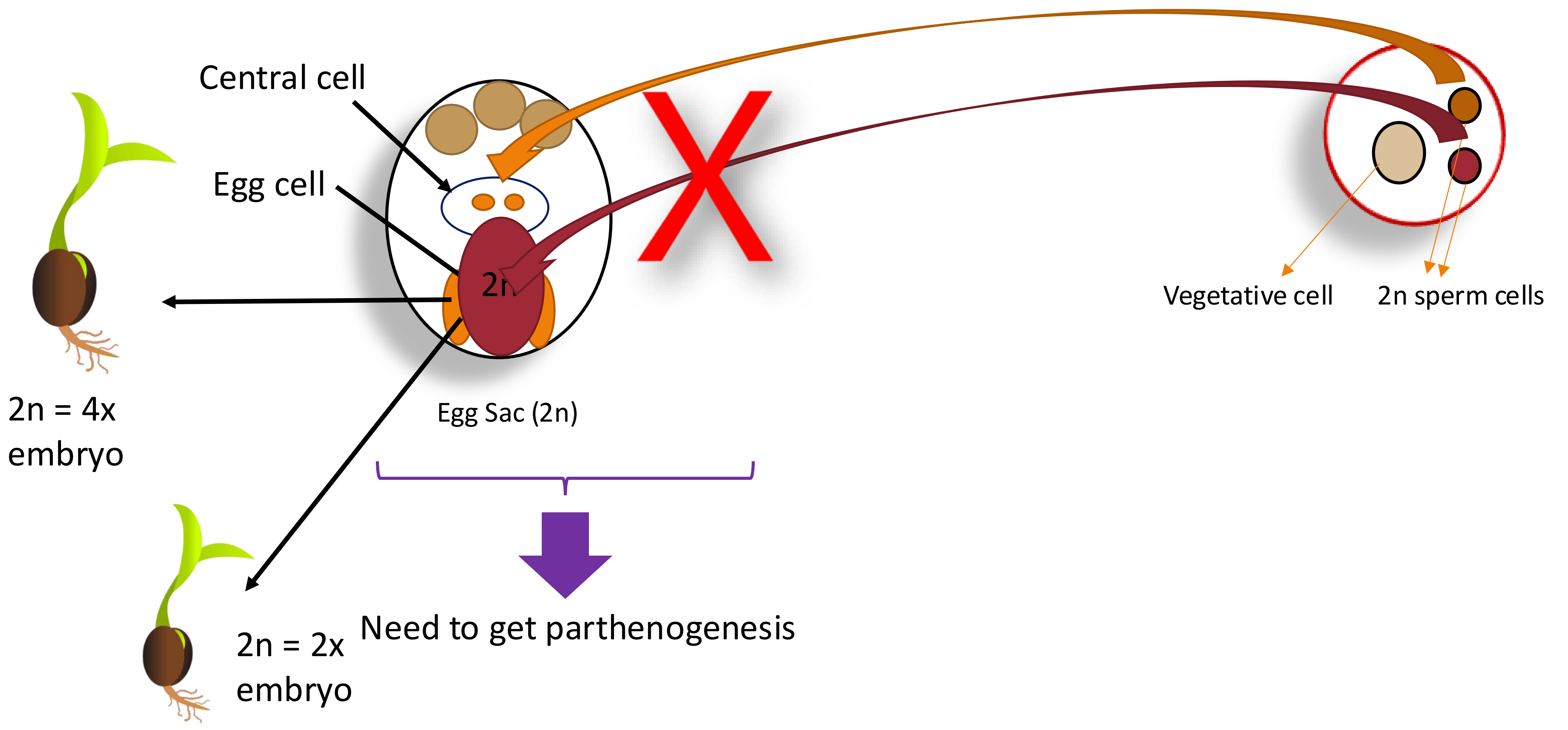


T_0: 2n = 2x = 10 T_1: 2n = 4x = 20 T_2: 2n = 8x = 40



MiMe + Parthenogenesis

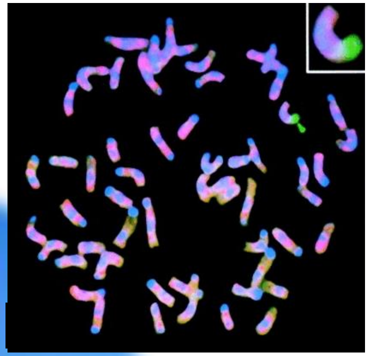
Slide by Lovepreet Chahal



PsASGR-BBML can induce parthenogenesis

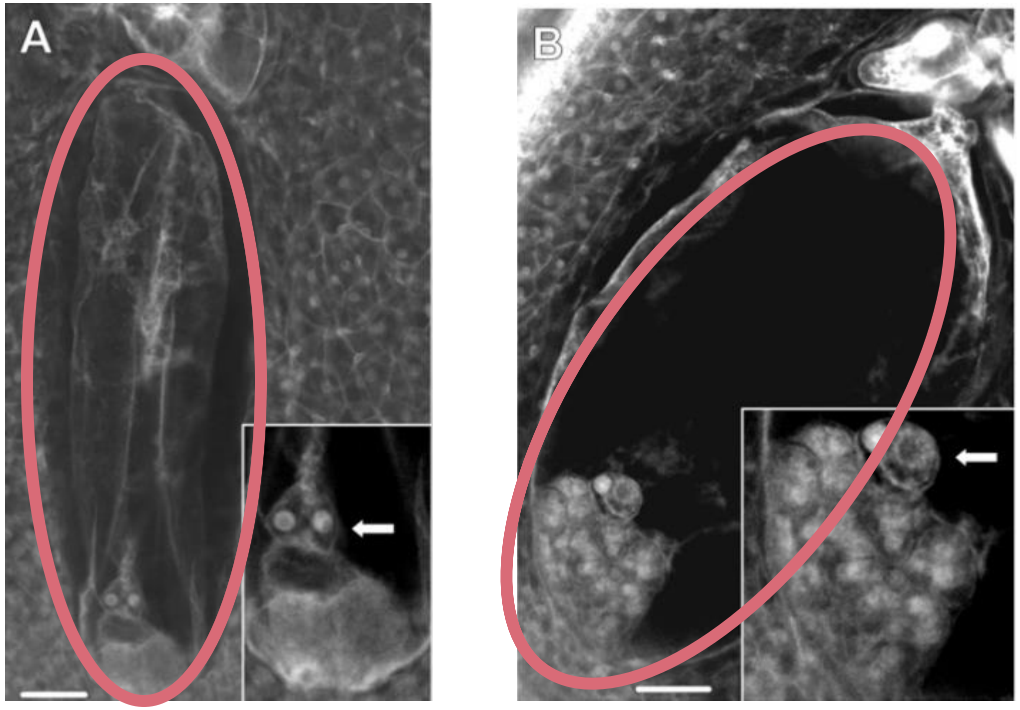
Conner et al. 2015

Slide by Lovepreet Chahal



Pennisetum squamulatum *Pennisetum glaucum*

Without fertilization



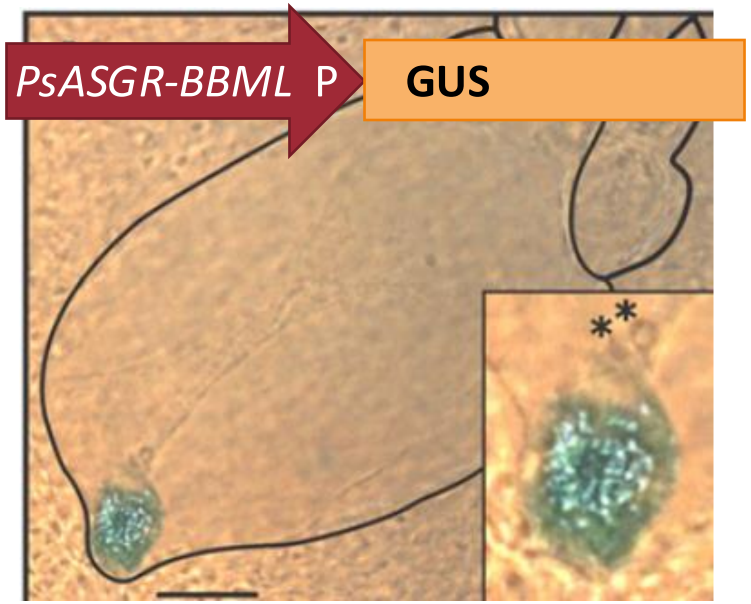
Wild type

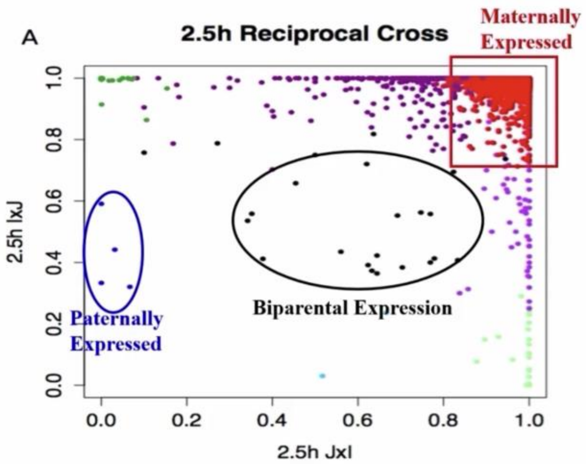
PsASGR-BBML

oziasakinslab.org; cdn.pixabay.com

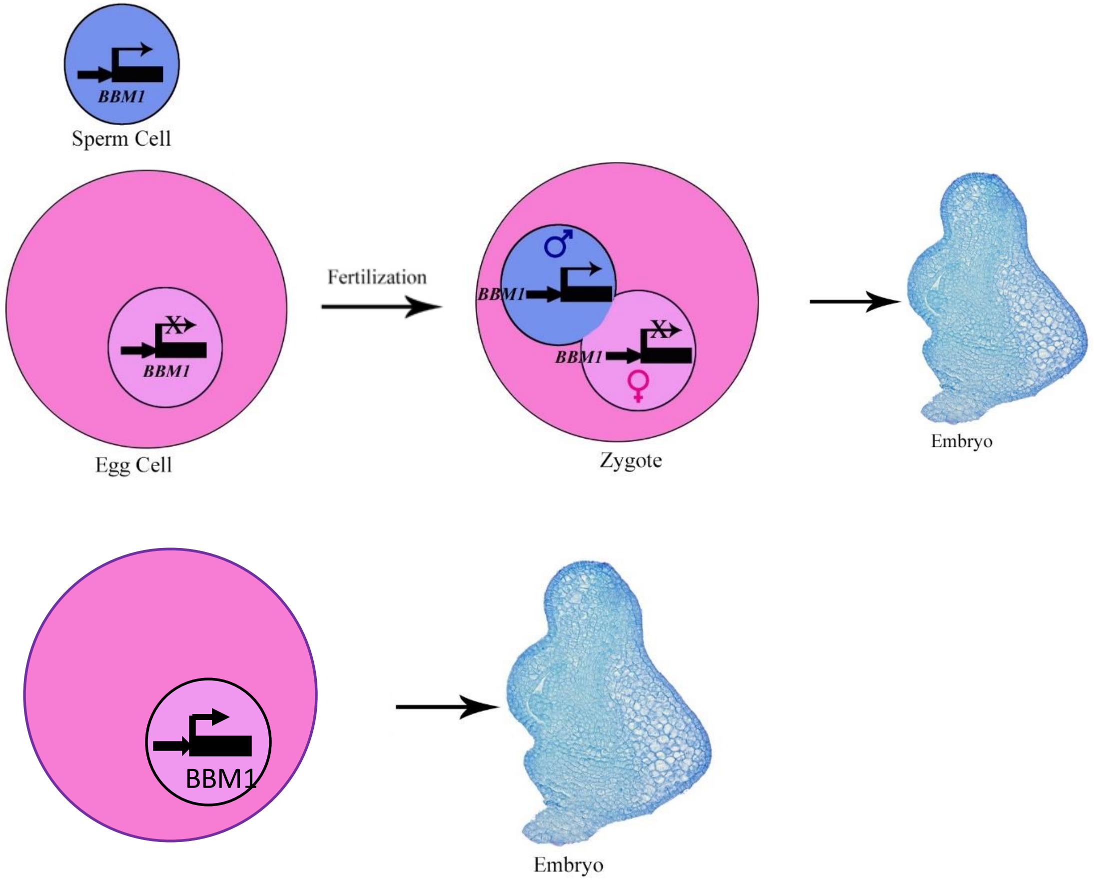
Baby boom like genes

Conner et al. 2015



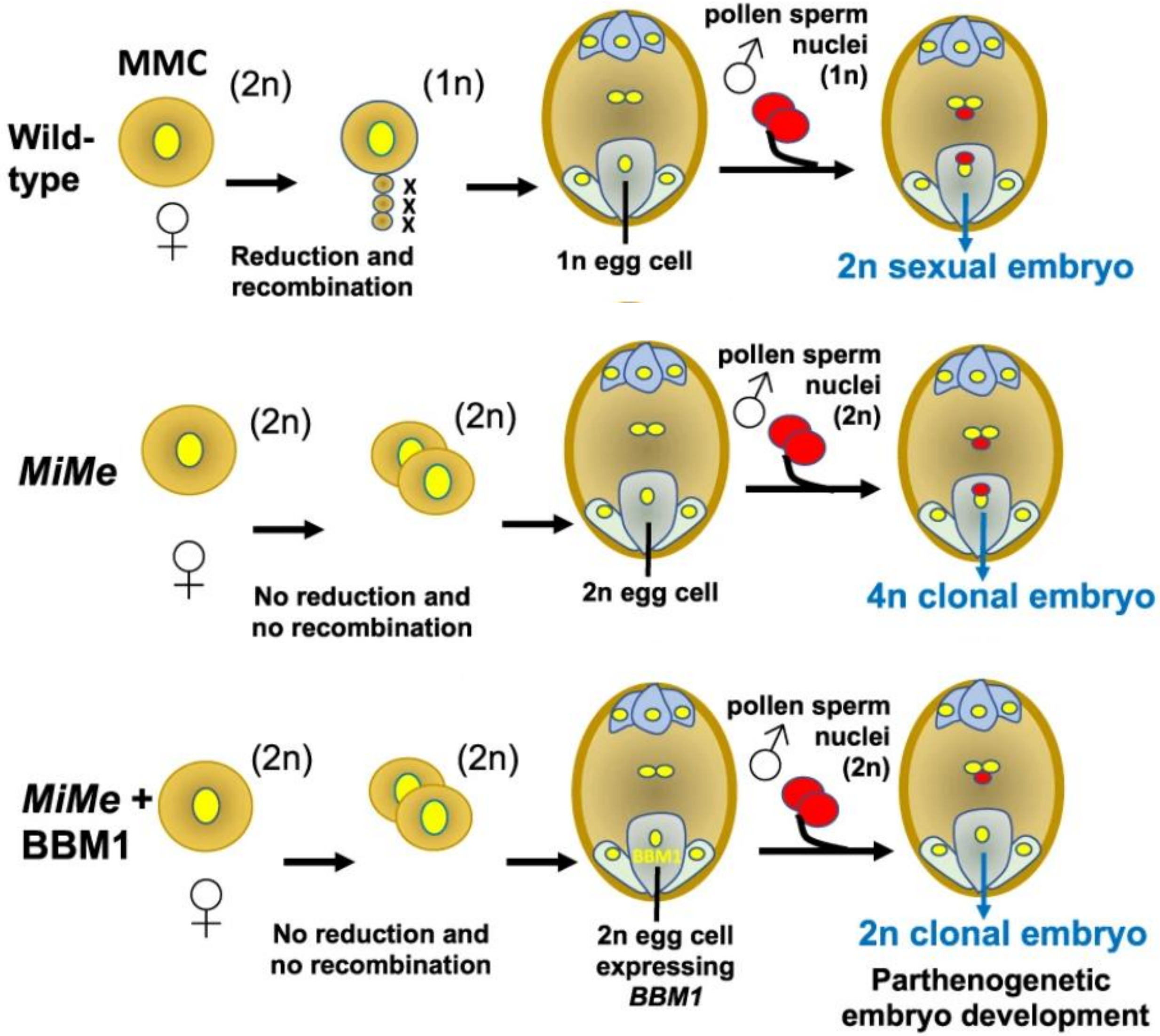


Khanday et al, 2019

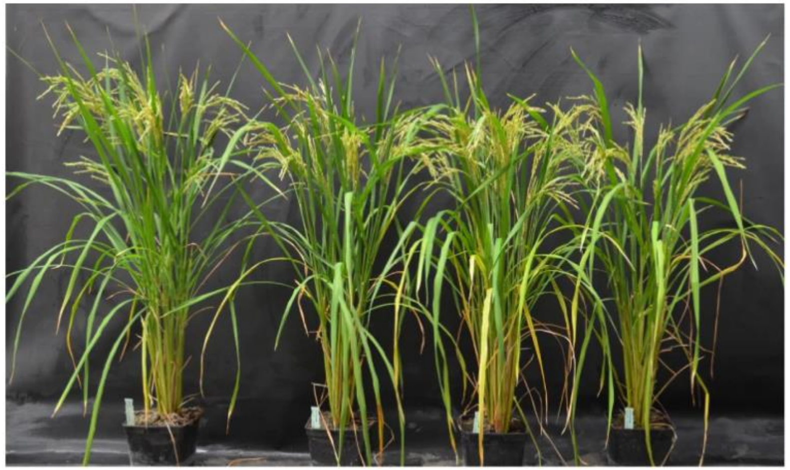


Synthetic apomixis in Rice

Khanday et al, 2019; Vernet et al, 2022



F1 — F2 progeny —



F1 — T1 apomictic progeny —