Meiosis: Apomixis

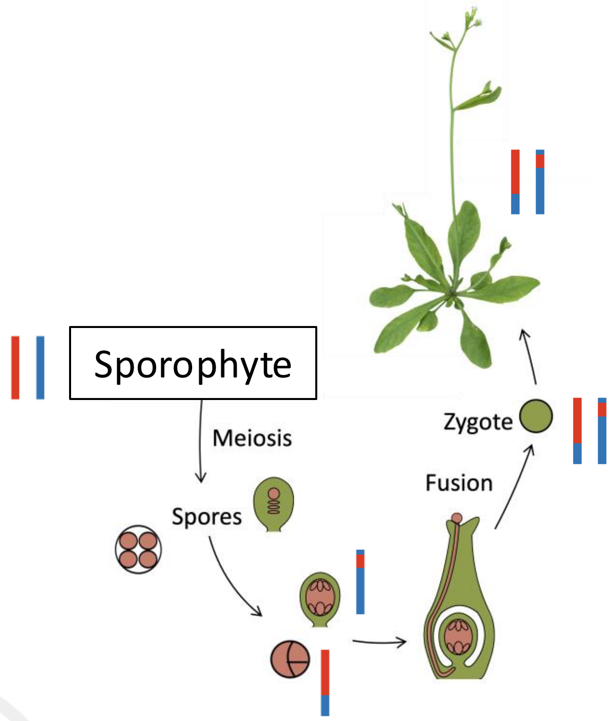
Section IV-F

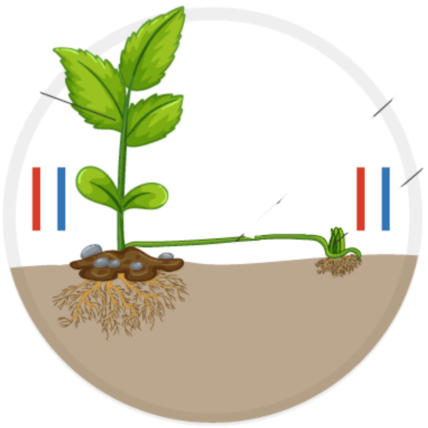
Modes of reproduction in plants

Sexual

Asexual

Apomixis: asexual reproduction through seeds.





byjus.com reddit/cannabisbreeding (UmamiSeedCo)

Modes of reproduction in plants

Sexual vs Asexual reproduction

● pro ● con

Sexual reproduction
Genetically diverse progeny
Seeds: easy dispersal over space and time
Needs time & energy

Apomixis
Clonal progeny
Seeds
Needs time & energy

Vegetative reproduction
Clonal progeny
Vegetative materials: bulky and perishable
Fast & less energy intensive

Little bit of history.. back in 1841

- *Alchornea ilicifolia*
- John Smith (1841):

Wikipedia/Ethel Aardvark

The Northern Lads/ Ron McEwen

History of Apomixis

Mendel **Bicknell et al. 2016; Nogler, 2006; Van Dijk and Ellis, 2016, Correns 1905**

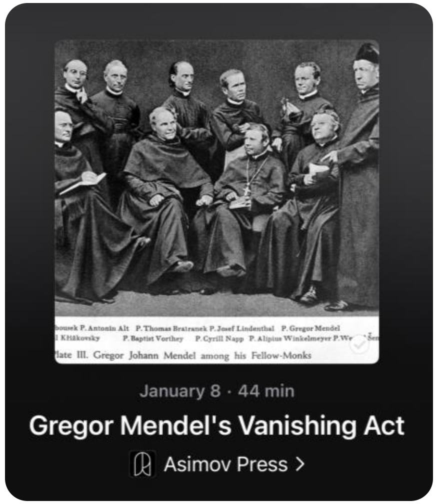
- Three laws of inheritance:

> *"I attempted to inspire some control experiments, and for that reason discussed the Pisum experiments at the meeting of the local society of naturalists.*
> *I encountered, as was to be expected, divided opinion; however, as far as I know, no one undertook to repeat the experiments"*

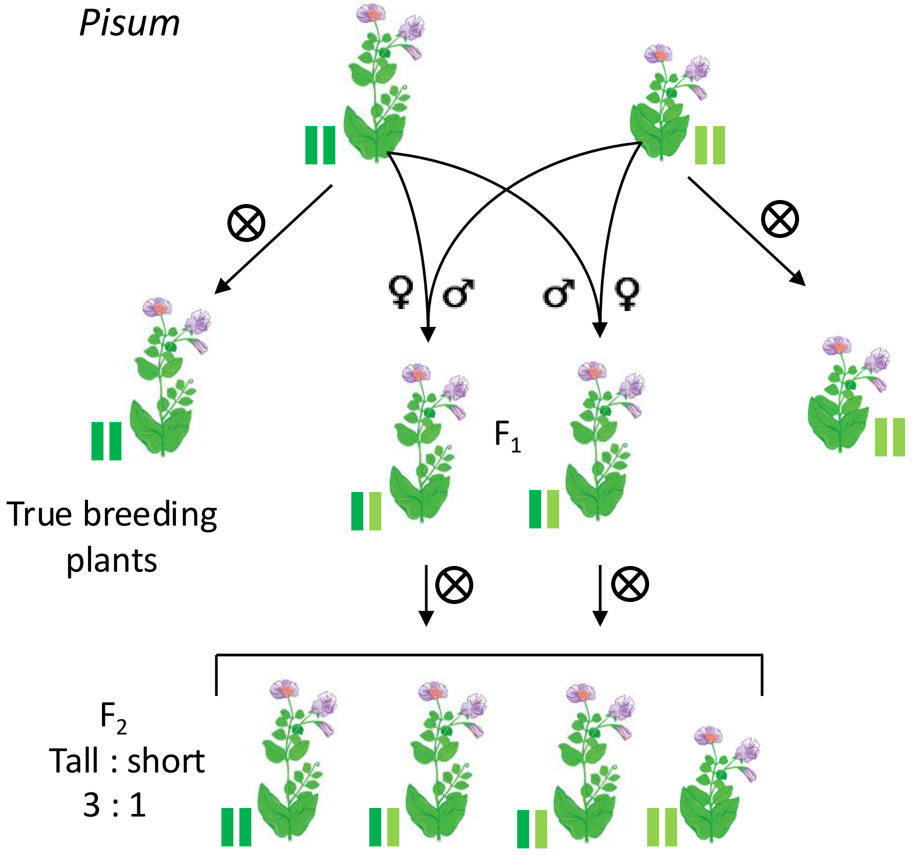
- Worked on several species:

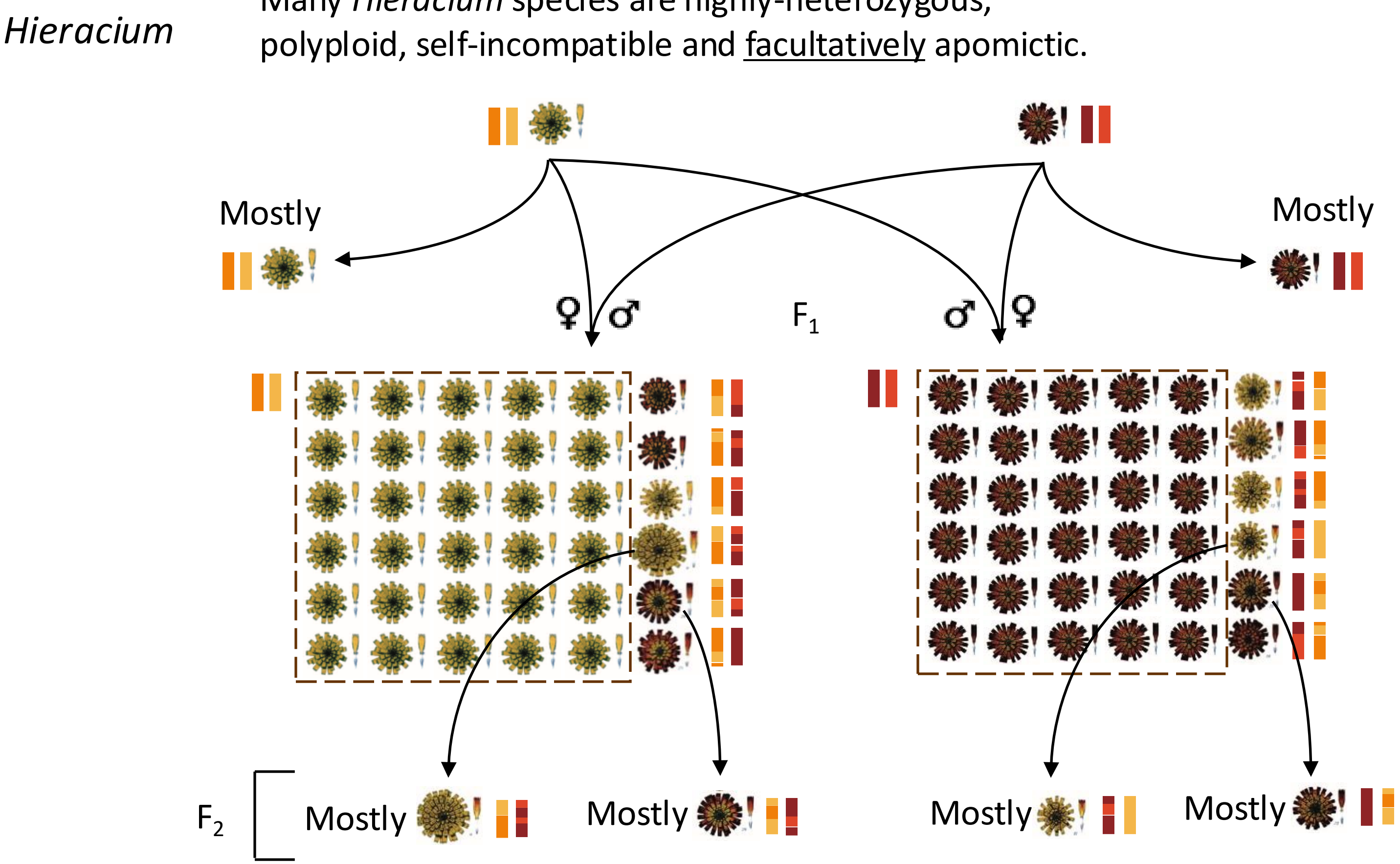
> *"I knew that the results I obtained were not easily compatible with our contemporary scientific knowledge, and that under the circumstances, publication of one such isolated experiment was doubly dangerous; dangerous for the experimenter and for the cause he represented. Thus, I made every effort to verify, with other plants, the results obtained with Pisum"*

Podcast



History of Apomixis





Many *Hieracium* species are highly-heterozygous, polyploid, self-incompatible and facultatively apomictic.

"In Pisum, the hybrids (. . .) have the same appearance in every instance; their progeny, however, are variable and segregate according to a distinctive law. In Hieracium, the direct opposite seems to reveal itself, based on the experiments conducted to date . . . I must admit to you, honored friend, how greatly I was deceived in this respect."

prodosgames.com, ck12.org, Hieracium flowers modified from Ostenfeld (1910).

History of Apomixis

Mendel **Bicknell et al. 2016**

- Classified inheritance in plants into two types:
  1.
  2.

	Pisum	*Hieracium*
	Uniform F_1	Variable F_1
	Variable F_2	Uniform F_2

In a letter to Nägeli:

> "At this point, I cannot hold back remarking that it must be noticed that the hybrids of *Hieracium* show an almost opposite behavior when compared with those of *Pisum*. We are here, obviously, confronted with only isolated phenomena, which are the emanation of a higher general law."

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> "I am really unhappy about having to neglect my plants and bees so completely. Since I have a little spare time at present, and since I do not know whether I shall have any next spring…"

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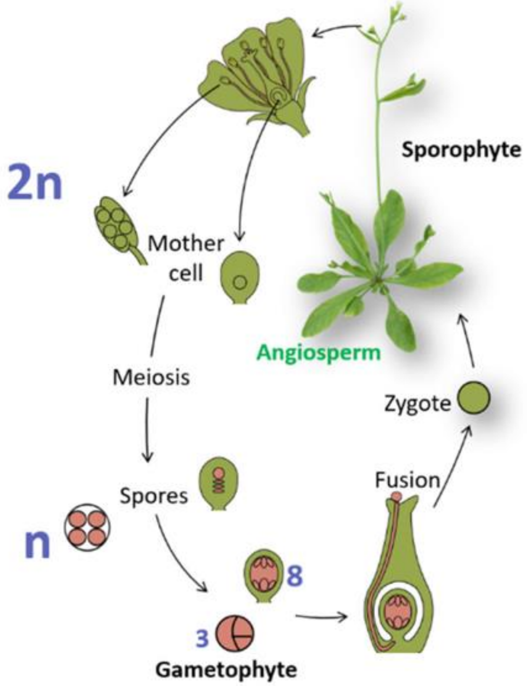
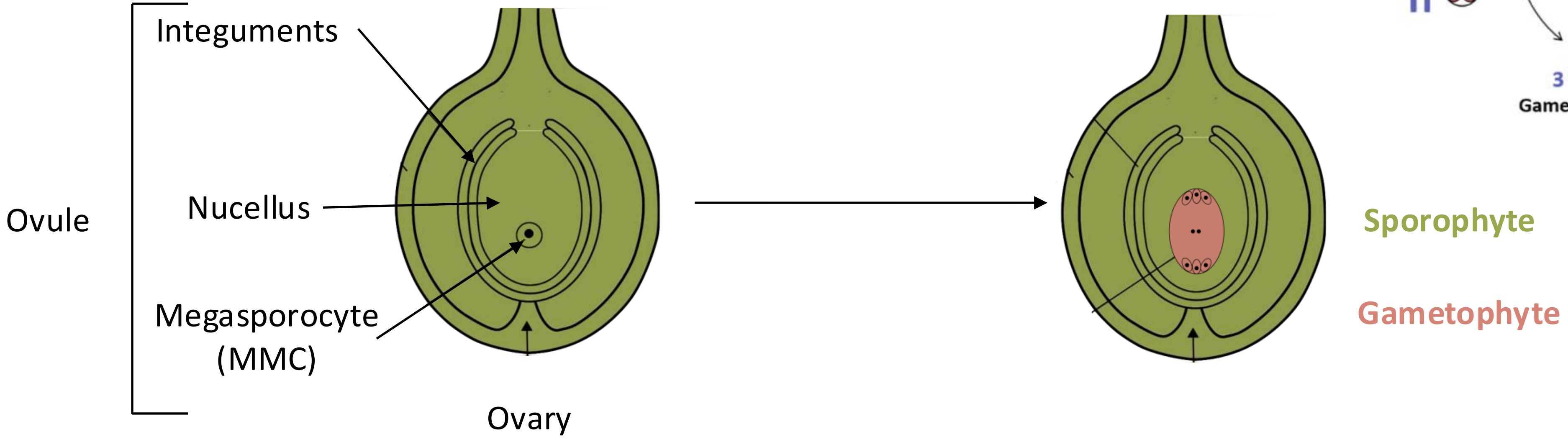
Types of Apomixis

Terminology

- Sporophyte
    -
- Gametophyte
    -
    -
    -



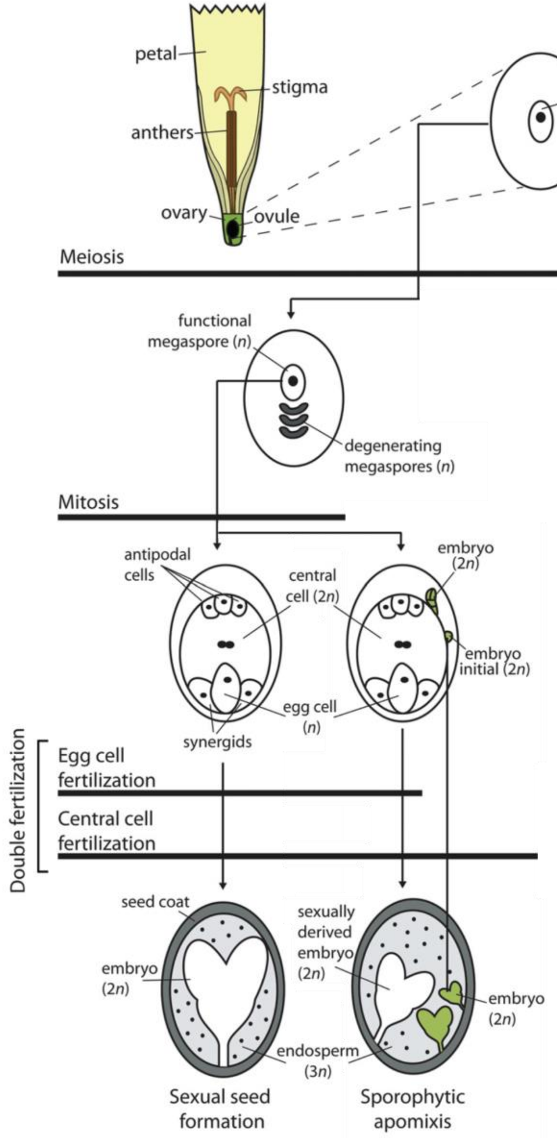


Wikipedia/Tameeria

Types of Apomixis

Sporophytic apomixis

Hand and Koltunow, 2014

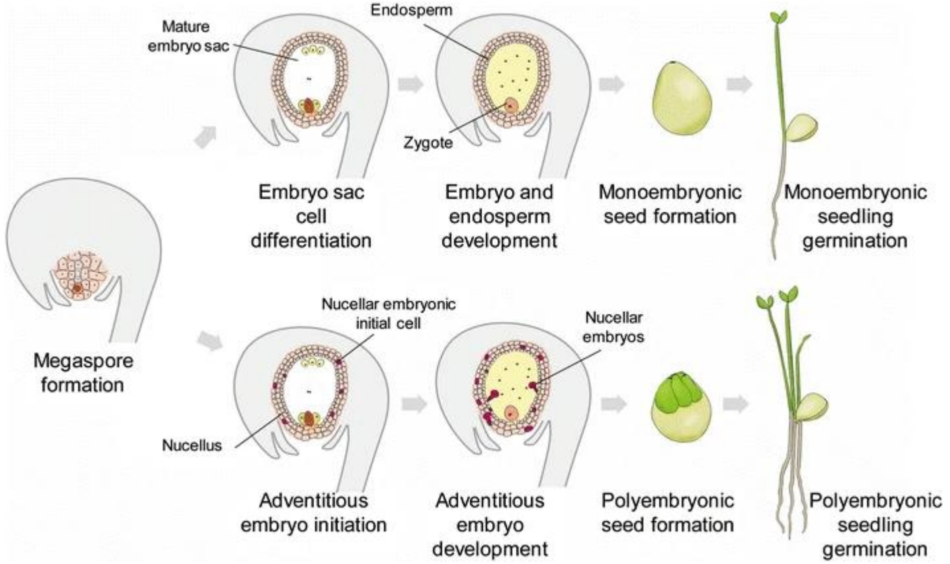


Types of Apomixis

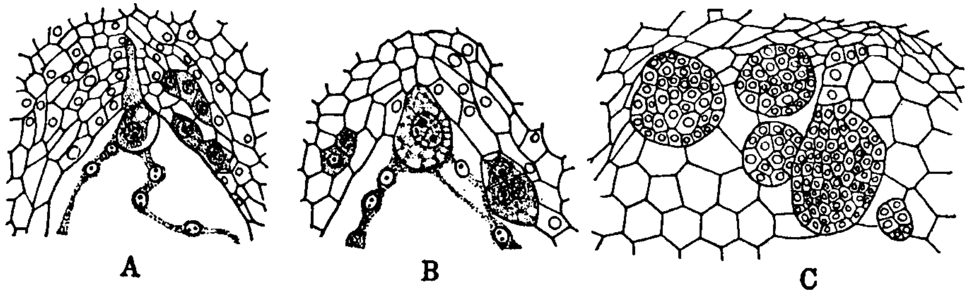
Sporophytic apomixis

Zhang et al., 2018

Citrus

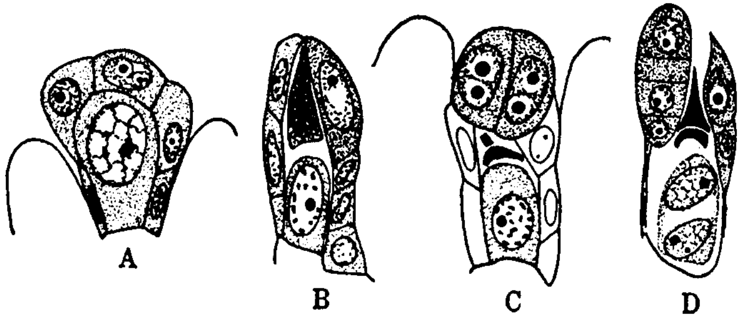


www.paramountplants.co.uk



Adventive embryos in *Citrus trifoliata*. A. Zygote, densely cytoplasmic nucellar cells. B. More advanced. C. Zygotic & somatic embryos growing into endosperm. (Maheshwari, 1950 after Osawa, 1912).

Wikipedia/Photo2222



Adventitious embryony in *Nigritella nigra*. A. Megaspore mother cell. B. Dyad stage. C. Functional megaspore, degenerating megaspores, and enlarged nucellar cells. D. Two nucleate egg sac & somatic embryos forming from the nucellus (Maheshwari, 1950 after Afzelius, 1928).

Types of Apomixis

Gametophytic apomixis

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Diplospory

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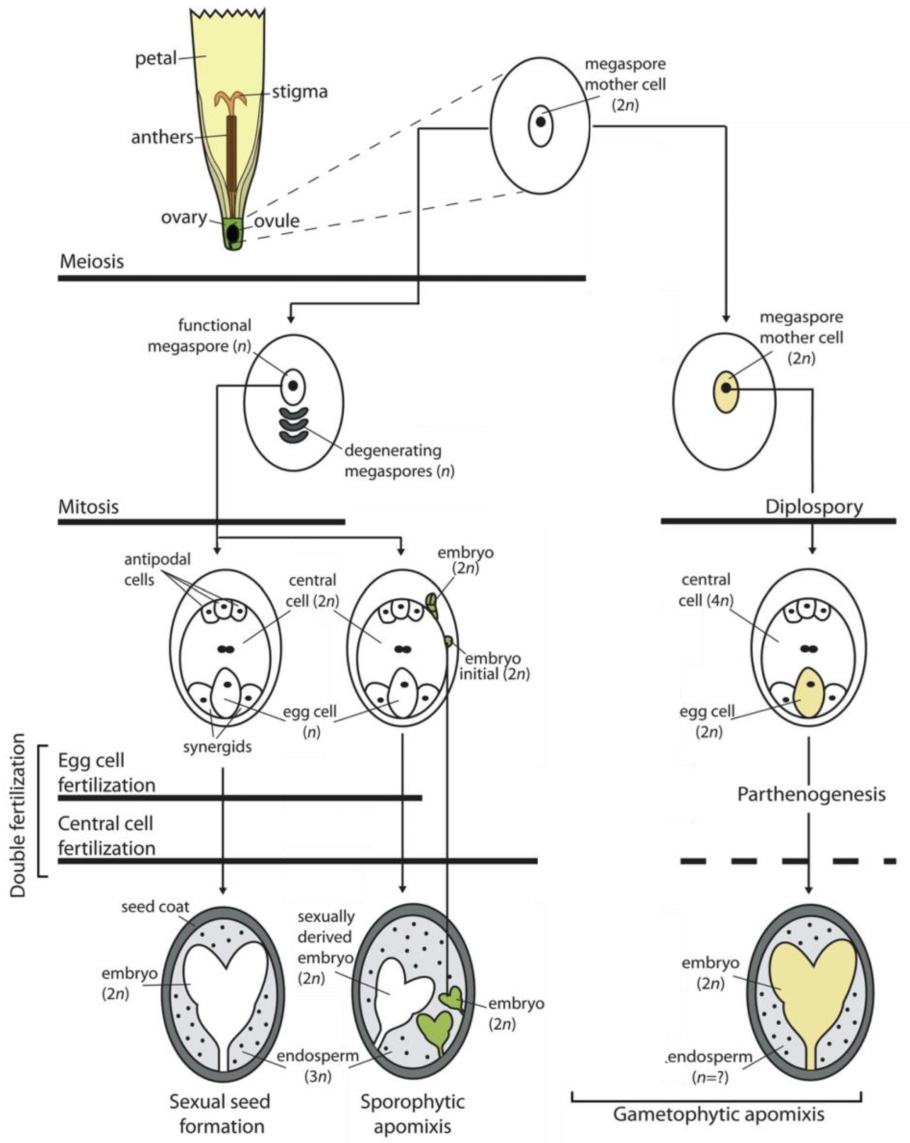
Hand and Koltunow, 2014



Types of Apomixis

Hand and Koltunow, 2014

Gametophytic apomixis

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Apospory

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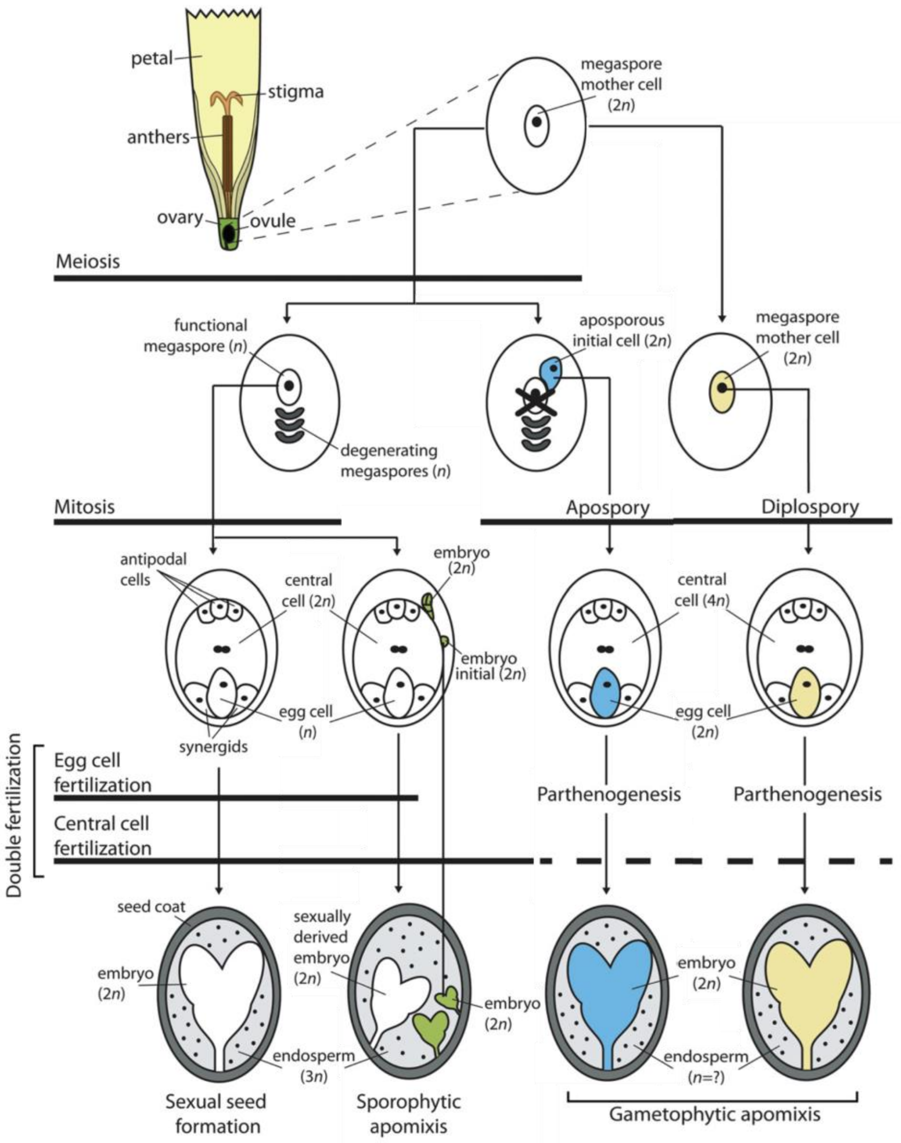
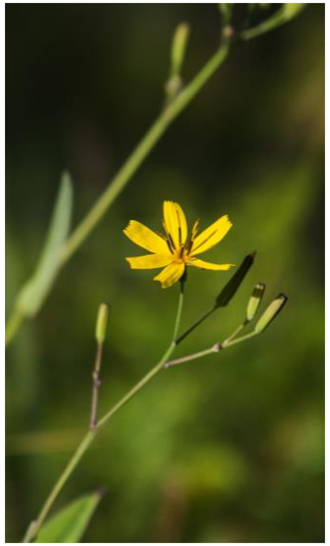


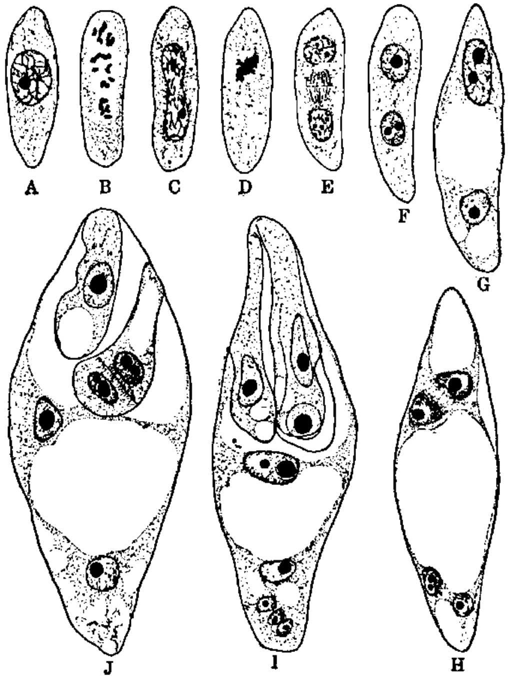
Types of Apomixis

Gametophytic apomixis

Diplospory

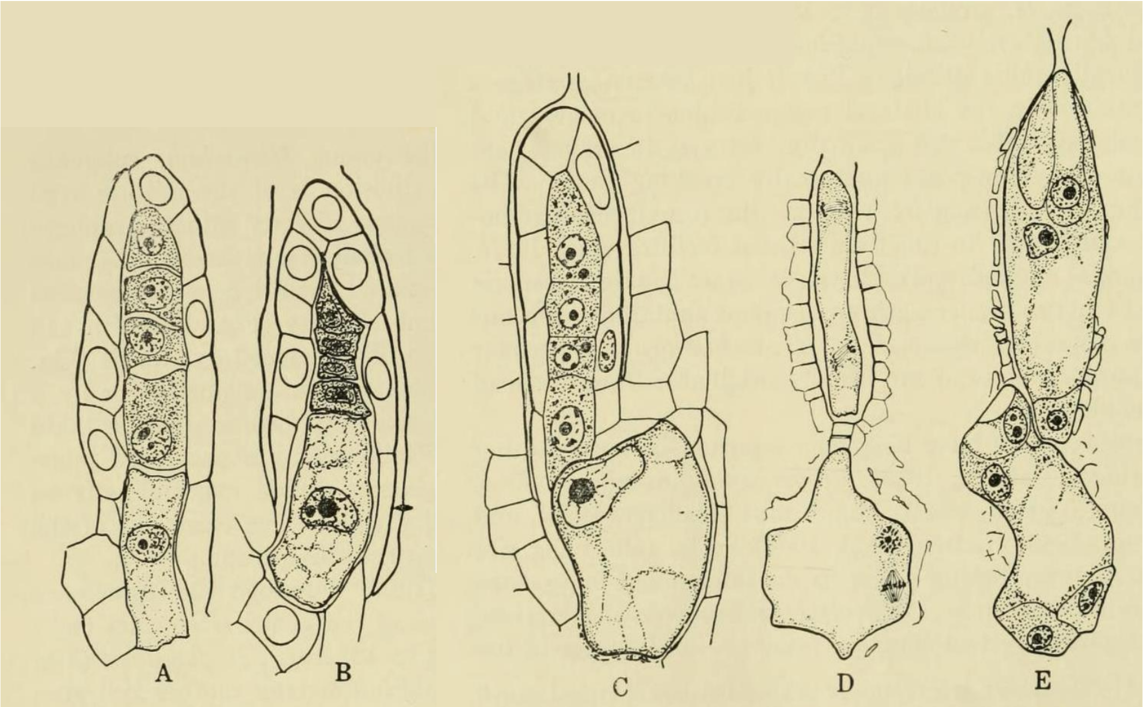


Wikipedia/bastus917



Diplospory in *Ixeris dentata*. A, MMC at Prophase. B, later stage with 21 univalents. C, restitution. D, metaphase. E, telophase. F, G, two-nucleate embryo sac. H, four-nucleate embryo sac. I, mature embryo sac. J, two-celled proembryo. (Maheshwari, 1950 after Okabe, 1932)

Apospory



Apospory in *Hieracium excellens.* A, nucellus, showing tetrad of megaspores; note enlargement of cell lying just below chalazal megaspore. B, megaspore tetrad in process of degradation. C, megaspore tetrad and large nucellar cell destined to give rise to embryo sac. D, normal and aposporic embryo growing simultaneously. E, two fully developed embryo sacs; lower is probably of aposporic origin. (Maheshwari, 1950 after Rosenberg, 1907)

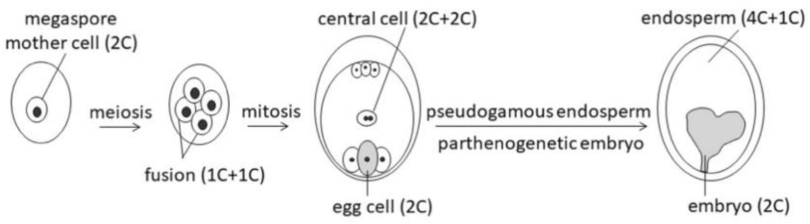
Types of Apomixis

Automixis (rare in plants)

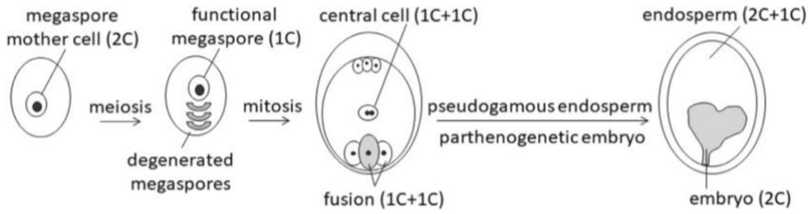
Šarhanová et al., 2024

Wiechmann, 2012

- Meiosis is successfully completed, then
  1.



  2.



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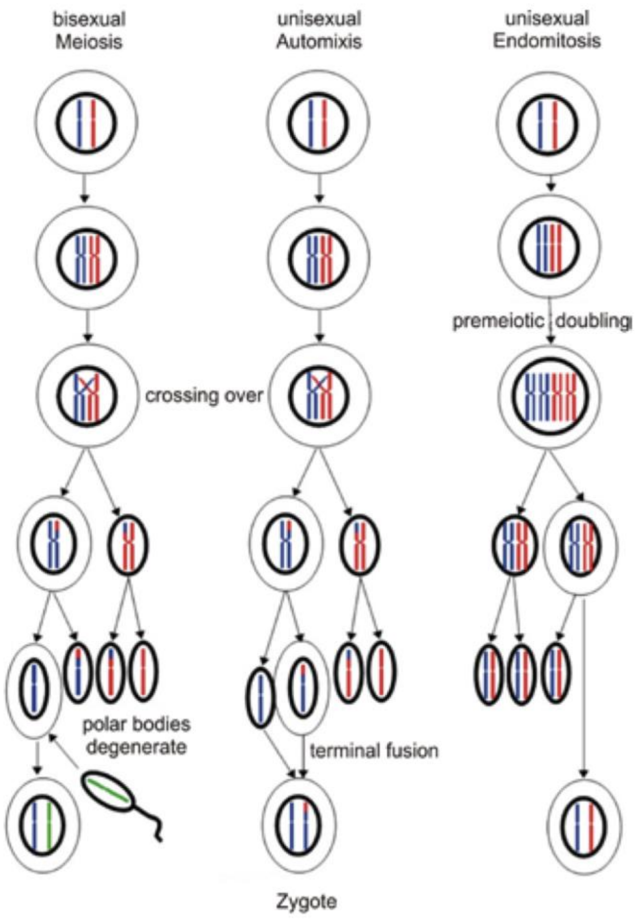


Desert grassland whiptail lizard:

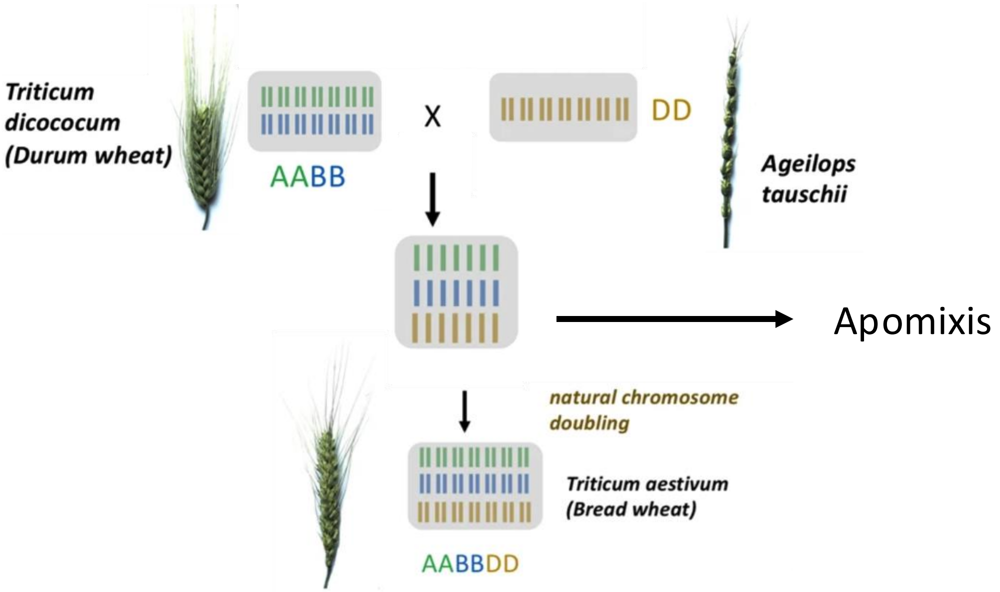
sarawrightnature.wordpress.com

Apomixis: role in evolution

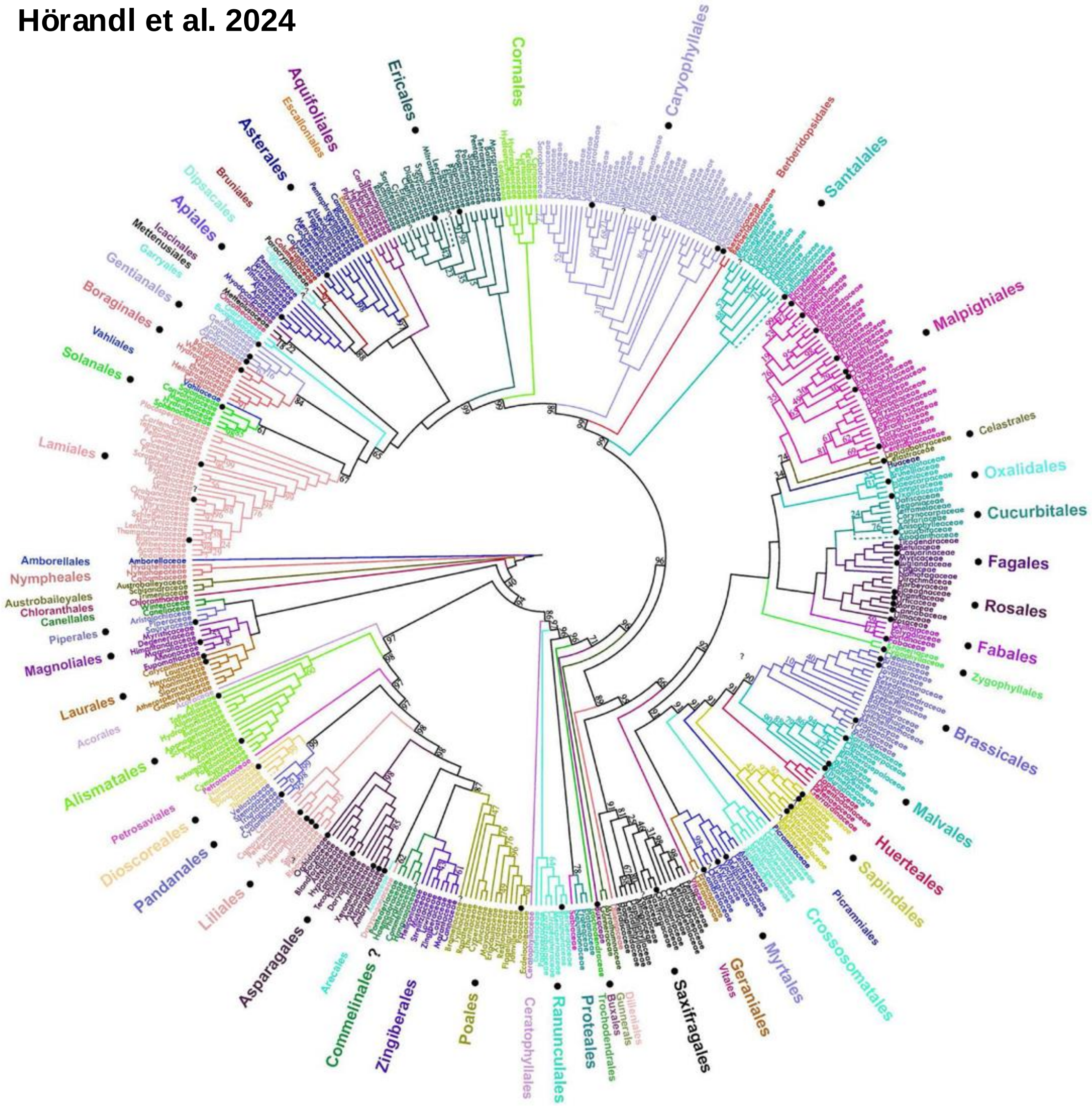
Occurrence

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

Hörandl et al. 2024



Modified from Rosyara et al. 2019



Apomixis: role in evolution

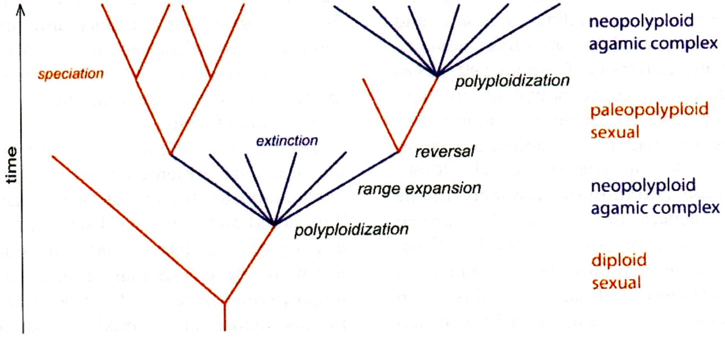
Occurrence

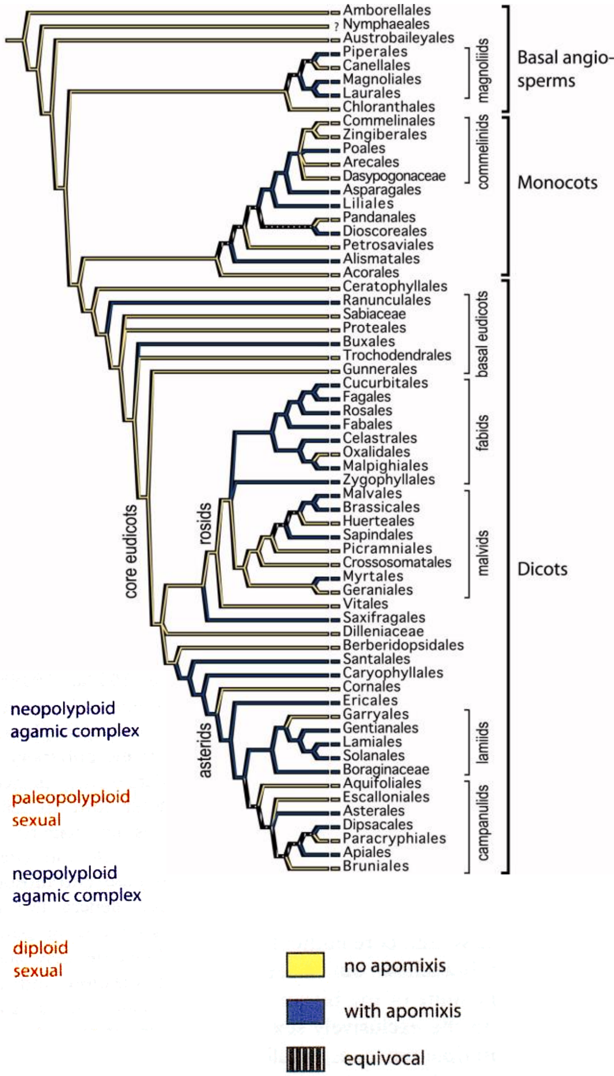
- **Darlington, 1939**: "Apomixis is an escape from sterility, but an escape into a blind alley of evolution."
- However, this view has been found to be incorrect:

Dandelions (*Taraxacum* spp.)
Insideecology.com

Kentucky bluegrass (*Poa prantensis*)
thespruce.com

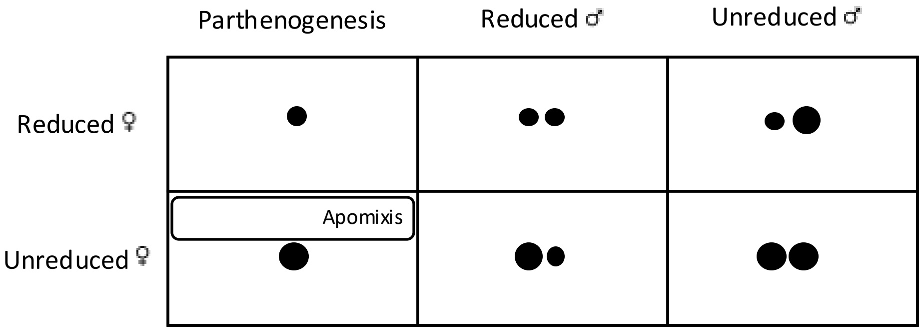
Hörandl and Hojsgaard, 2012



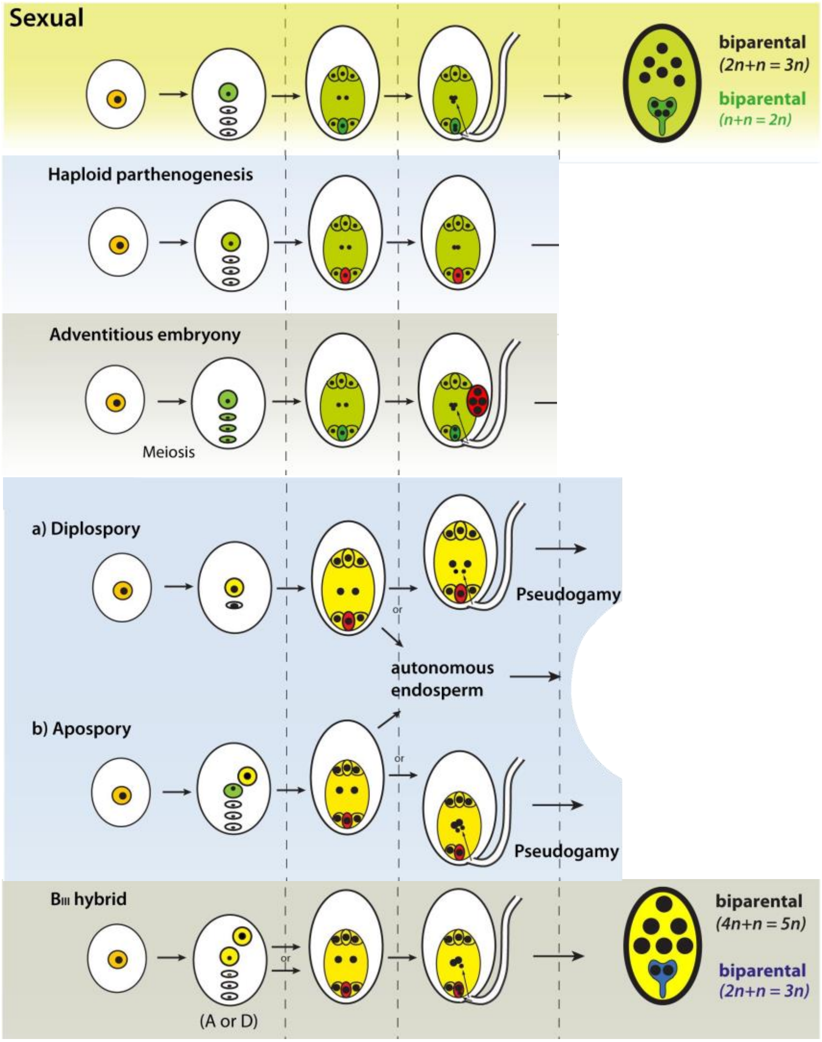


Indicators of Apomixis

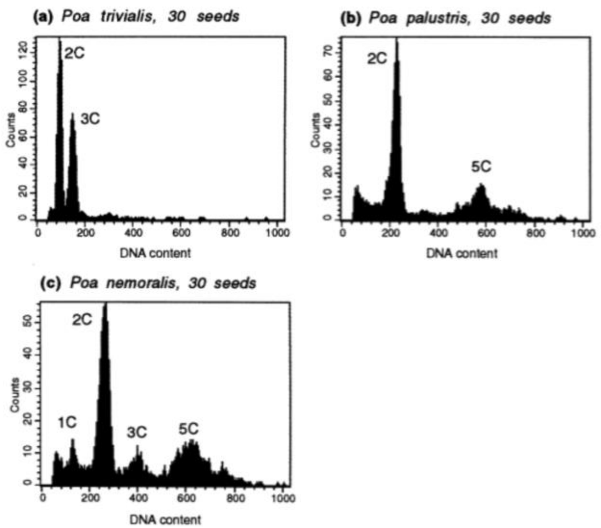
Occurrence



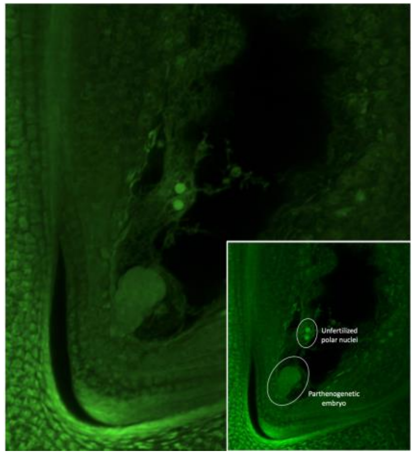
Hojsgaard and Hörandl, 2012



Matzk et al, 2001



Sidhu et al. 2022



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

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Simplex genotype → Low recombination → Tight linkage

Goel et al., 2003; Akiyama et al., 2003 & 2011

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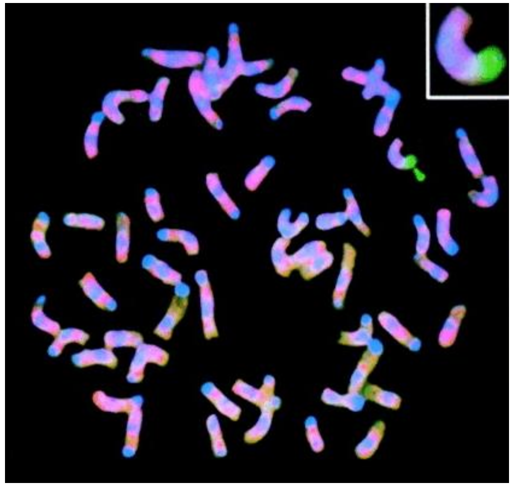

Goel et al. 2003. ASGR in *Pennisetum squamulatum* (2n = 8X = 56). Mitotic spread. ASGR is ~50 Mb long (almost ¼ of the chromosome).

Ozias-Akins & Van Dijk, 2007

Species	Apomixis type	Loci	Genotype	Suppression of recombination
Brachiaria brizantha	Apospory, pseudogamous endosperm	1	Aaaa	–
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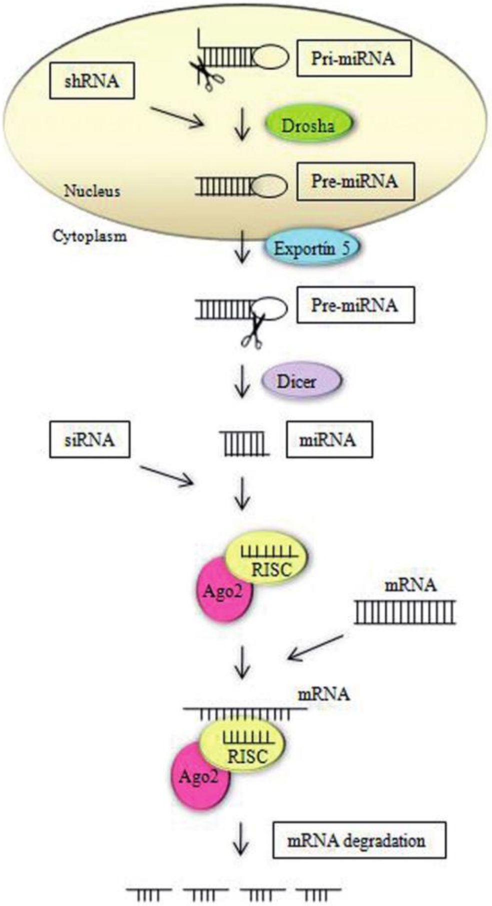
Erigeron annuus	Diplospory, mitotic, autonomous endosperm	2	D/dd*) Fff	+ –
Hieracium caespitosum	Apospory, autonomous endosperm	2	Aaaa Pppp	– +
Panicum maximum	Apospory	1	Aaaa	+
Paspalum notatum	Apospory, pseudogamous endosperm	1	Aaaa	+
Paspalum simplex	Apospory, pseudogamous endosperm	1	Aaaa	+
Pennisetum 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

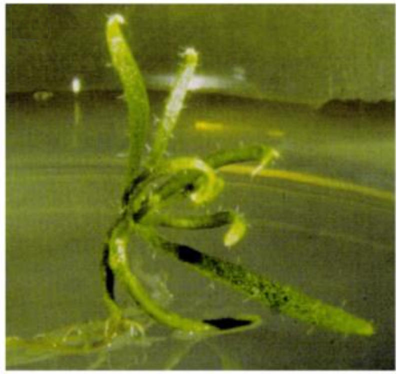
(Epi)genetic control of Apomixis

Singh et al. 2011

Small RNA gene silencing mechanism



BETÁKOVÁ and ŠVANČAROVÁ 2013



Ago1 mutant of arabidopsis
Bohmert et al, 1998

Arganoute (www.scandfish.com)

From: 1551 book, "*L'Histoire naturelle des estranges poissons marins*"