Purpose of Meiosis

- Reduction in chromosome number
- Basis for genetic recombination
    - Independent assortment (interchromosomal recombination)
    - Crossing over (intrachromosomal recombination)

During development, cells (the germ line) are set aside that undergo meiosis. Called **meiocytes**

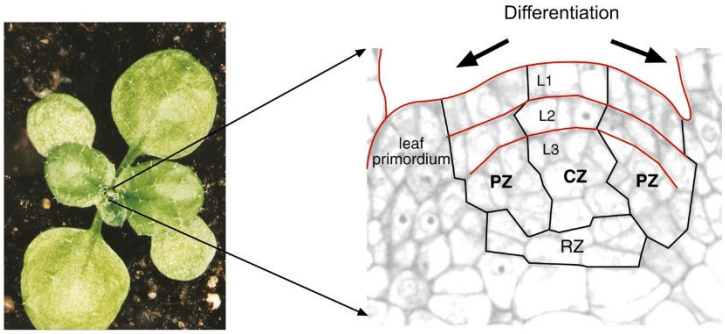
- gonial tissue (animals)
- sporogenous tissue (plants)

Setting gonial tissue aside early in development permits DNA changes to occur in somatic tissues during development

- In lower animals (e.g., the horse nematode (*Ascaris megalocephala*), and in the fungus gnat (*Sciara coprophila*), chromosome breakage, loss, and diminution occurs during the development of somatic cells
- In contrast to gonial tissue, sporogenous tissue is set aside late in development. Consequently somatic mutations can get passed along to the progeny
- Because sporogenous tissue is not set aside early in plant development, diminution was thought not to exist in plants, however
    - Tomaszewski et al (1991) found a 5 kb DNA segment present in wheat embryos, but absent in the terminally-differentiated endosperm.

In conclusion, the only place where DNA remains constant is in the germ line.

- **Lanfear 2018** – Conventional wisdom may be wrong, as mutation rates in trees are lower than expected→ Central Zone cells formed in lower frequencies than previously thought



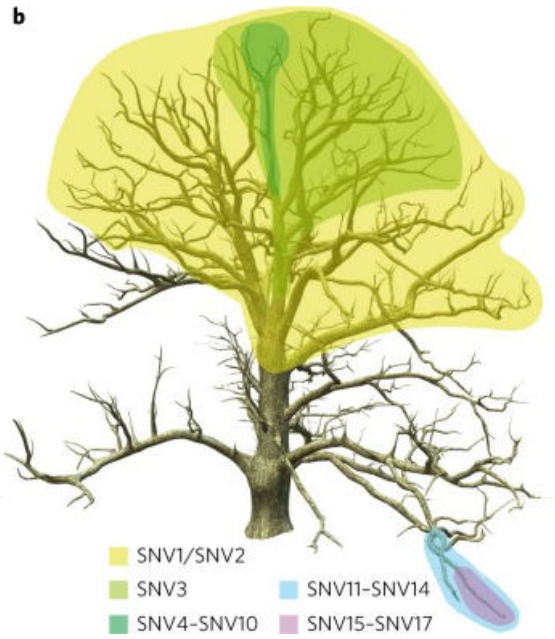
Organization of the Arabidopsis *shoot meristem. Gross-Hardt & Laux, 2003*

Only cells in the CZ give rise to gametes. But, CZ cells form from older cells (RZ and below)

But, perhaps not the case in long-lived perennials

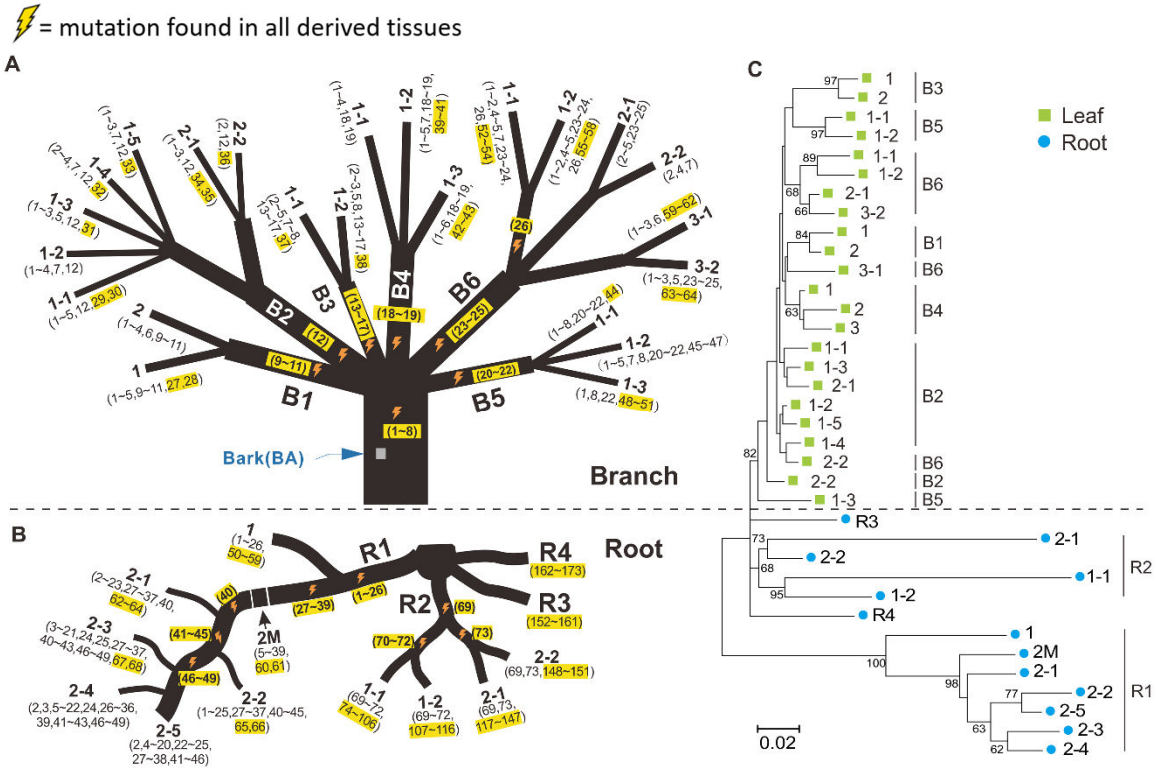
Schmid-Siegert et al, 2017

- Napoleon oak, planted 1788
    - Only 38-47 somatic mutations in meristems
    - What protects germline from accumulation of mutations?
- Arabidopsis gametic rate is 7 x 10^{-9}/generation
- Oak somatic rate = ~4.7 x 10^{-8}



Wang et al, 2019

- Somatic mutations in annuals → usually not transmissible
- Perennials → fewer mutations, but transmissible
- The longer-lived the tissue, the lower the mutation rate



Life cycles

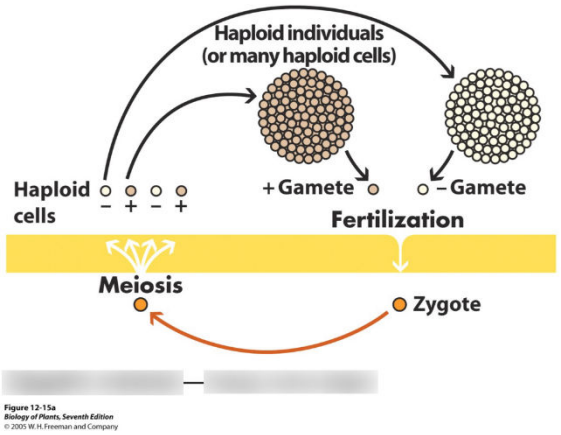
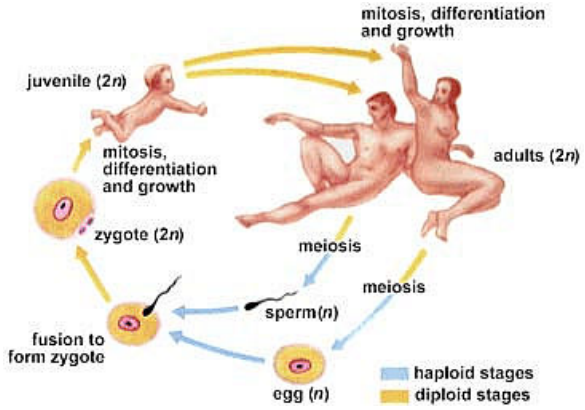


Figure 12-15a
Biology of Plants, Seventh Edition
© 2005 W. H. Freeman and Company

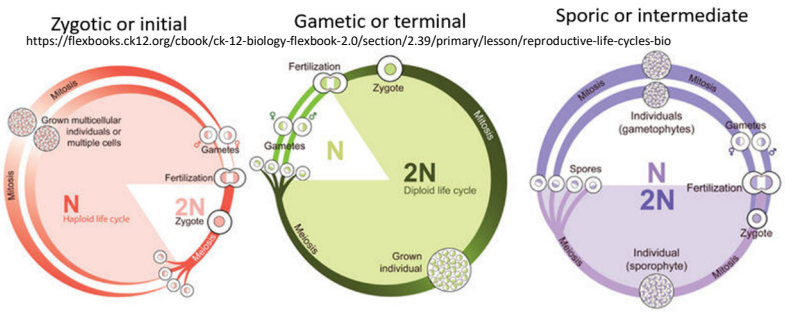
Zygotic or initial meiosis- Found in algae, fungi, protists



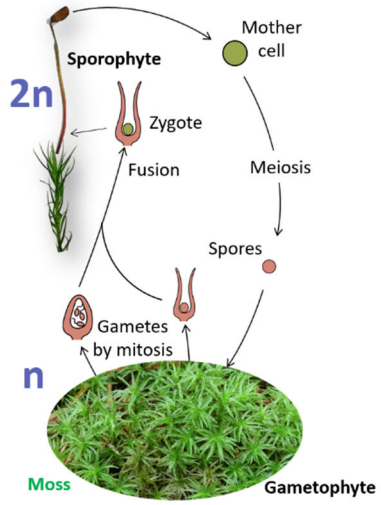
http://www.biosci.uga.edu/almanac/bio_103/notes/apr_4.html

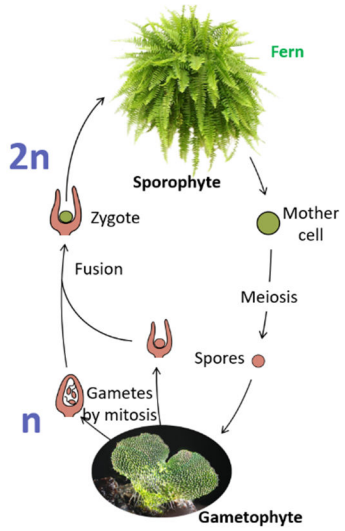
Gametic or terminal meiosis. Found in most animals.

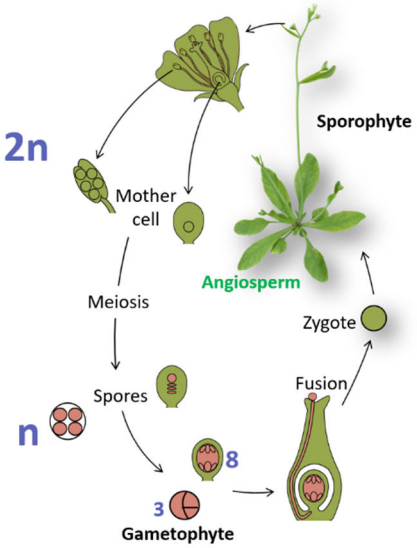
Sporic or intermediate, known as alternation of generations. Plants have **alternation of generations**. Alternation of generations discovered in plants in 1851 by **Hofmeister**.



Graphics by course alumnus Gurjot Singh Sidhu



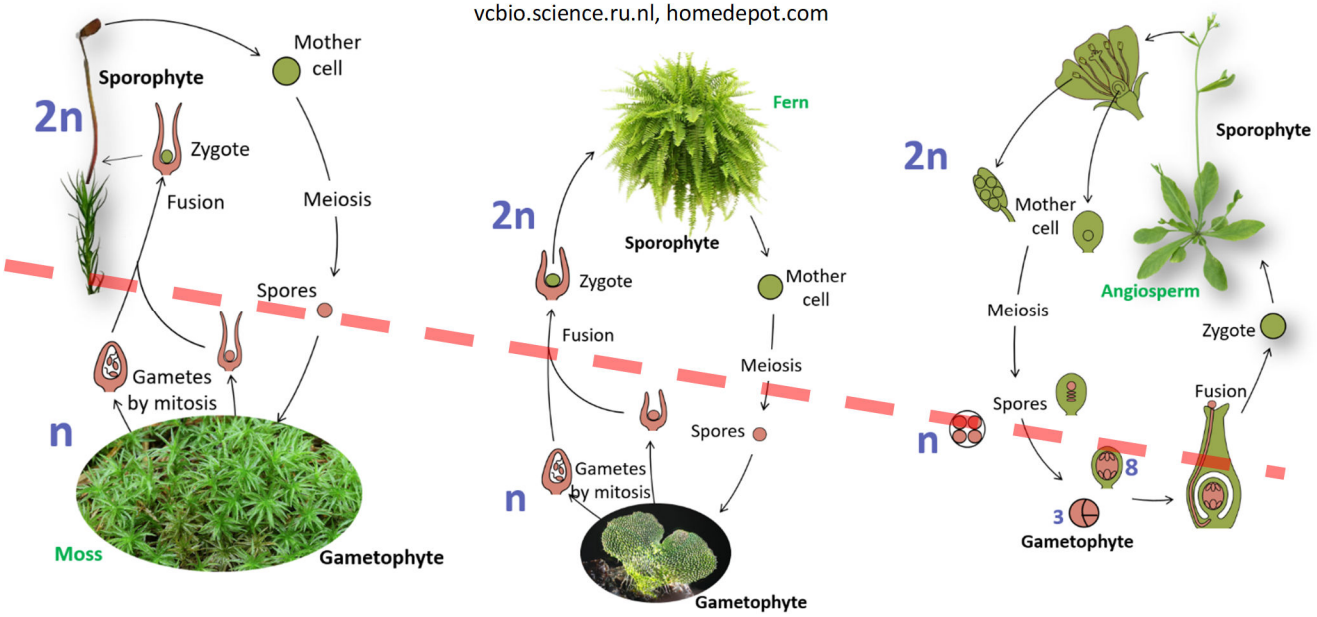




In higher plants

- The microgametophyte is reduced to 3 cells
- The megagametophyte is usually reduced to 8 cells

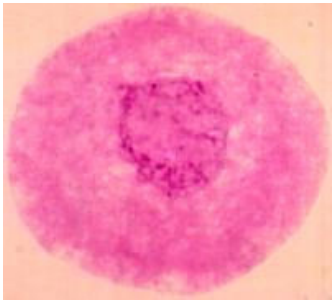
vcbio.science.ru.nl, homedepot.com



Stages of Meiosis: Meiosis I

Prophase I

For a cell that is
2n=2x=2c=6



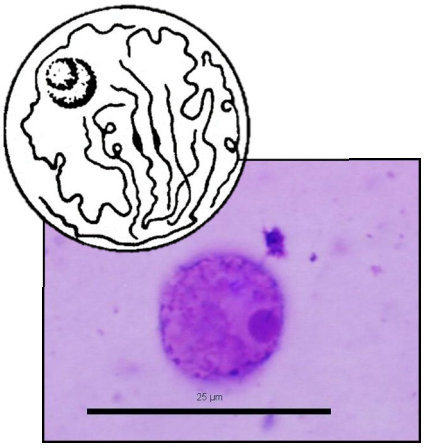
Class Alum Zengbang Chen. Pearl millet-Pennisetum squamulatum hybrid

Prophase - The initial phase, and consists of various stages:

- Leptotene, zygotene, pachytene, diplotene, and diakinesis
- "Leaping Zebras Prance on Dainty Daisies"

Leptotene

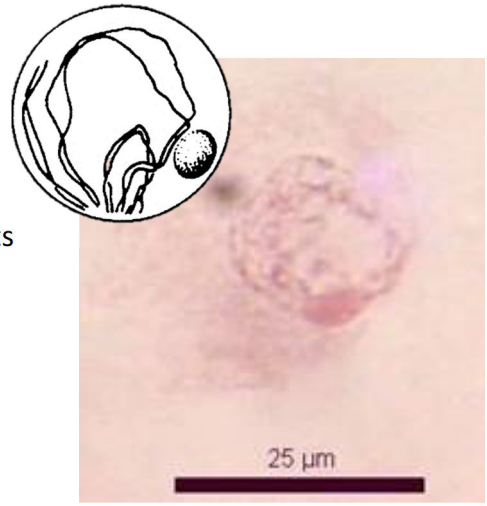
- Translates into "thin thread"
- Chromosomes begin to condense
- Early in this stage, the chromosomes rearrange within the nucleus, so homologues can come together. This may account for the length of this stage.
- 99% of DNA replication is completed
- Telomeres still attached to nuclear membrane
    - ***Gerton & Hawley, 2005***– Double strand breaks take place that will generate ssDNA tails to help pairing



Class alum Doug Heckart. Seashore paspalum

Zygotene

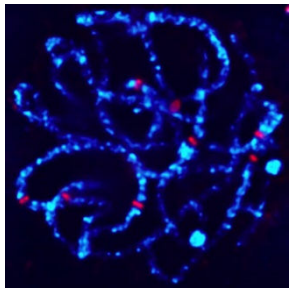
- "Yoked thread" (from Greek “zugon”, yoke, as in 'yoked oxen')
- Continued shortening of the chromosomes
- Pairing of homologues (**synapsis**) occurs
- Formation of the **synaptonemal complex**, which consists of a nucleoprotein core between the two homologues
- Recombination nodules attach to central region of synaptonemal complex
- Telomeres cluster together to form a ‘bouquet’ at the inner surface of the nuclear envelope



Class alumna Rebecca Tashiro. White clover

Pachytene

Class Alumnus Ed Kentner. Iris fulva x I. brevicaulis F1 Hybrid



Class alumna Jinghua Shi. Maize

- "Thick thread" (Remember: pachyderm = thick skin = elephant)
- Pairing is complete
- Each pair visible as 2 threads, called a **bivalent**
- Contraction of chromosomes continues
- Knob number & size clearly visible, helping identify individual chromosomes
- Crossing over occurs

Diplotene

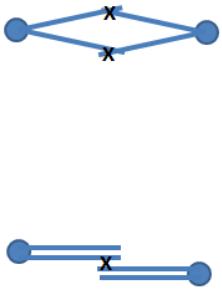
- "Double thread" - Each chromosome appears as two threads, each pair as 4 threads. ∴ each bivalent can also be called a **tetrad**
- Degradation of synaptonemal complex
- Sister chromatids become visible
- Synaptonemal complex remains at crossover points, acting as stabilizers = **chiasmata**
- Repulsion begins
- "Scrubbing" (i.e., degradation) of most previously synthesized mRNA is completed
    - Transfer of siRNA & phasiRNA from tapetal cells
- Chiasma are essential to maintain the bivalents together and maintain the correct orientation of the chromosomes

Class Alum Ed Kentner. Iris fulva

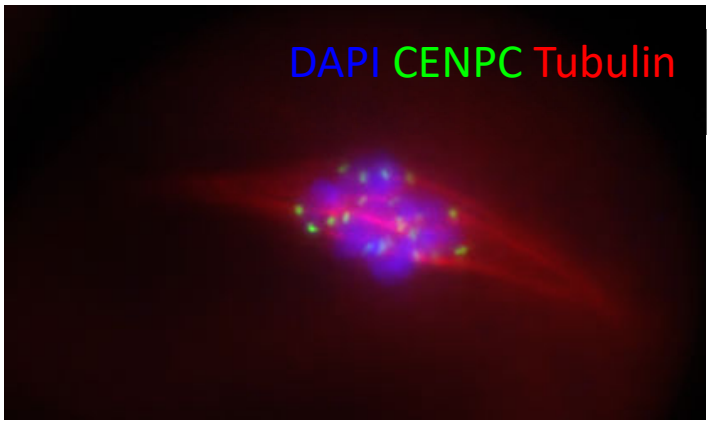
Diakinesis

- Most condensed stage
- Nucleolus disappears
- Spindle assembly begins
- Nuclear envelope starts to disappear
- Interpreting pairing configurations

Class alum Doug Heckart. Seashore paspalum

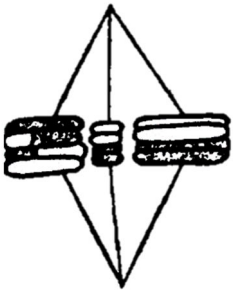


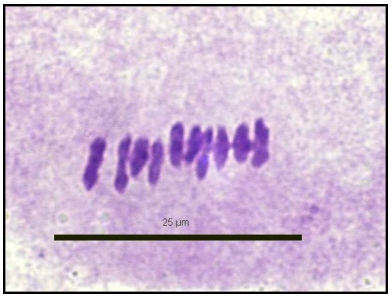
Prometaphase I



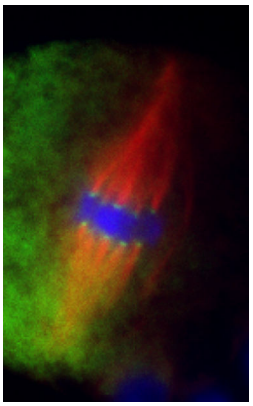
Class alum Kyle Swentoski

Metaphase I

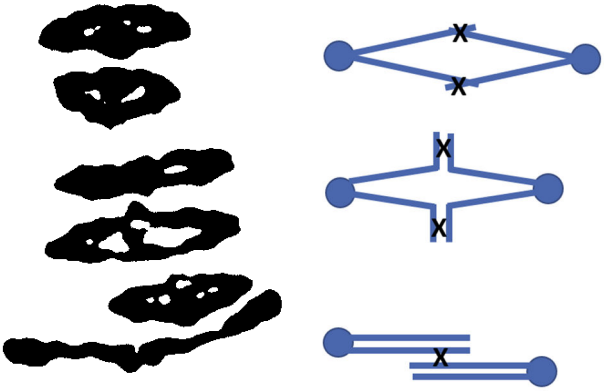




Class alum Doug Heckart. Seashore paspalum



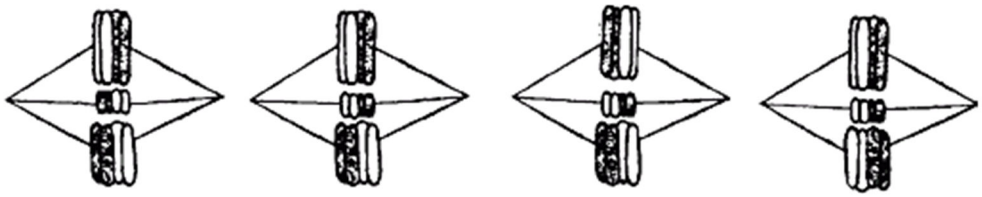
Class alum Kyle Swentoski. Maize



- Nuclear envelope has disappeared
- Spindle is fully formed
- Bivalents are aligned on the metaphase plate

Metaphase I orientation

Note that each bivalent can have 2 orientations during Metaphase I. Thus, for this example, each of the following metaphase I orientations is equally likely:

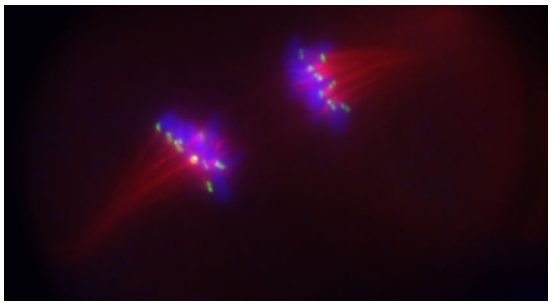


- Each combination results in a different combination of chromosomes at Telophase II.
- This is the basis for independent assortment.

Anaphase I

- Coorientation -- i.e., pairs are oriented with each other
- Called "**heterotypic division**" in the older literature

Figure 1. Class alum Kyle Swentoski



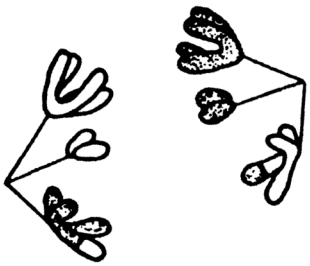
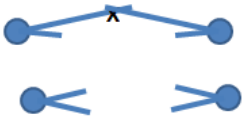
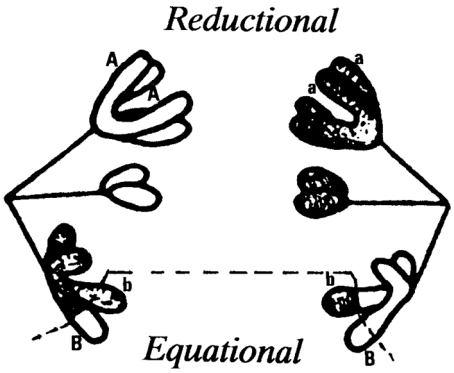


Figure 2. Class Alum Ed Kentner. Iris fulva



Reduction



Reduction: has 2 different meanings:

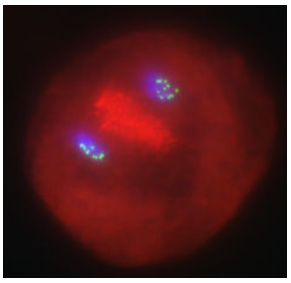
- Reduction in chromosome number, or
- Reduction in allelic diversity at a locus.

- Taking a closer look at what happens during Anaphase I:
  - In areas where no cross overs took place, the division is said to be **reductional**, as in the top chromosome pair of this diagram.
  - Original cell was *Aa*, but now each resulting daughter cell will be either *AA* or *aa*.
  - Segregation of genes has occurred, resulting in a loss (reduction) of the original genetic information (i.e., a decrease in allelic diversity)
- In areas where a cross over occurred, an **equational** division will result
  - No segregation of genes occurs.
  - Original cell was *Bb*, and each daughter cell will still be *Bb*.

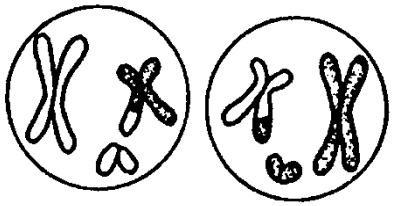
Telophase I

Slight decondensation of chromosomes

Class alum Aaron Hoskins. Jalapeño pepper



Class alum Kyle Swentoski, Maize

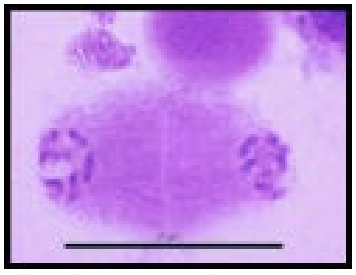


Possible interphase

- There can be an interphase prior to Meiosis II

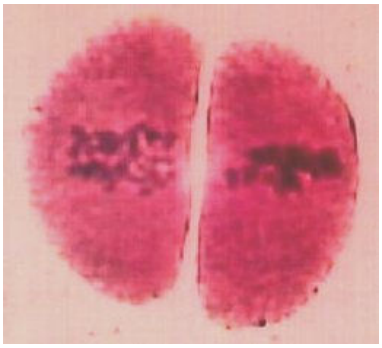
Meiosis II = mitosis

Prophase II

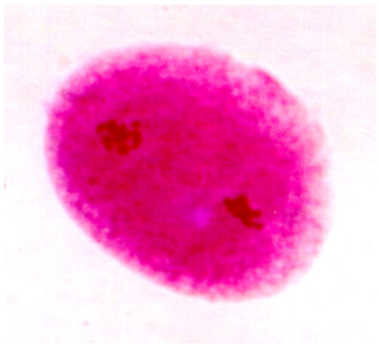


Class alum Doug Heckart. Seashore paspalum

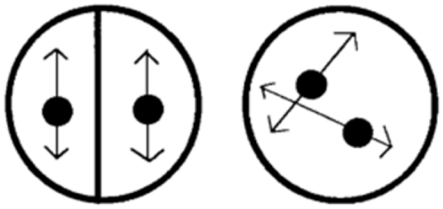
Metaphase II



Class alum Zenbang Chen. Pearl millet-Pennisetum squamulatum hybrid



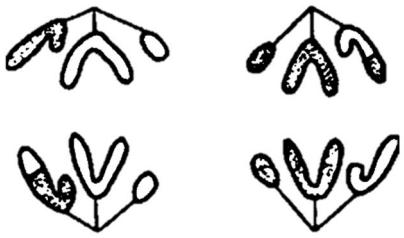
Class alumna "Mike" Scheiber. Abelia schumannii

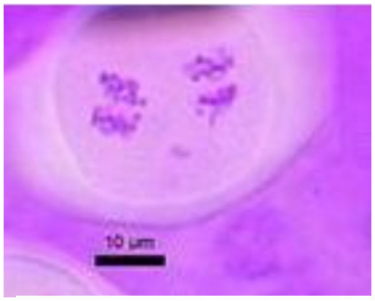


The spindle axes are parallel to each other in Met II in monocots. For eudicots, they define the poles of a tetrahedron.

- Autoorientation of chromosomes
  - same as in mitosis
- Spindle orientation differs between monocots and eudicots

Anaphase II

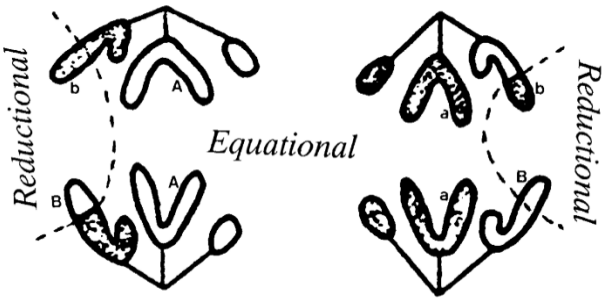




Class alumna Amanda Hershberger. Lantana camara 'Miss Huff'

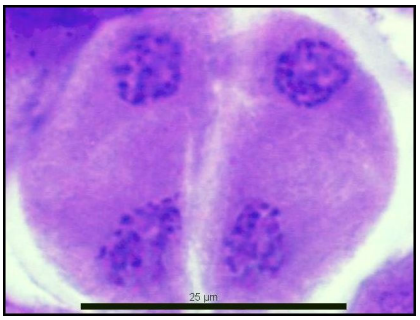
- Called the "homotypic" division in the older literature

Reduction



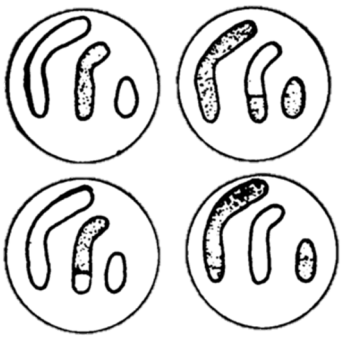
- Now, the cross over regions are undergoing a reductional division (from *Bb* to *B* or *b*), and
- The non-crossover areas are undergoing an equational division (from *AA* to *A*, or *aa* to *a*).
- This is reversed from what happens in the first division

Telophase II

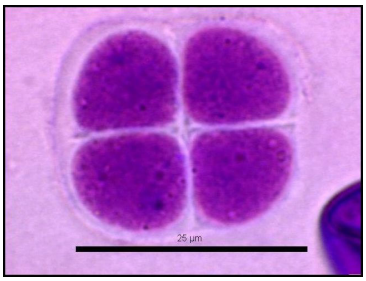


Class alum Doug Heckart. Seashore paspalum

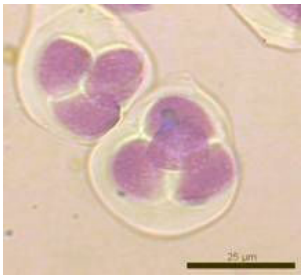
Class Alum Aaron Hoskins. Jalapeño pepper



Cytokinesis



Class alum Doug Heckart. Seashore paspalum



Class alumna Rebecca Tashiro. White clover