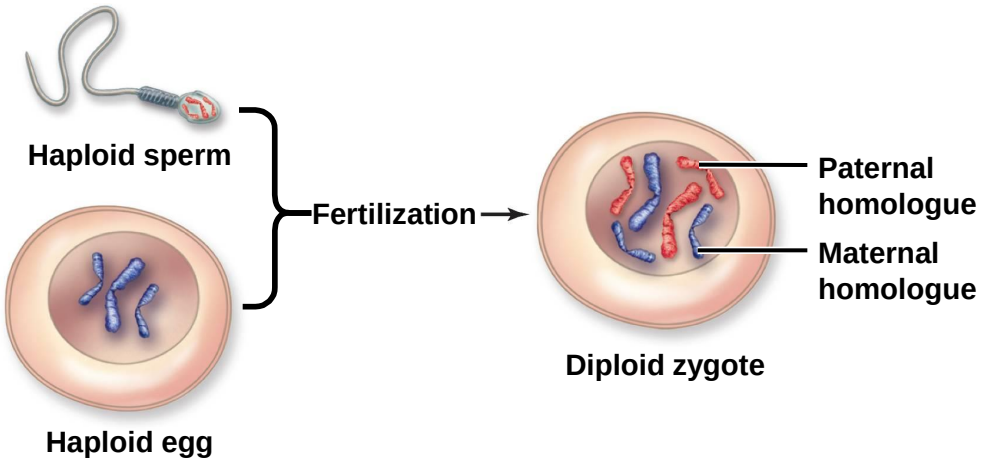
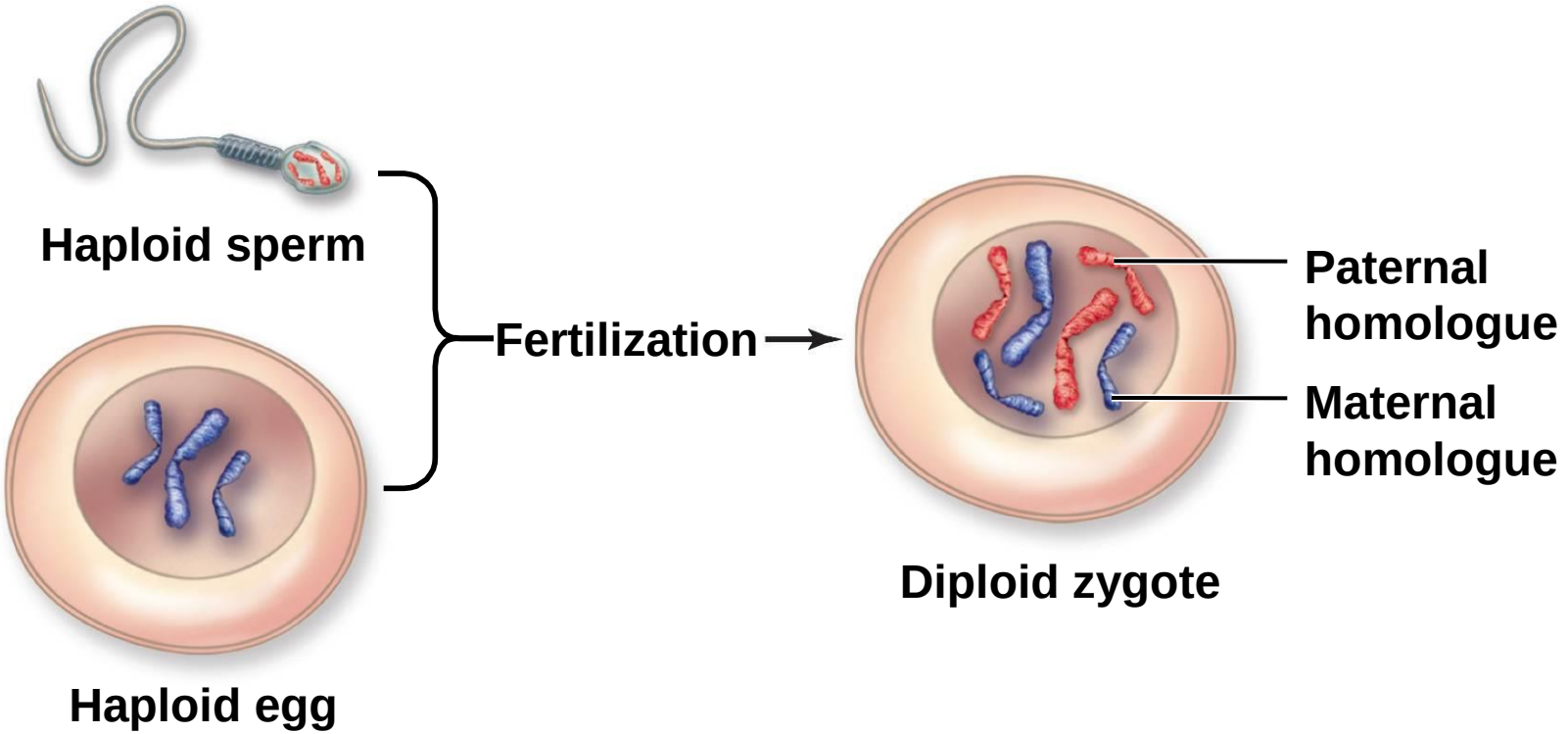
Sexual Reproduction and Meiosis

Chapter 11

Sexual life cycle

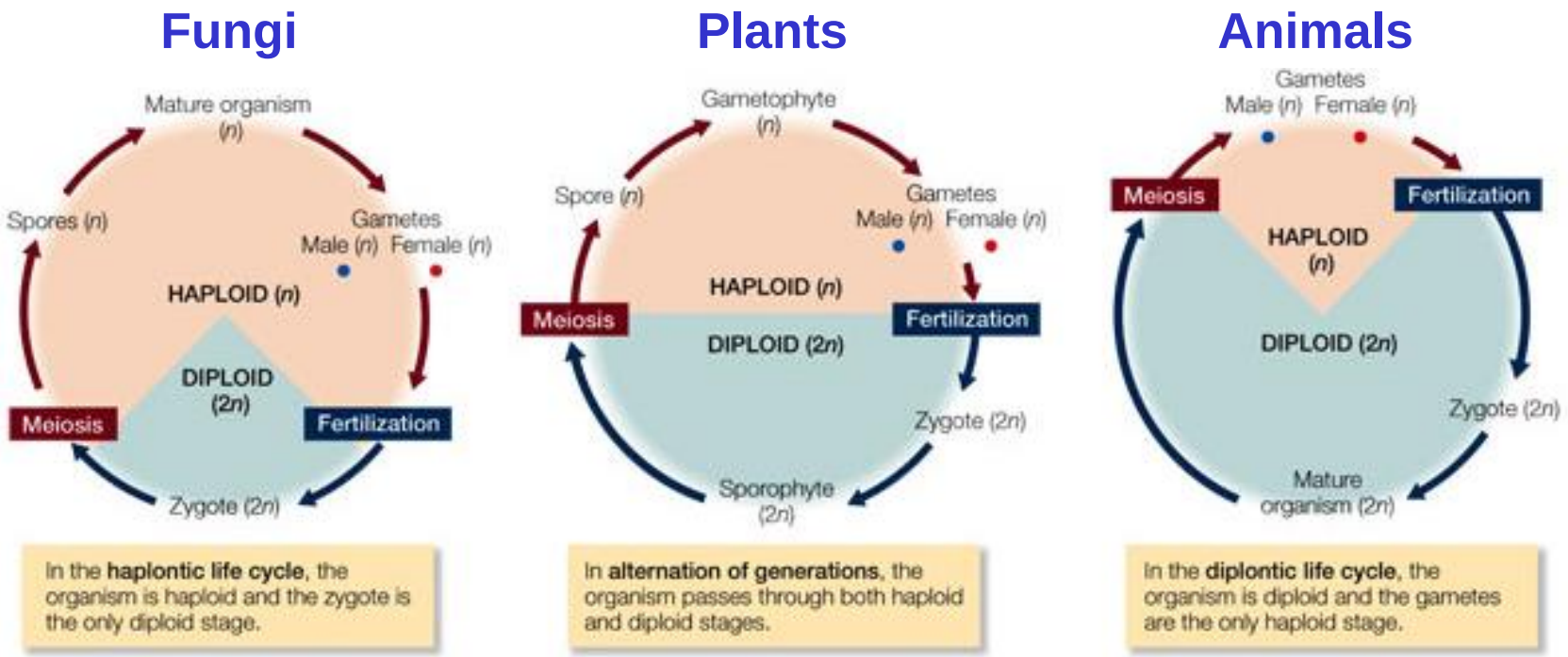
- Made up of **meiosis** and **fertilization**
- **Diploid cells**
  - **Somatic cells** of adults have 2 sets of chromosomes
- **Haploid cells**
  - **Gametes** (egg and sperm) have only 1 set of chromosomes
- Allows offspring to inherit genetic material from 2 parents





- Life cycles of sexually reproducing organisms involve the *alternation of haploid and diploid stages*

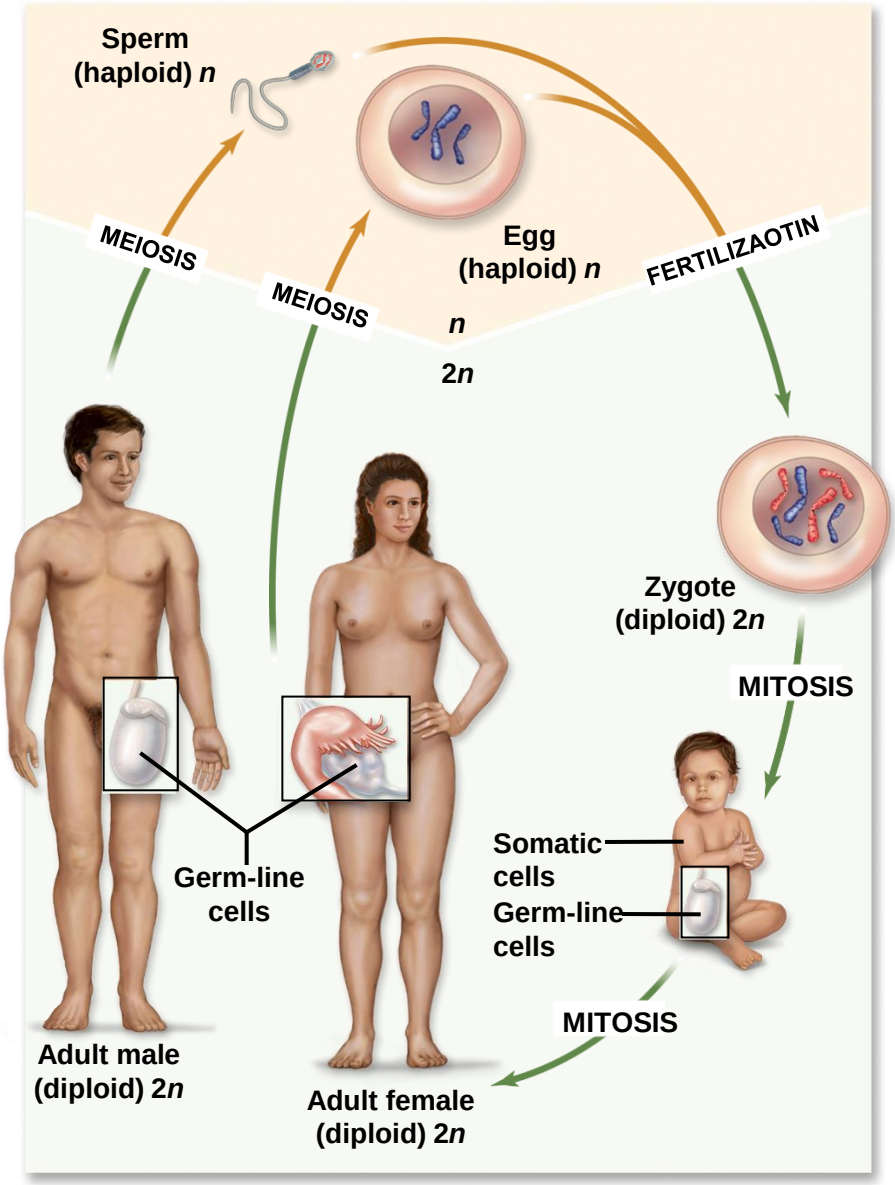
- Some life cycles include longer diploid phases (animals), some include longer haploid phases (fungi), plants are “in between”

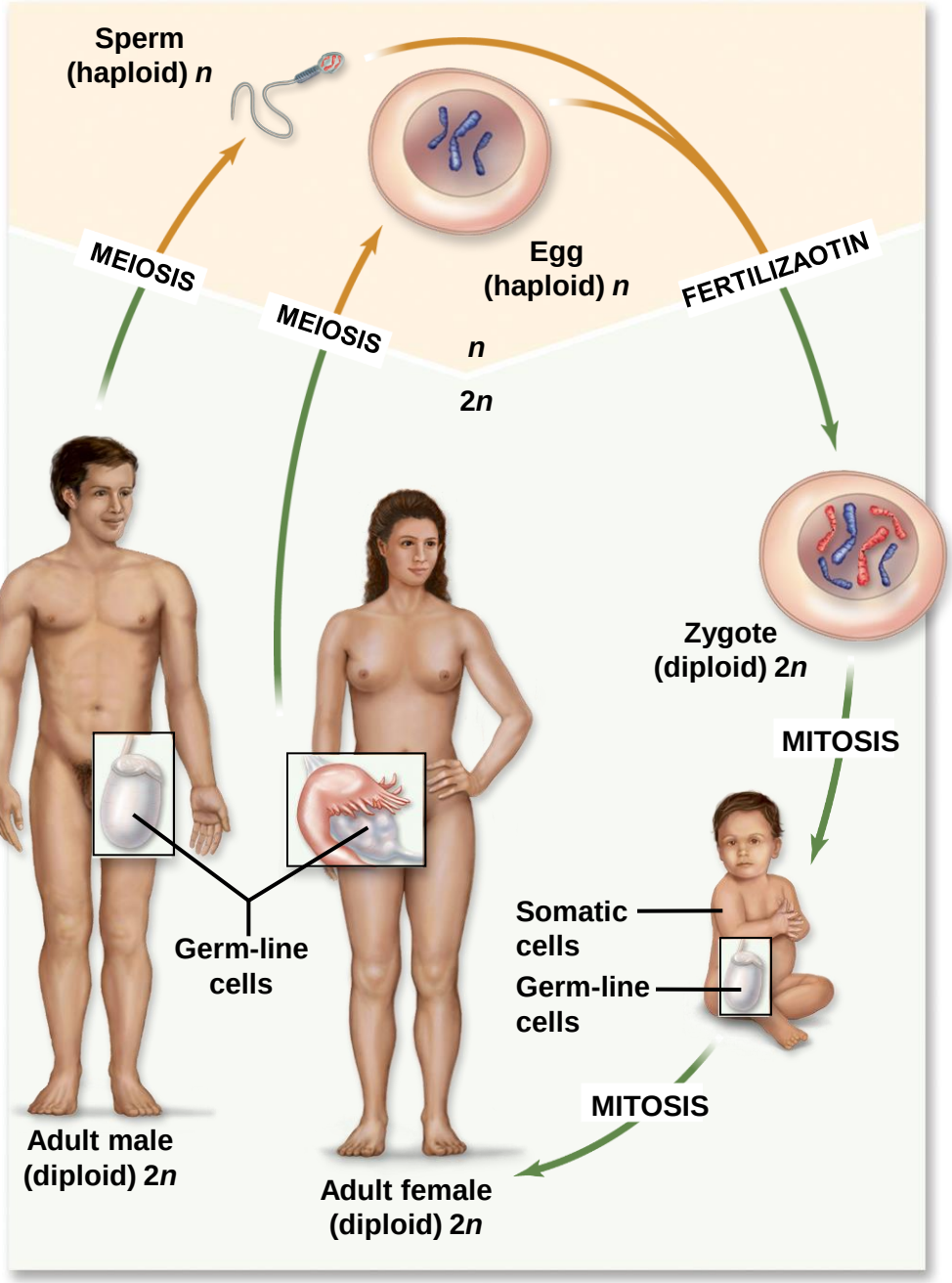


LIFE 8e, Figure 9.14

http://bcs.whfreeman.com/thelifewire8e/content/cat_010/09010-01.htm?v=chapter&i=09010.01&s=09000&n=00010&o=|00120|

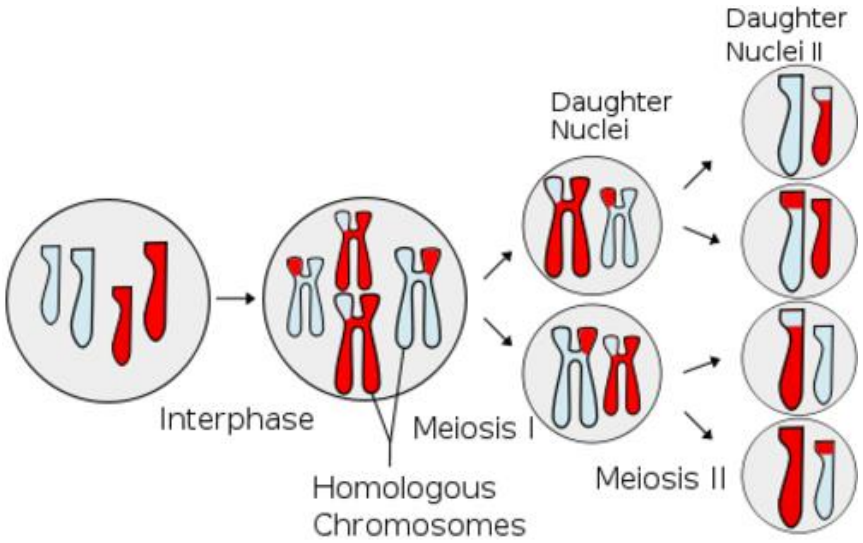
- In most animals, the diploid state dominates
  - **Zygote** first undergoes mitosis to produce diploid cells
  - Later in the life cycle, some of these diploid cells undergo **meiosis** to produce haploid gametes
    - (**sperm** & **eggs**)





Features of Meiosis

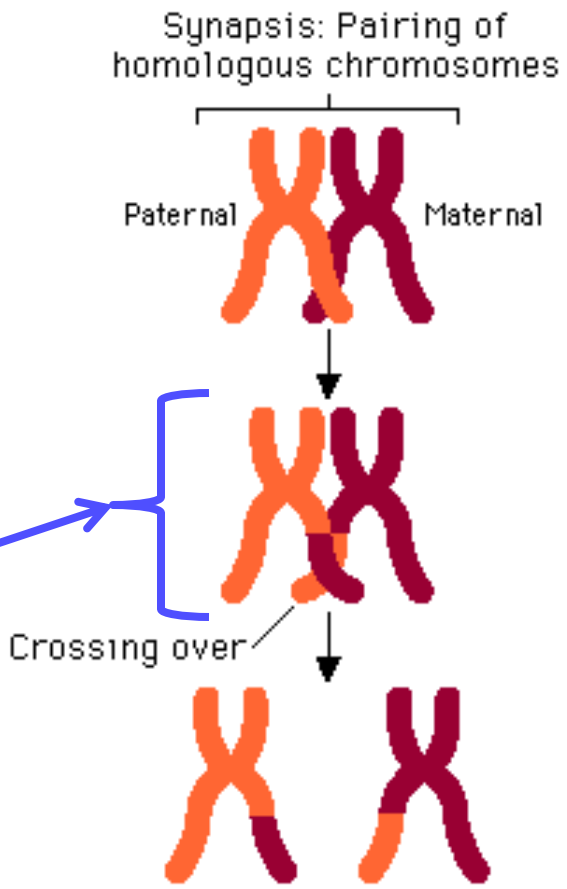
- Like mitosis, before meiosis begins, DNA is replicated in the S-phase of interphase
- Meiosis includes two rounds of division
  - **Meiosis I** and **meiosis II**
  - Each has **prophase**, **metaphase**, **anaphase**, and **telophase** stages (prophase I, metaphase I, etc.)



http://www.diffen.com/difference/Meiosis_vs_Mitosis

Features of Meiosis

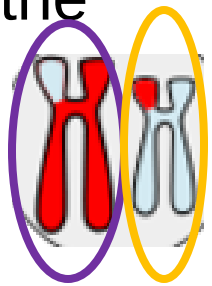
- **Synapsis** (**crossing-over**)
  - During early prophase I
  - Homologous chromosomes become closely associated (eventually swapping DNA)
  - Includes formation of **synaptonemal complexes**
    - Formation also called **tetrads** or bivalents

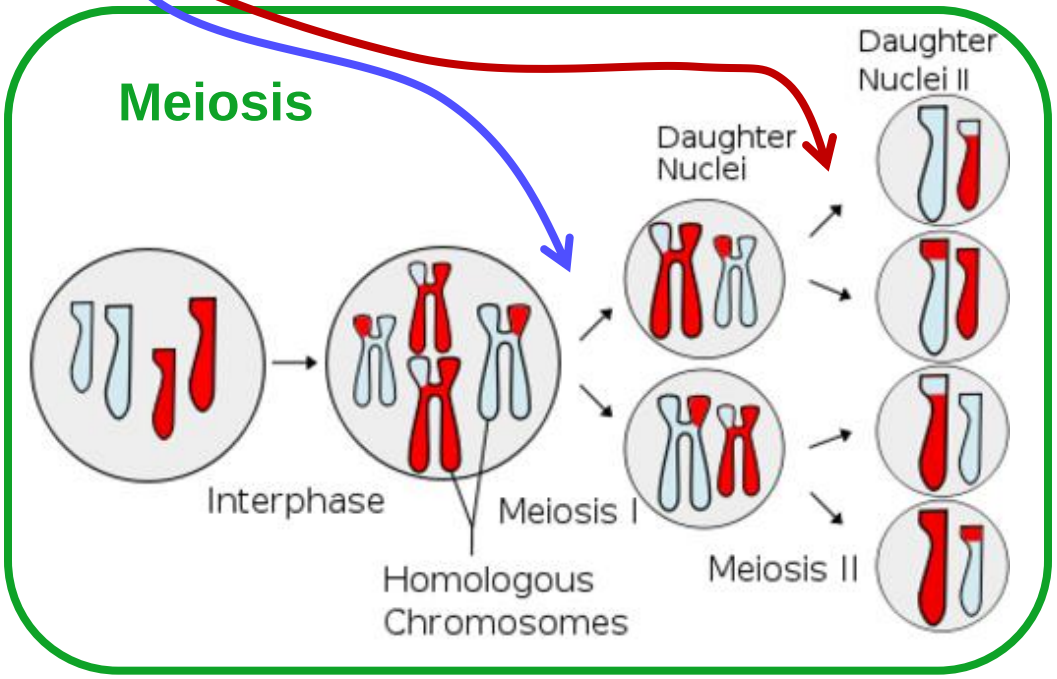


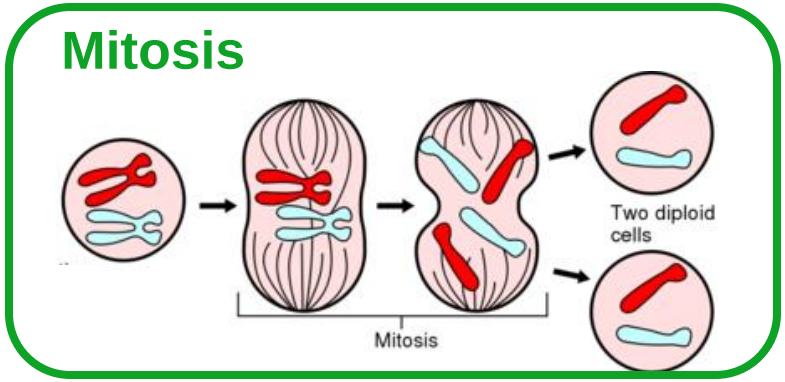
http://www.phschool.com/science/biology_place/labbench/lab3/crossovr.html

- **First meiotic division** is termed the "reduction division"
  - Results in daughter cells that contain one homologue from each chromosome pair (haploid)
  - There is *no DNA replication* between meiotic divisions

- Second meiotic division does not further reduce the number of chromosomes
  - Separates **sister chromatids** for each homologue
  - Meiosis II is very much like mitosis (but half the DNA)







http://www.diffen.com/difference/Meiosis_vs_Mitosis

The Process of Meiosis

- Meiotic cells have a prior interphase period that is similar to mitosis with G1, S, and G2 phases

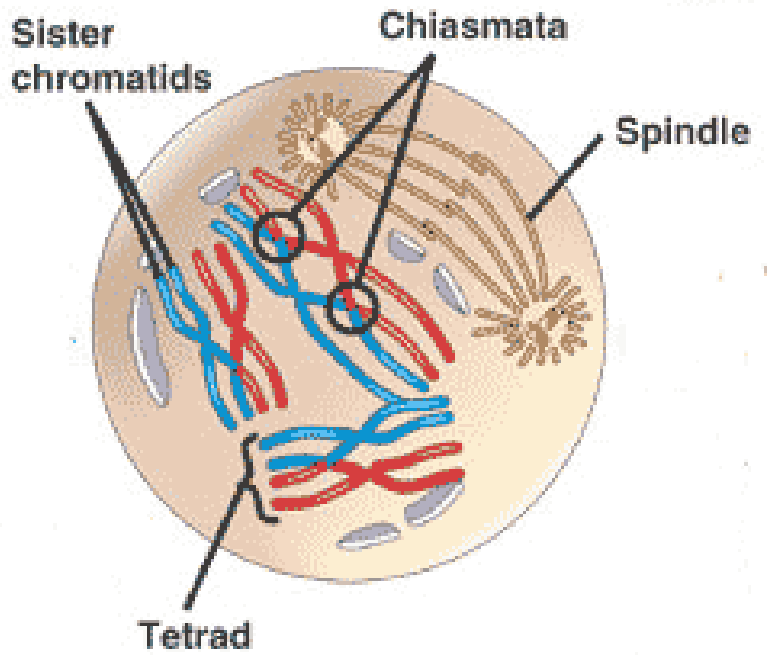
- After interphase, **germ-line cells** enter meiosis I

- Meiosis I
  - Prophase I
  - Metaphase I
  - Anaphase I
  - Telophase I
- Meiosis II
  - Prophase II
  - Metaphase II
  - Anaphase II
  - Telophase II

Know each stage and what goes on in each!!

Prophase I

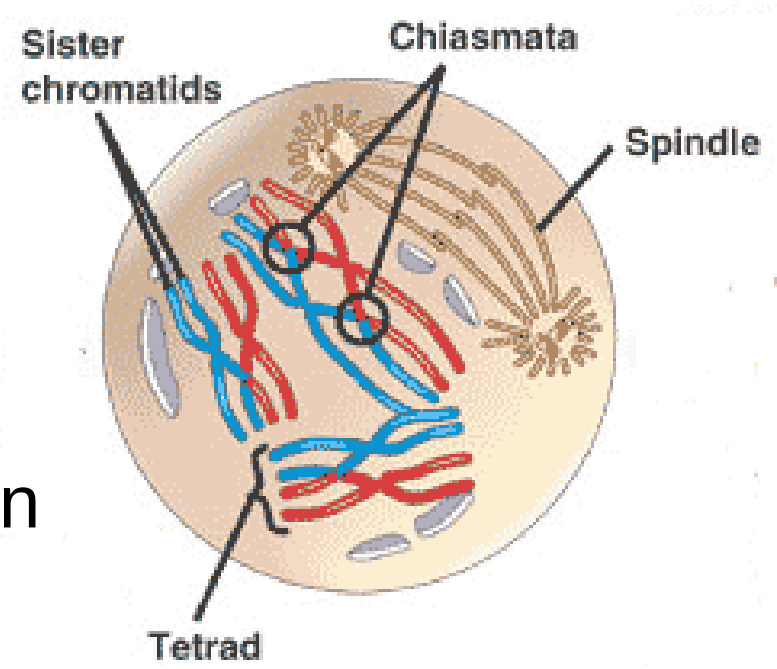
- Chromosomes coil tighter and become visible
- Nuclear envelope disappears
- Microtubule spindle forms
- Each chromosome composed of two **sister chromatids**



http://www.quia.com/jg/1255802list.html

Prophase I

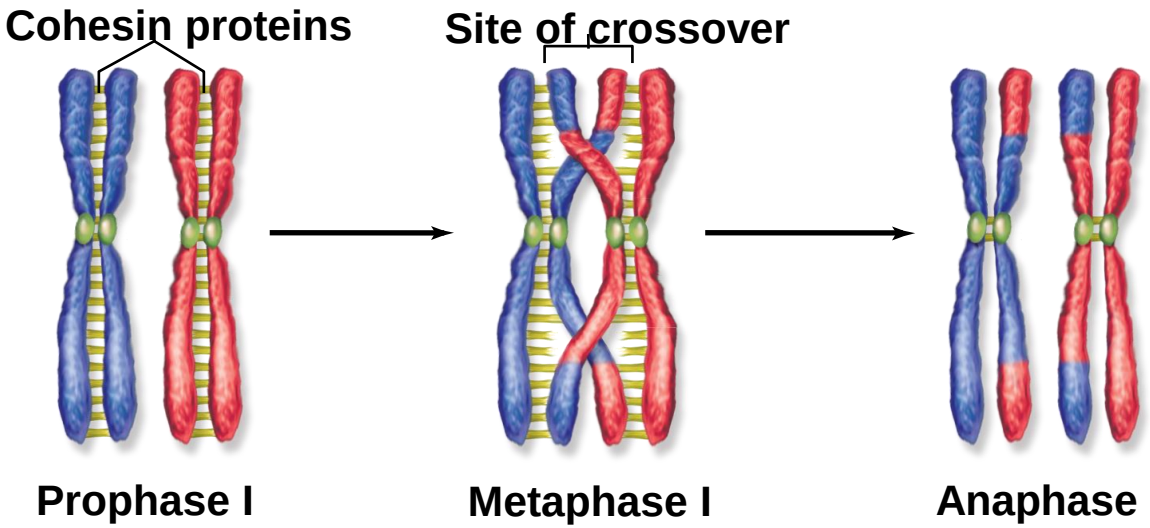
- **Synapsis** (**crossing-over**)
  - Homologues become closely associated as **tetrad**
  - Crossing over occurs *between non-sister chromatids*
  - Non-sister chromatids remain attached at **chiasmata**
    - Chiasmata move to the end of the chromosome arm before metaphase I



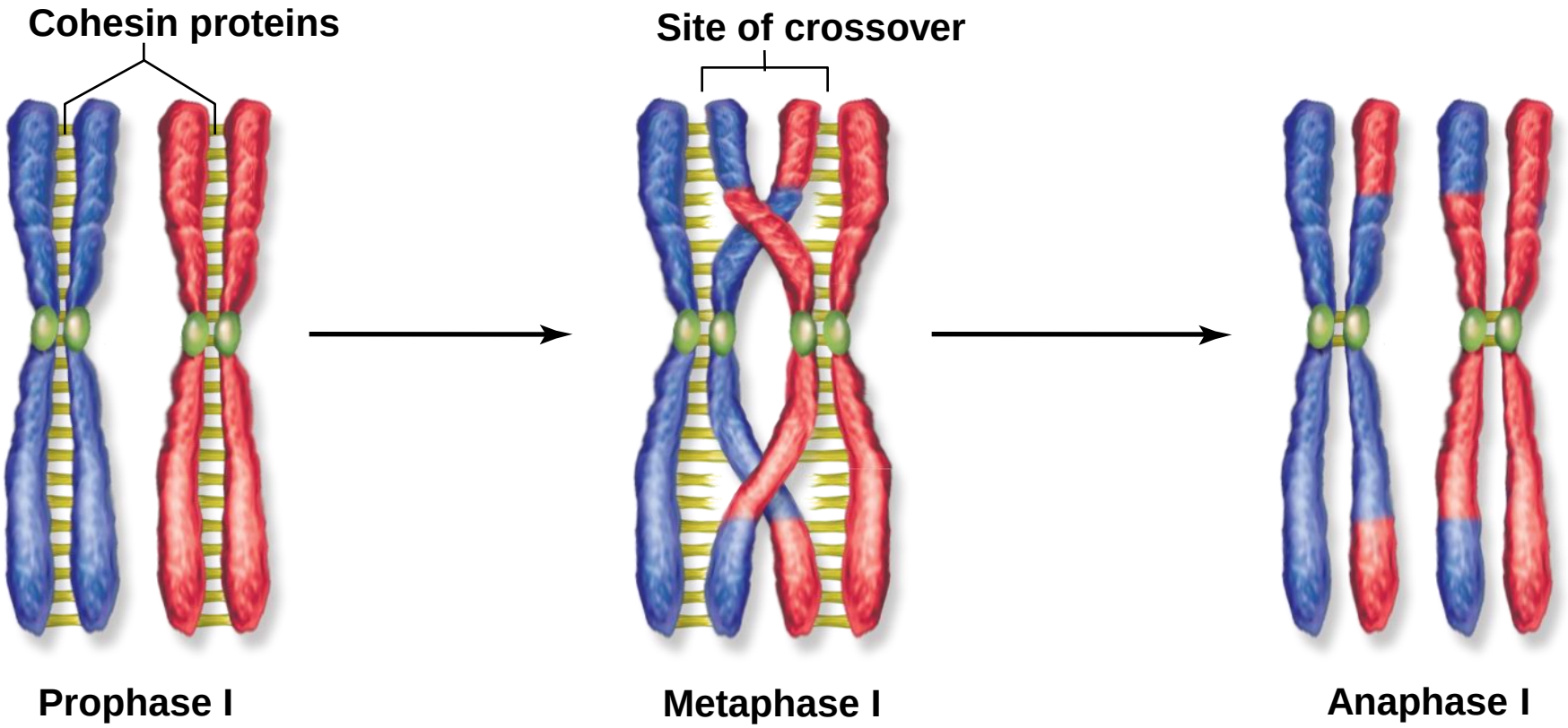
http://www.quia.com/jg/1255802list.html

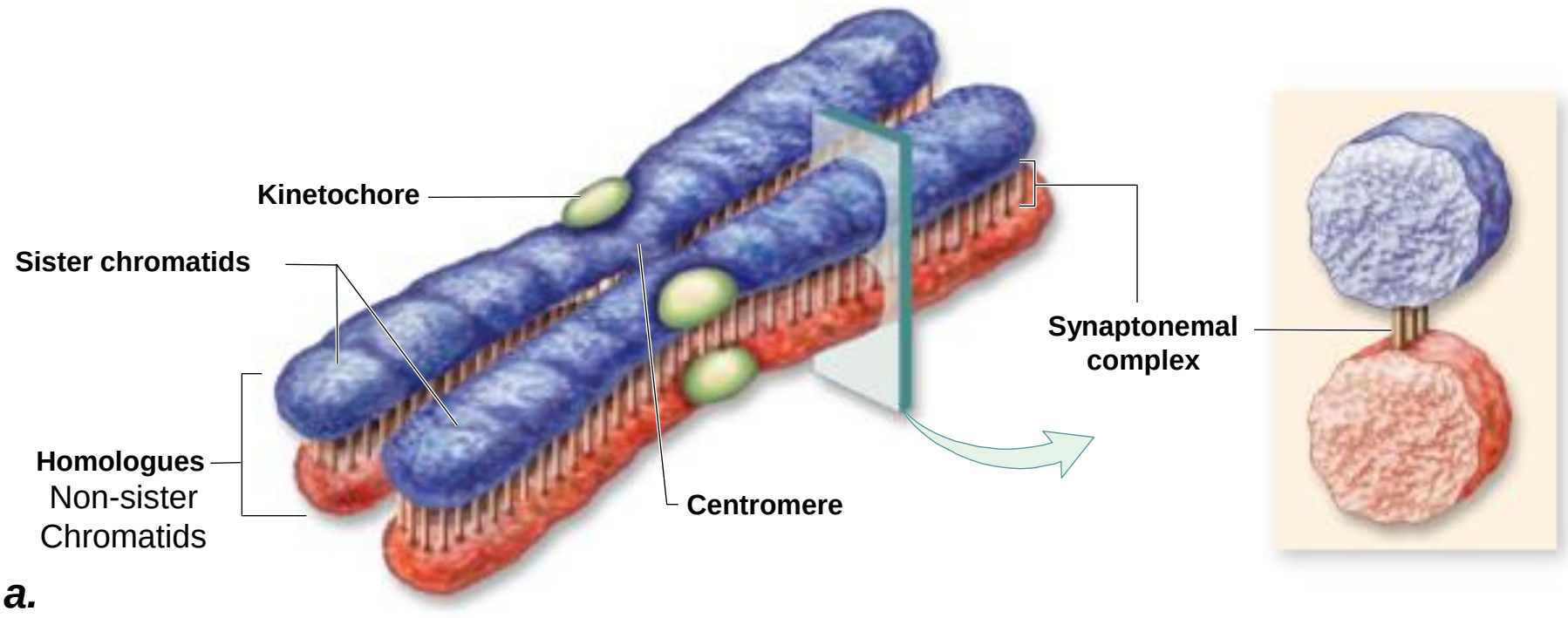
Crossing over

- Occurs between non-sister chromatids
- Allows the maternal and paternal homologues to exchange chromosomal material (recombination)
  - Alleles of genes that were formerly on separate homologues can now be found on the same homologue
  - **Chiasmata** (site of crossing over) maintained until anaphase I



Crossing over





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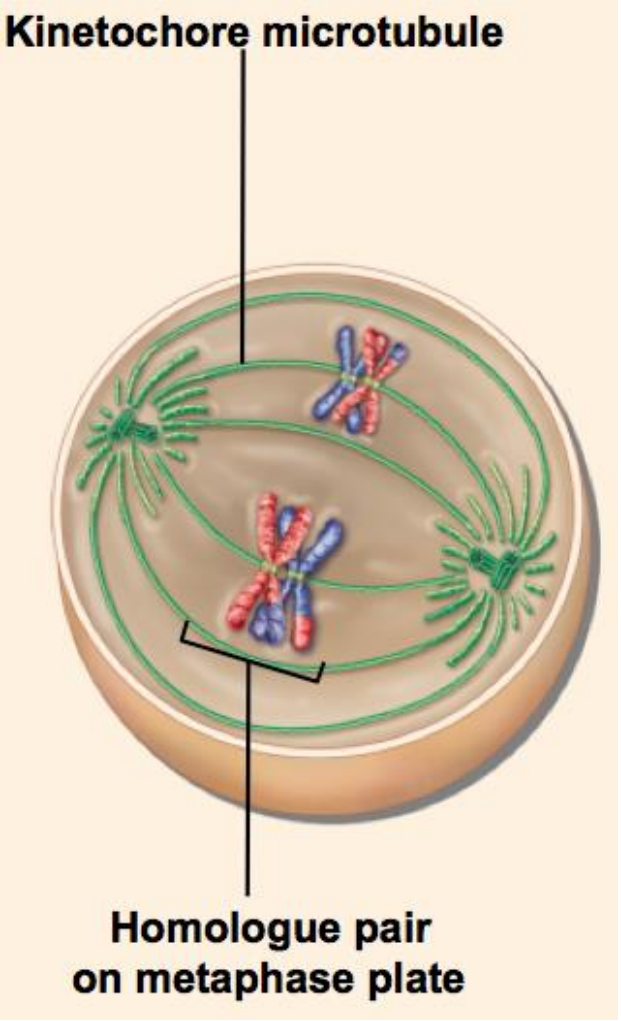
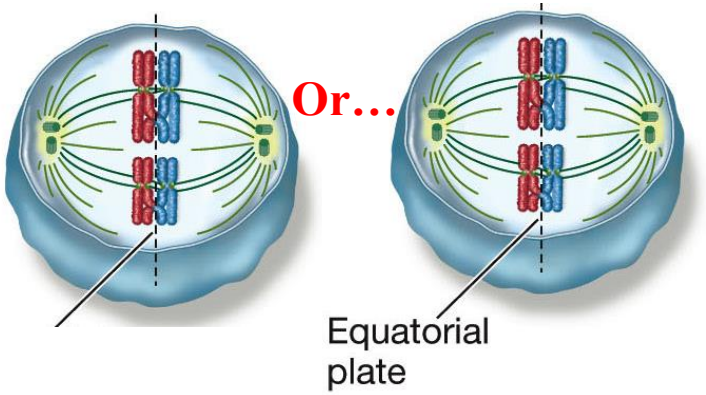
Metaphase I

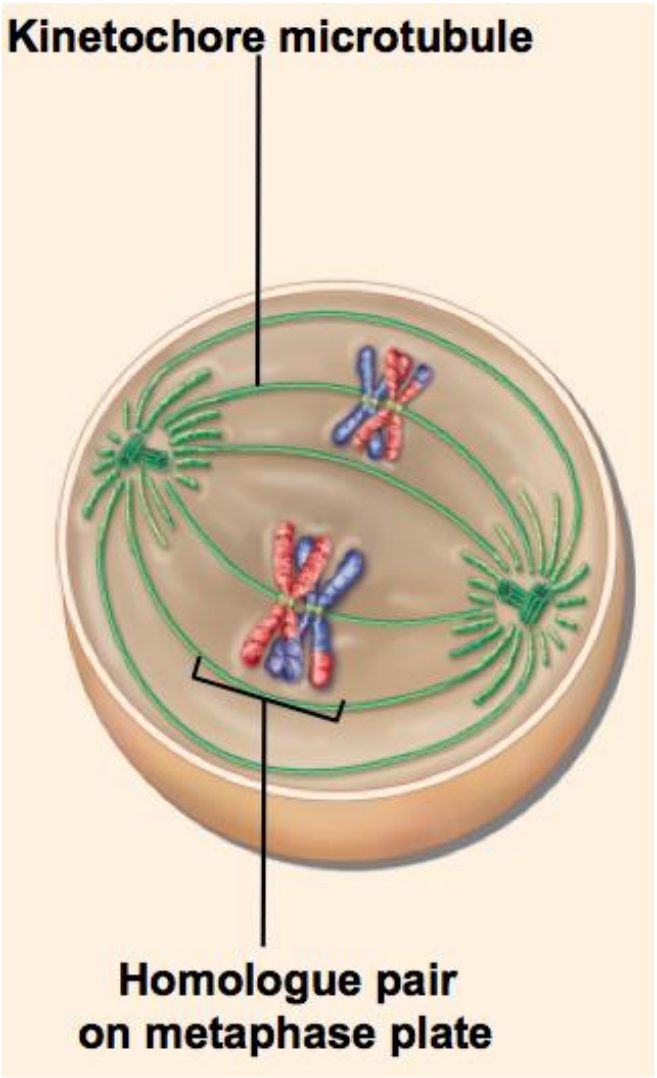
- Terminal chiasmata hold homologues together following crossing over
- Microtubules from opposite poles attach to *kinetochore of each homologue*…(not each sister chromatid)



Metaphase I

- Homologues are aligned at metaphase plate side-by-side
  - Orientation of each pair of homologues on spindle is random
  - This random orientation sets up **independent assortment**



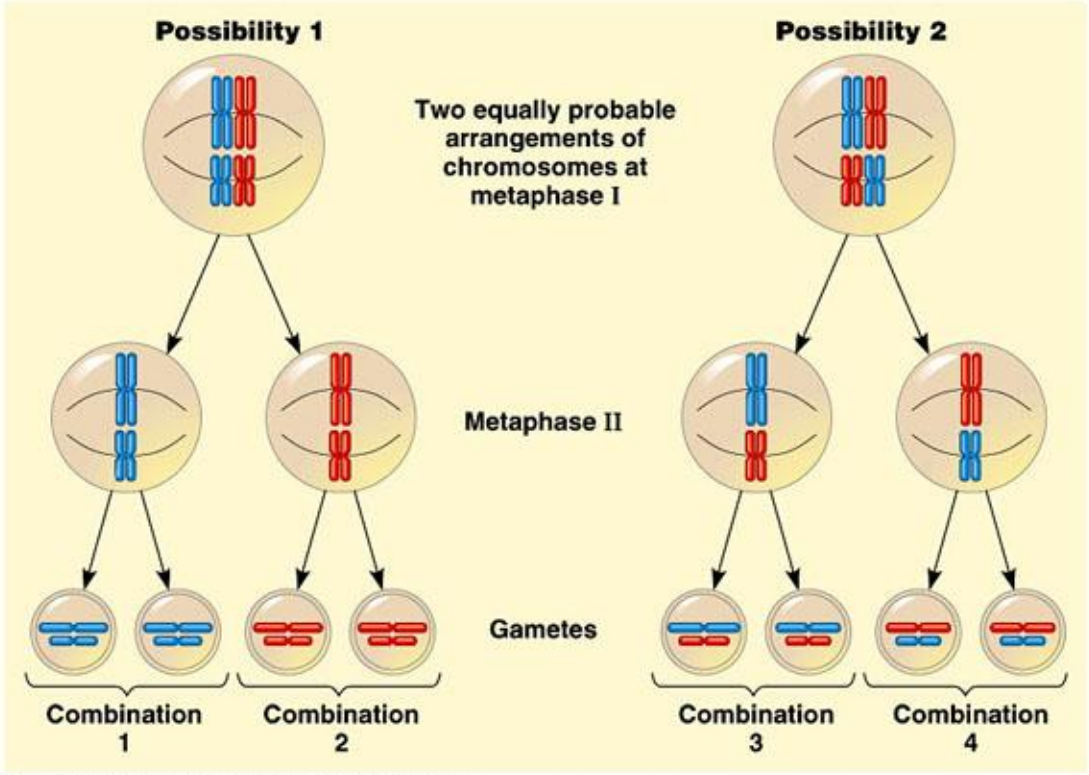


Independent Assortment

The more chromosomes, the greater likelihood of novel combinations of genetic material

- Humans have 23 pairs; 2^{23} (8,388,608) combinations are possible from independent assortment alone

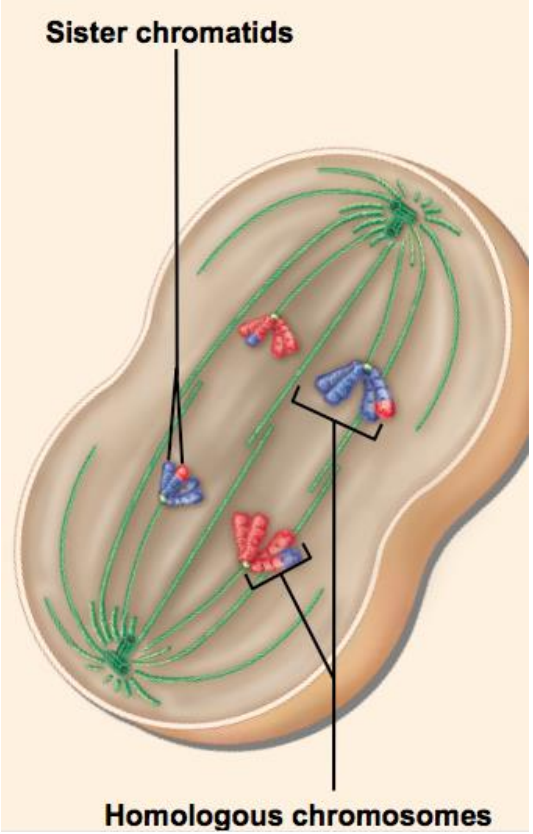
With only 2 pairs of chromosomes, the possibilities are $2^2 = 4$



http://www.bio.miami.edu/~cmallery/150/mitosis/c13x9independent-assortment.jpg

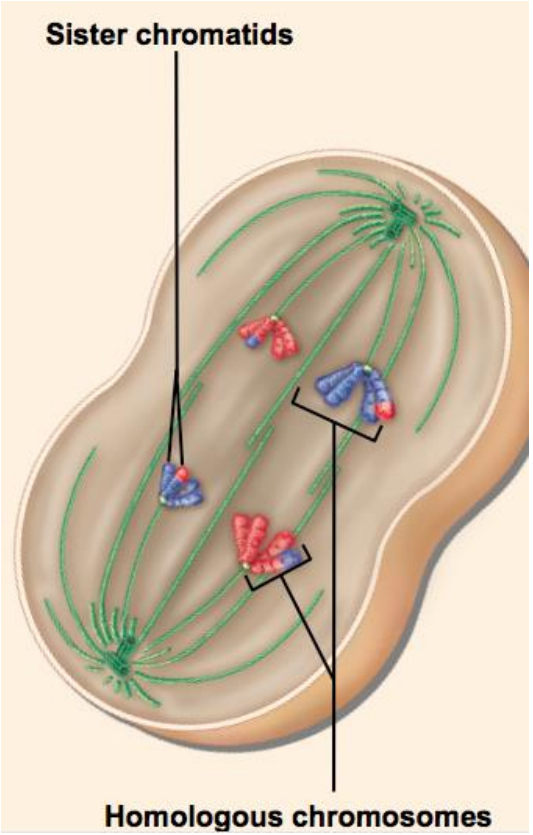
Anaphase I

- Microtubules of spindle shorten, homologues are pulled apart
  - Chiasmata break
  - The effect of crossing over can now be seen
- Homologues are separated from each other and move to opposite poles
  - Sister chromatids remain attached to each other at their centromeres
  - This differs from mitosis



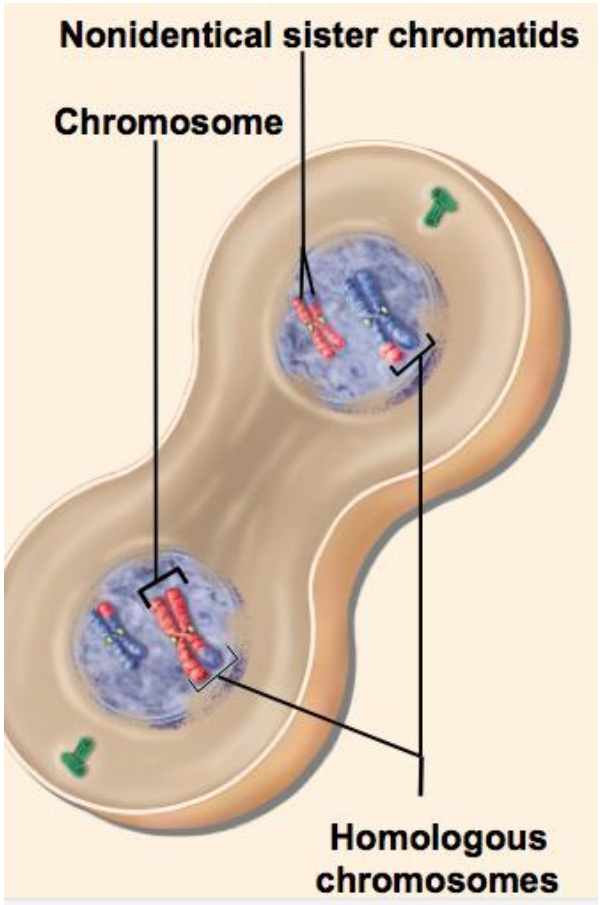
Anaphase I

- Each pole has only one haploid set of chromosomes consisting of one member of each homologous pair
- **Independent assortment** of maternal and paternal chromosomes occurs
  - With many chromosomes, there are many possible combinations of maternal and paternal sister chromatids



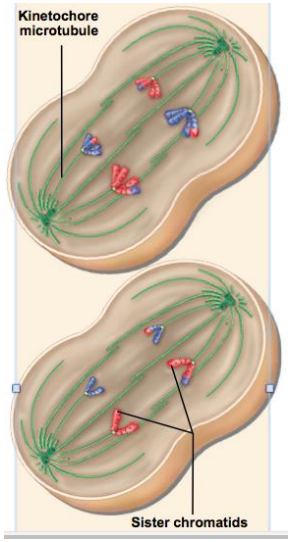
Telophase I

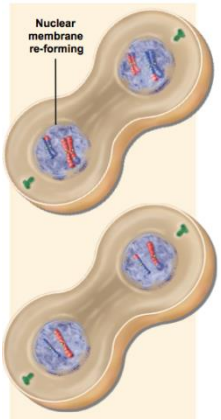
- Nuclear envelope re-forms around each daughter nucleus
- Sister chromatids are no longer genetically identical because of crossing over (prophase I)
- Cytokinesis may or may not occur after telophase I
- Meiosis II occurs after an interval of variable length



Meiosis II

- Meiosis II is similar to mitosis
  - But with haploid rather than diploid cell
- **Prophase II:** nuclear envelopes dissolve and new spindle apparatus forms…no crossing over
- **Metaphase II:** chromatids align on metaphase plate
- **Anaphase II:** sister chromatids are separated from each other
- **Telophase II:** nuclear envelope re-forms around four sets of cells *genetically unique daughter chromosomes*; cytokinesis follows





Final result of Meiosis

- Four cells containing haploid sets of chromosomes
- In animals, these cells develop directly into gametes
  - In Spermtogenesis: 4 sperm
  - In Oogenesis: 1 egg, 3 polar bodies
- In plants, fungi, and many protists, haploid cells then divide mitotically
  - Produce greater number of haploid cells

Sexual Reproduction: Increases Genetic Variation

- *Sexual reproduction only mixes existing genes to increase genetic diversity of offspring*
  - Meiosis increases genetic diversity in two ways:
    - Synapsis & **crossing-over** mixes genetic material *between maternal and paternal (homologous) chromosomes*
    - **Independent assortment** randomly mixes parental chromosomes *among daughter cells*
  - *Random fertilization* between parents results in further increased genetic diversity of zygotes
- But **mutations** *are the only way to create new genes (alleles)*

Know this!!

Mitosis and Meiosis Compared

Unlike mitosis:

- In meiosis I, homologous pairs of chromosomes come together and pair along their entire lengths
- Crossing over occurs in prophase I
- In anaphase I, homologous pairs segregate
- Sister chromatids remain together until anaphase II
- Four haploid daughter cells are produced

Meiosis vs. Mitosis

Meiosis is characterized by 4 features:

1. Synapsis & crossing over in prophase I, and homologous pairs segregate in anaphase I

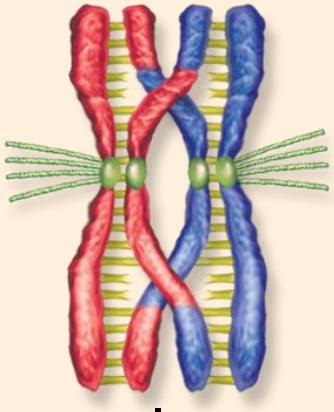
2. Kinetochores of sister chromatids attach to the same pole in meiosis I → move together

3. Sister chromatids remain joined at their centromeres until anaphase II

4. DNA replication is suppressed between meiosis I and meiosis II

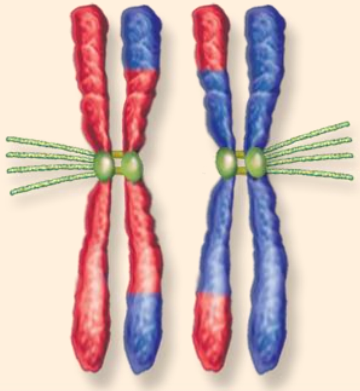
Meiosis I

Metaphase I



Crossovers and sister chromatid cohesion lock homologues together. Microtubules connect to the kinetochores of sister chromatids so that homologues are pulled toward opposite poles.

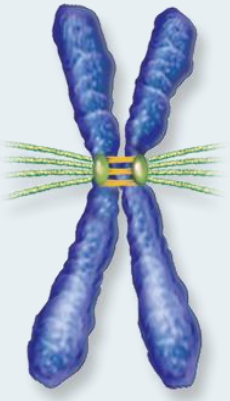
Anaphase I



Microtubules pull the homologous chromosomes apart, but sister chromatids are held together at the centromere.

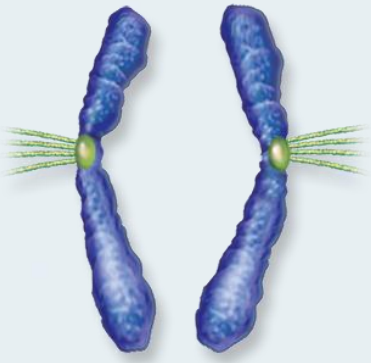
Mitosis

Metaphase

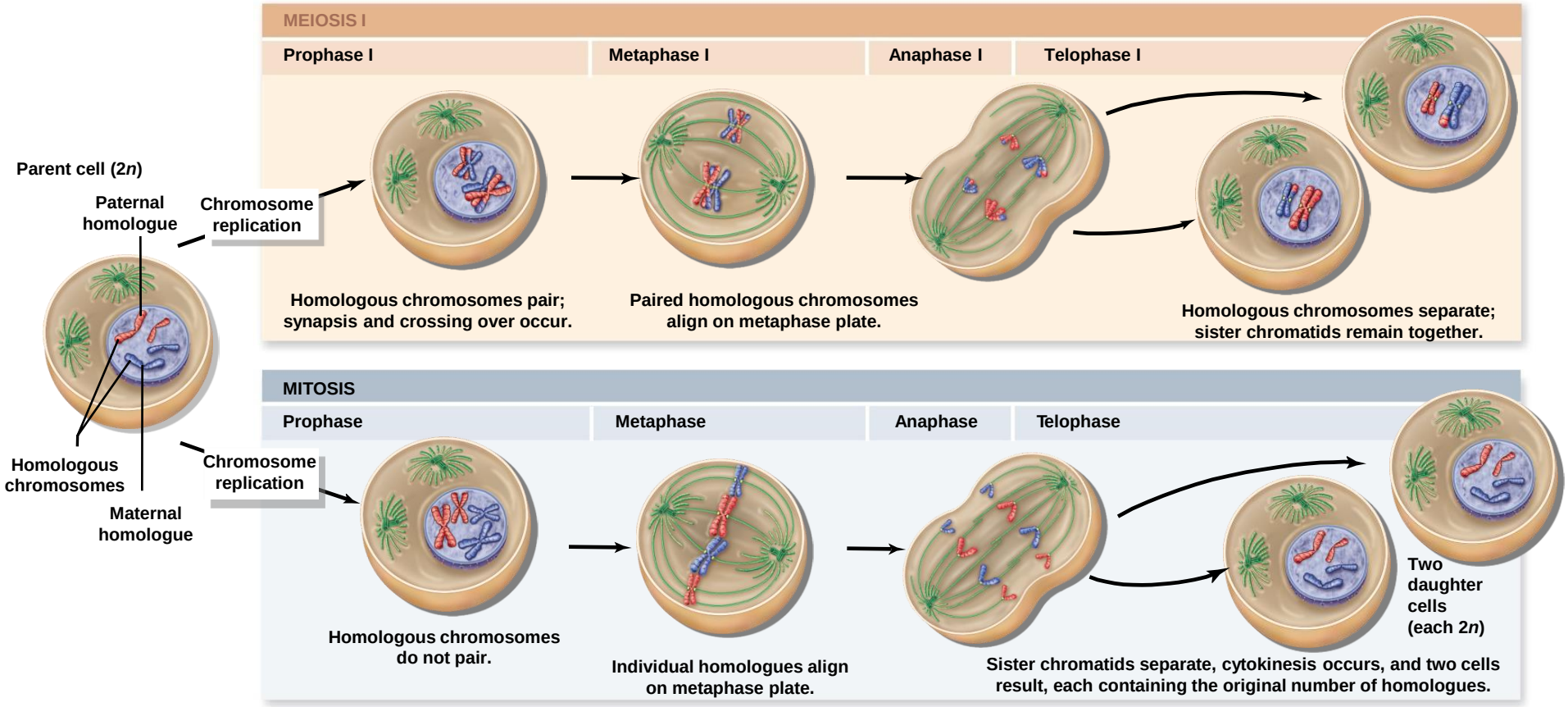


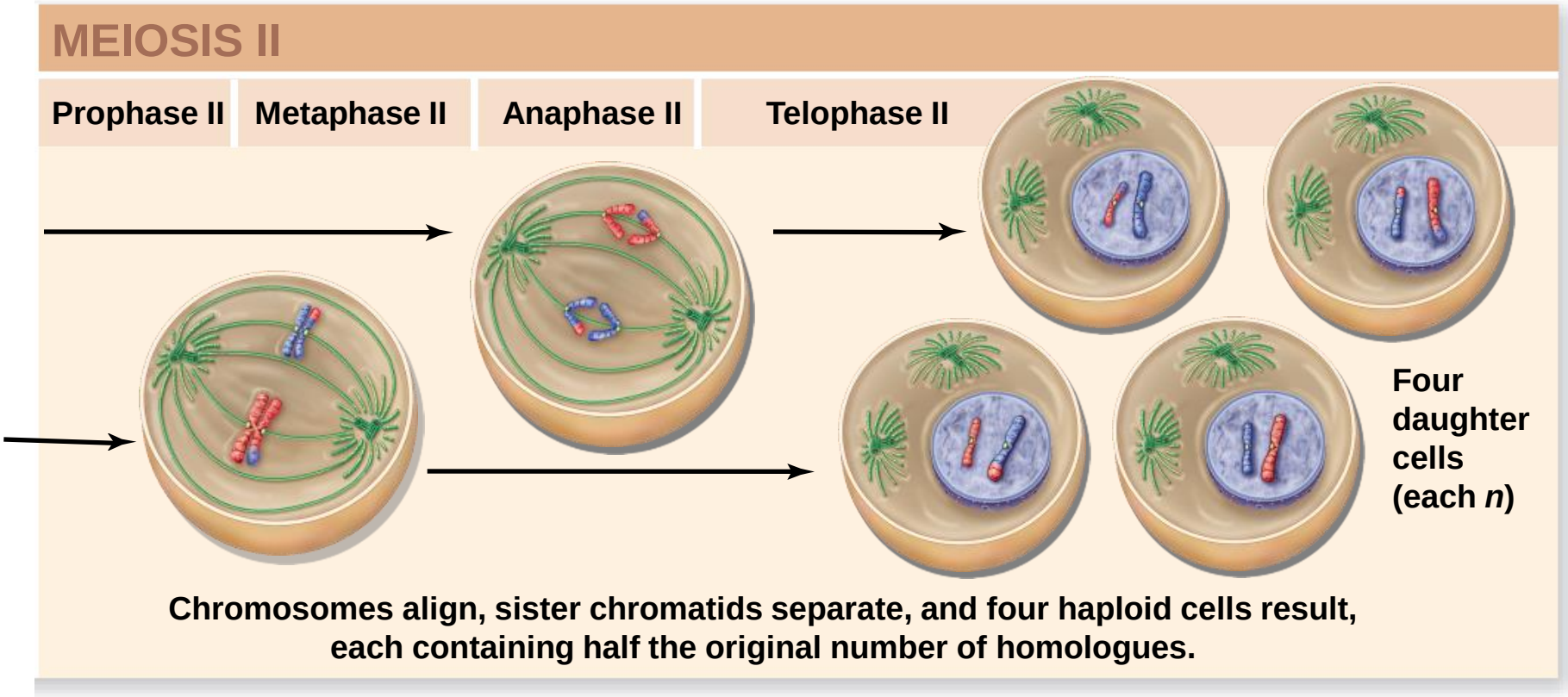
Homologues do not pair; kinetochores of sister chromatids remain separate; microtubules attach to both kinetochores on opposite sides of the centromere.

Anaphase



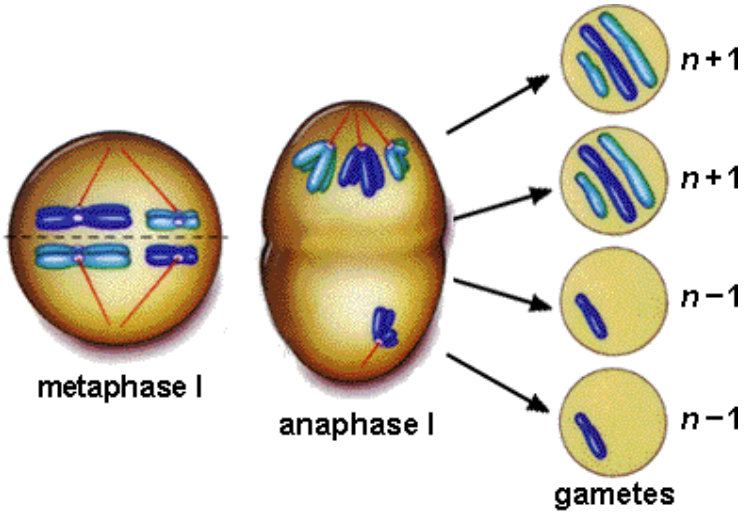
Microtubules pull sister chromatids apart.





Errors in Meiosis

- **Nondisjunction** – failure of chromosomes to move to opposite poles during either meiotic division
  - **Aneuploid gametes** – gametes with missing or extra chromosomes
  - Most common cause of spontaneous abortion in humans



http://www.biology.iupui.edu/biocourses/N100/2k2humancsomaldisorders.html