Meiosis – Production of Chromosome Hybrids & Gametes

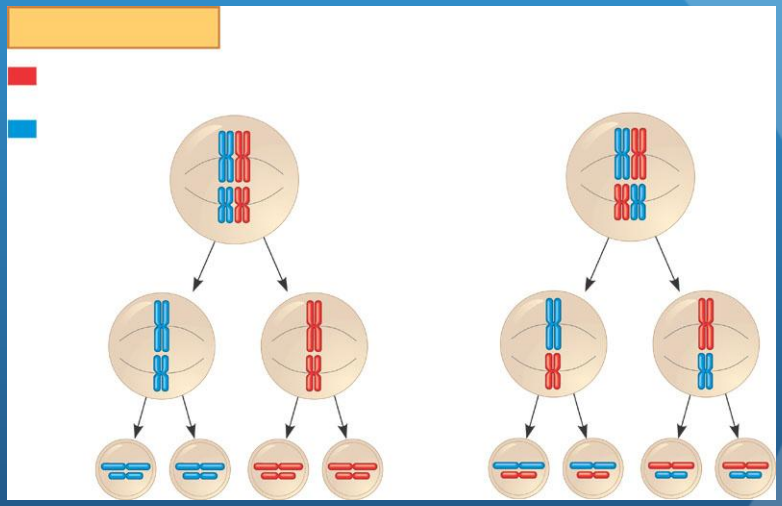
Packet #11

Introduction

- Meiosis, discovered in 1883, was first observed through the fertilized egg and individual gametes, sperm and unfertilized egg, of a worm.
- Meiosis, from the Greek language, means *diminution* or *lessening*.
- Meiosis is used in the formation of sex cells and decreases the ploidy in half.
  - Generally from diploid to haploid.

Introduction II

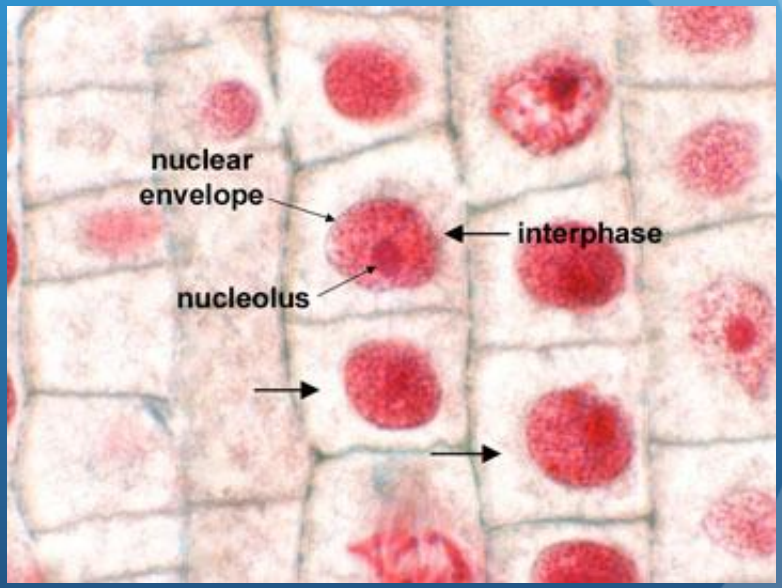
- Meiosis has *two* cell divisions and three general phases to meiosis.
  - Interphase
  - Meiosis I
    - PMAT I
  - Interkinesis
  - Meiosis II
    - PMAT II



Interphase

Interphase

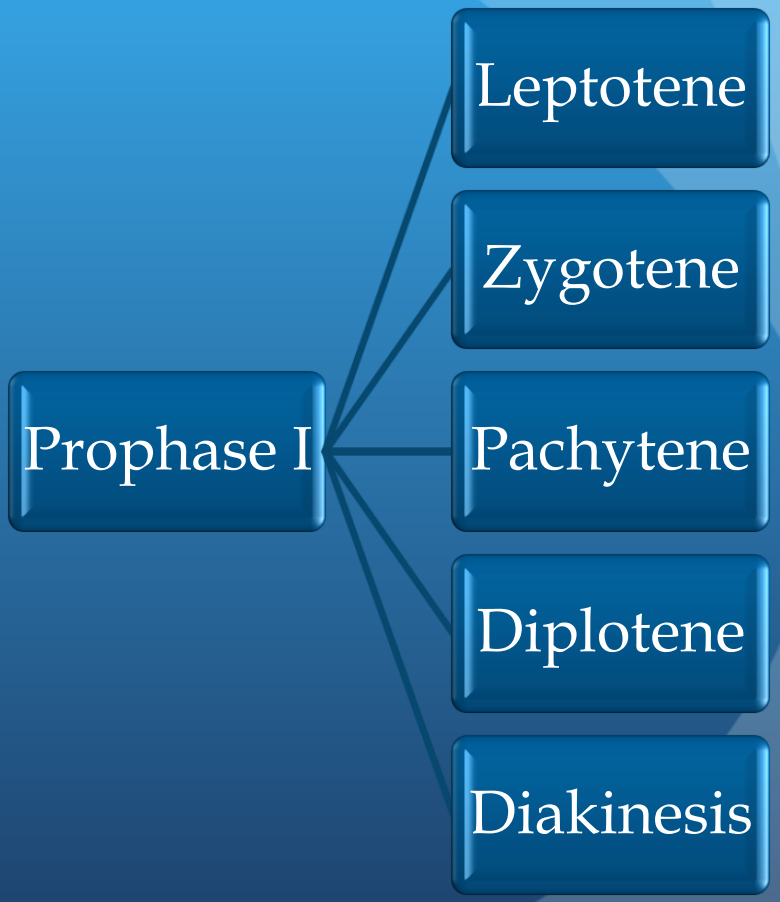
- G1 phase
  - Gap Phase I
- S Phase
  - Synthesis Phase
    - DNA is replicated
    - Chromosomes are replicated
- G2 Phase
  - Gap Phase II
    - Cell continues to grow in size



Meiosis I

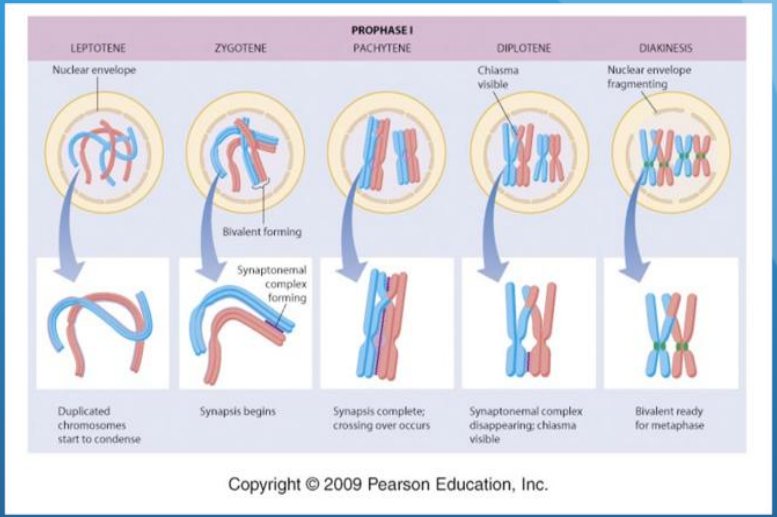
Meiosis I
Prophase I

- During prophase I of meiosis I, there are five stages that occur.



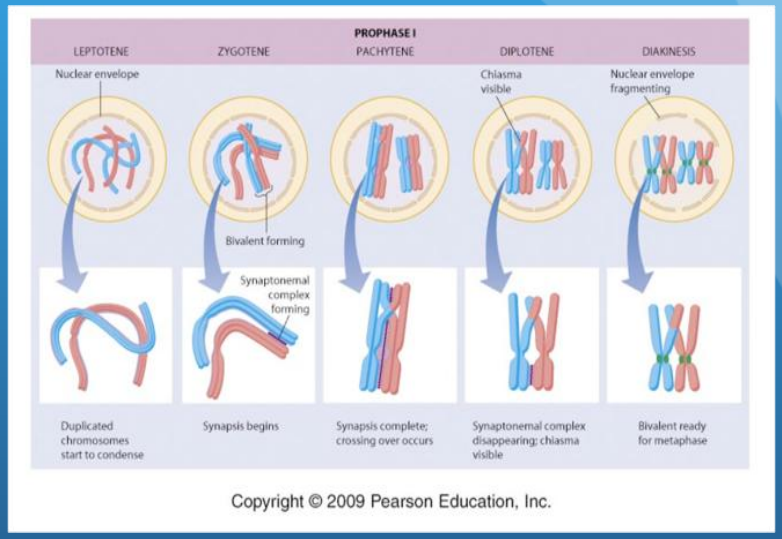
Meiosis I
Prophase I—Leptotene

- Replicated chromosomes condense and become visible.



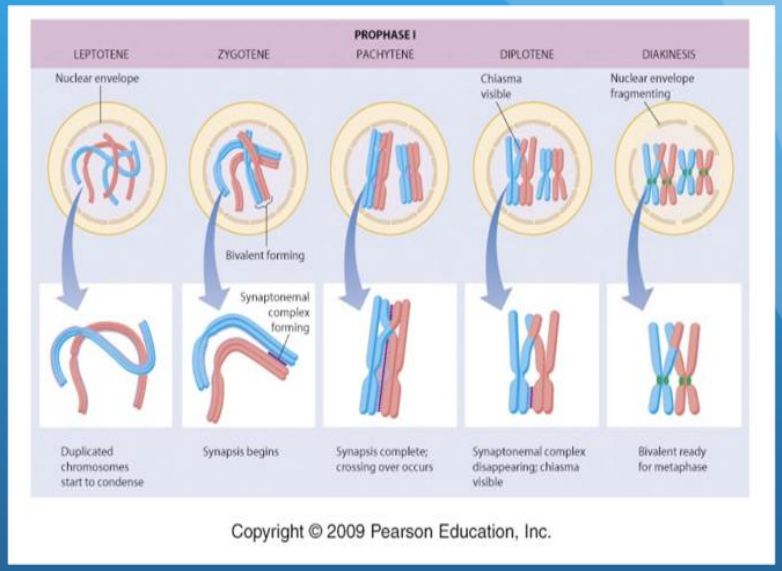
Meiosis I
Prophase I – Zygotene

- The process of synapsis begins.
  - **Homologous chromosomes recognize each other** and begin to align themselves.
  - Occurs because of the formation of a synaptonemal complex between the homologous chromosomes.



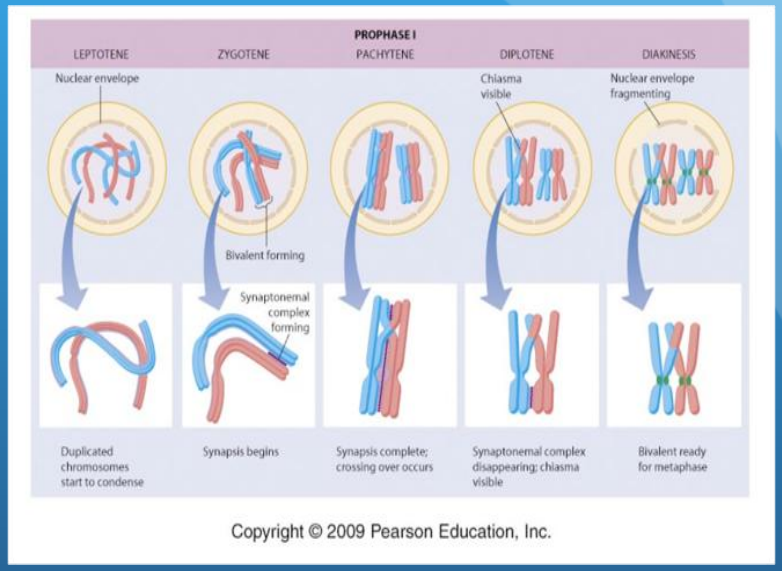
Meiosis I
Prophase I—Zygotene Continued…

- During synapsis
  - The two versions of each chromosome, even though they are not identical, align next to each other
    - Keep in mind at this time that the cell is diploid and has two copies of every chromosome
      - Paternal
        - Male parent
      - Maternal
        - Female parent



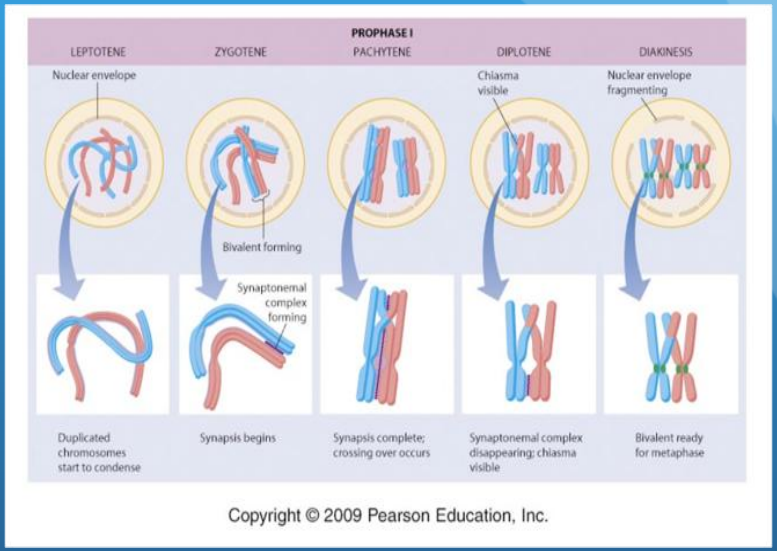
Meiosis I
Prophase I—Diplotene

- The **homologous pairs** are completely aligned with each other.
  - **Four sister chromatids** are aligned with each other
    - Four sister chromatids, of the same chromosome number, is called a **tetrad**.



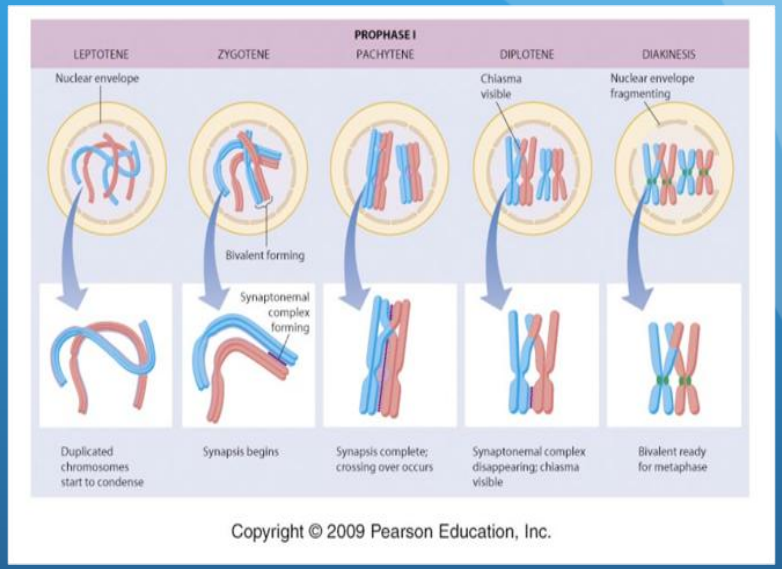
Meiosis I
Prophase I—Pachytene

- The **homologous pairs** are completely aligned with each other.
  - **Four sister chromatids** are aligned with each other
    - Four sister chromatids, of the same chromosome number, is called a **tetrad**.
  - Crossing over occurs.



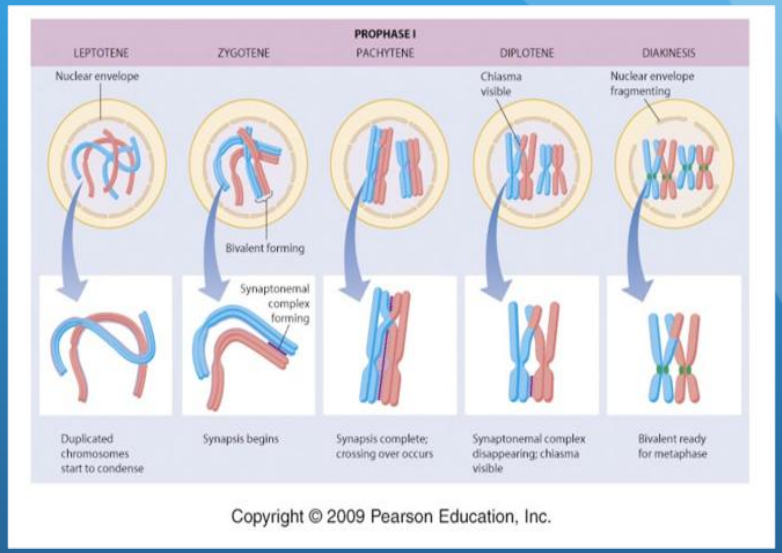
Meiosis I
Prophase I—Pachytene Continued…

- Crossing Over…
  - Process of genetic recombination
    - Exchange of genetic material between paternal and maternal chromosomes.
  - Occurs between the **bivalents**.
    - **Two pairs of sister chromatids.**
      - One pair is paternal.
      - One pair is maternal.
  - The number of times that crossing over occurs is dependent on the species, it number of crossing over events may range from 2 to 20+.
  - The new connection that results from crossing over is called the **chiasma (plural: chiasmata).**



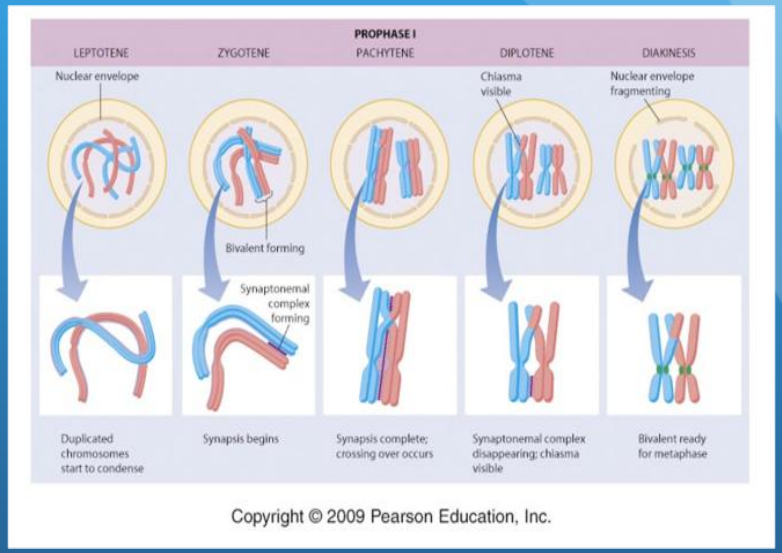
Meiosis I
Prophase I—Diplotene

- The synaptonemal complex starts to disappear.
  - This also results in the sister chromatids pull slightly apart.



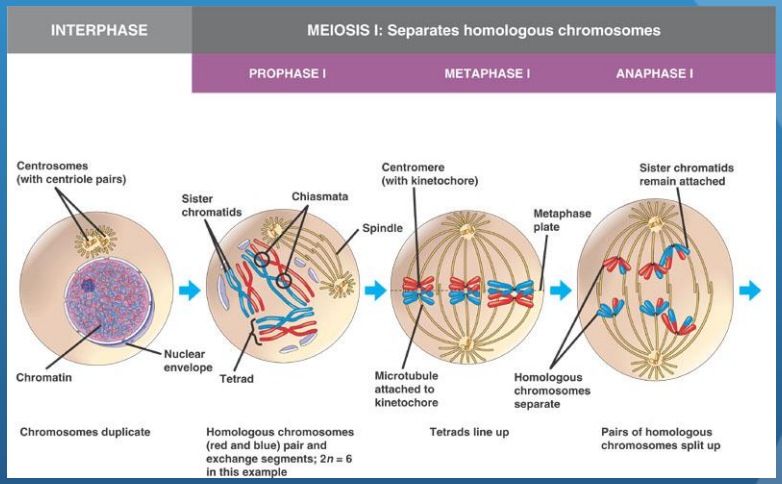
Meiosis I
Prophase I—Diakinesis

- The synaptonemal complex has completely disappeared.



Meiosis I
Prometaphase I

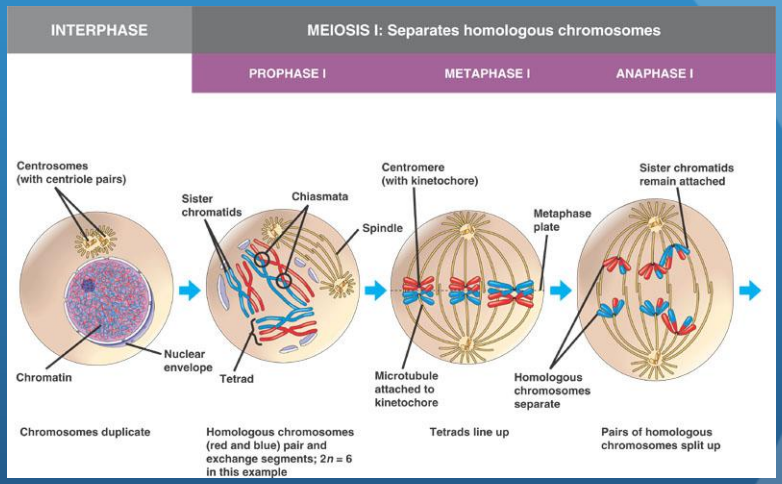
- Spindle apparatus is completed and prepares for the separation of the homologous pairs.
  - See prometaphase from the cell cycle packet.



Meiosis I
Metaphase I

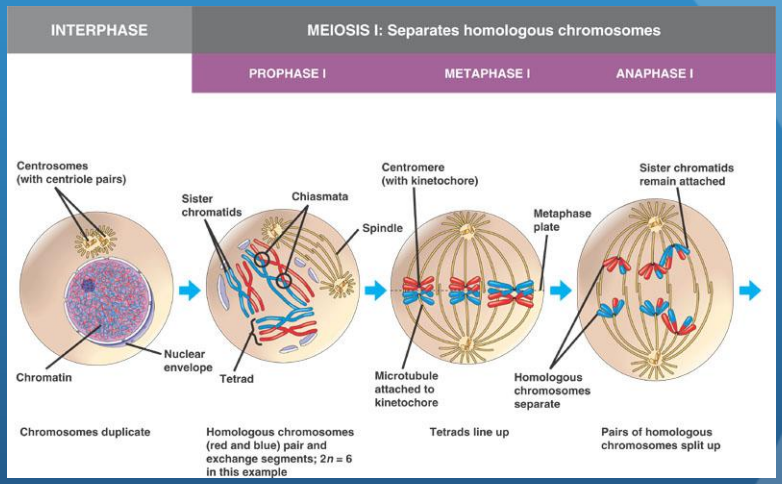
- Homologous pairs (bivalents/tetrads) align along the metaphase plate.
  - The sister chromatids are aligned in a double row.
  - **The arrangement of the sister chromatids is random.**
    - In regards to maternal vs. paternal.
    - **This fact, in addition to crossing over, allows for more variation between each gamete that is ultimately produced.**
    - The possible arrangement for human gametes is 2^n – where n = number of chromosomes.
      - There are 8 million possible combinations. $\{2^{23}\}$

- **The sister chromatids are ONLY attached to one spindle pole.**
  - In the cell cycle, they are attached to both.



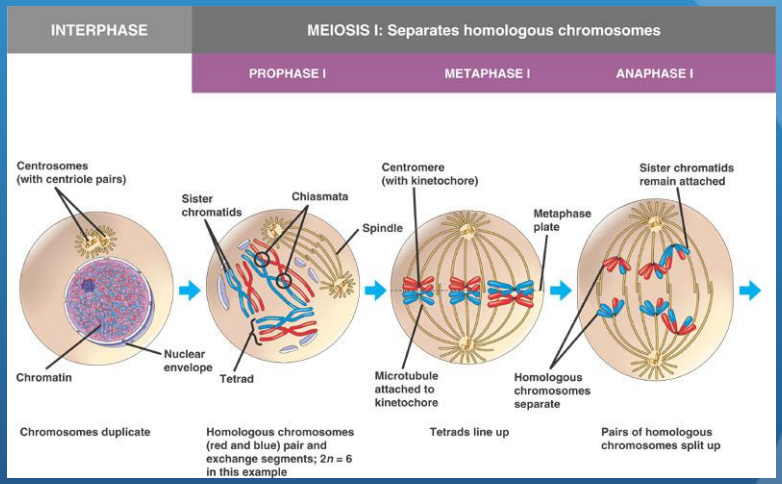
Meiosis I
Anaphase I

- Homologous pairs (bivalents/two pairs of sister chromatids) separate from each other and are distributed to different nuclei.
- **The sister chromatids are not seperated.**
  - **The pair of sister chromatids are what separate!**
- Each developing ***nucleus*** will contain the ***haploid*** number of chromosomes.



Meiosis I
Telophase I & Cytokinesis I

- Cleavage furrows form in animal cells
- Cell plates form in plant cells
- Nuclear envelope and nuclei re-form in some cells
- Sister chromatids are still joined together
- First cell division is complete
  - Two haploid cells
    - The transition from diploid to haploid is complete…but there is still a 2nd cell division to occur



Meiosis II

The events of meiosis II are similar to those that occur during mitosis of the cell cycle.

What is the difference between mitosis of the cell cycle and meiosis II? (EC on exam)

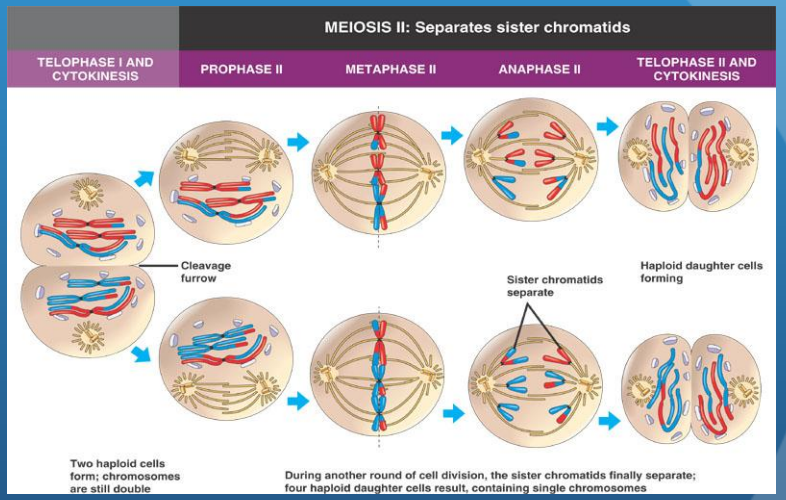
The notes provided for meiosis II is a condensed version. Please see cell cycle packet for more details.

Transitioning from Meiosis I into Meiosis II

- It is suggested that a second interphase occurs before entering into Meiosis II.
  - However, during this interphase, there is no copying of chromosomes.

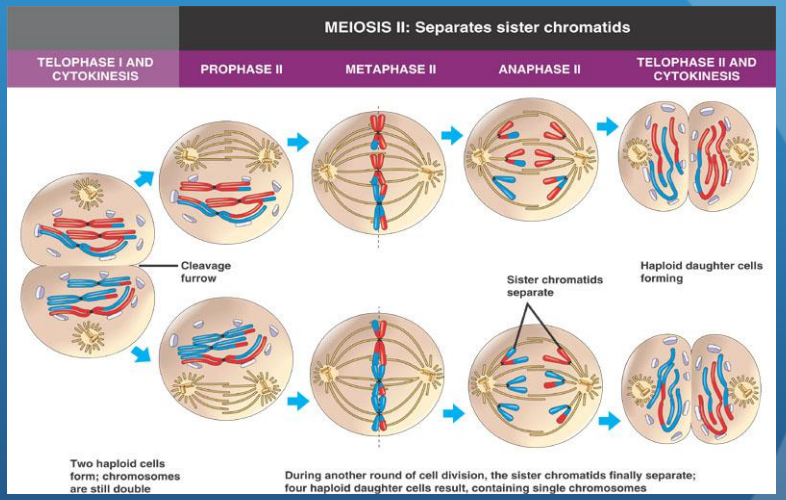
Meiosis II
Prophase II

- Spindle apparatus forms and chromosomes progress towards the equatorial plane (middle of the cell).



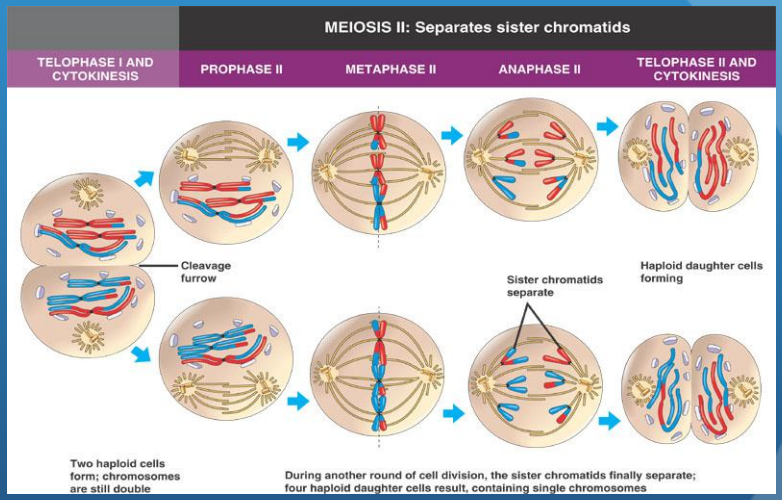
Meiosis II
Metaphase II

- Sister chromatids (chromosomes) arrange themselves on the equatorial plane (middle) of the cell. (metaphase plate)



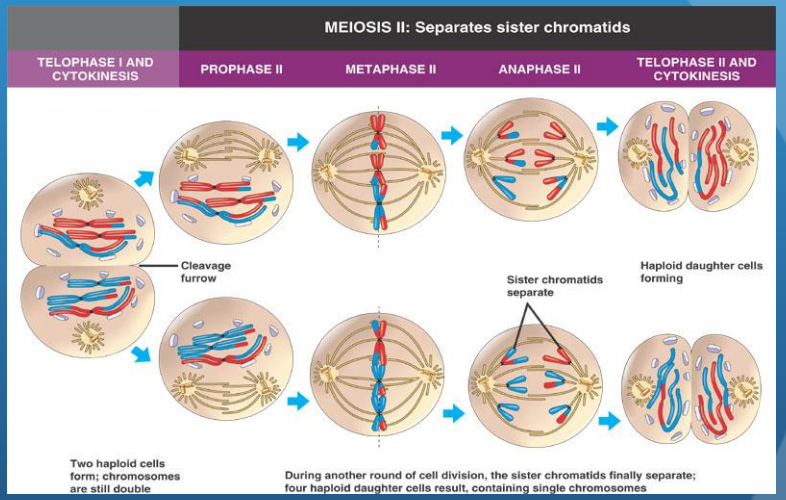
Meiosis II
Anaphase II

- Sister chromatids are pulled to opposite poles by spindle fibers
  - **This separation provides even greater variation due to crossing over that occurred within prophase I of meiosis I. Variation is in part due to the fact that one may not know how many crossing over processes occurred for each chromatid AND the side on which the chromatid aligns to, the pole to which it is pulled towards, is RANDOM.**
- **Centromeres divide**
- Sister chromatids are finally separated
  - The new, developing nuclei are still haploid.



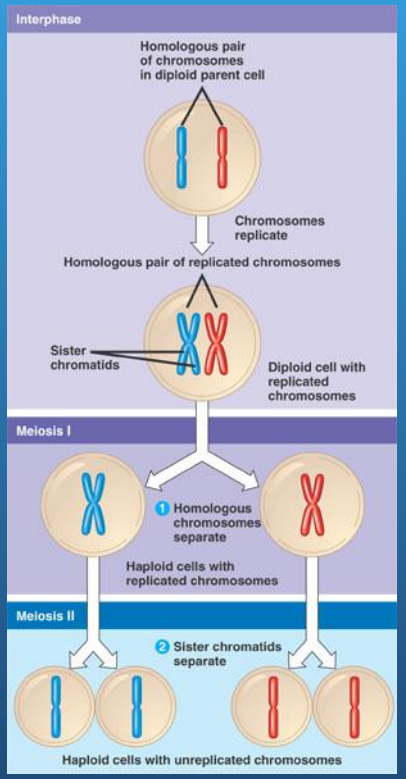
Meiosis II
Telophase II & Cytokinesis II

- Cleavage furrows form in animal cells
- Cell plates form in plant cells
- Nuclear envelope and nuclei re-form in some cells
- Second cell division is complete
  - Four haploid cells are produced.



Review of Meiosis

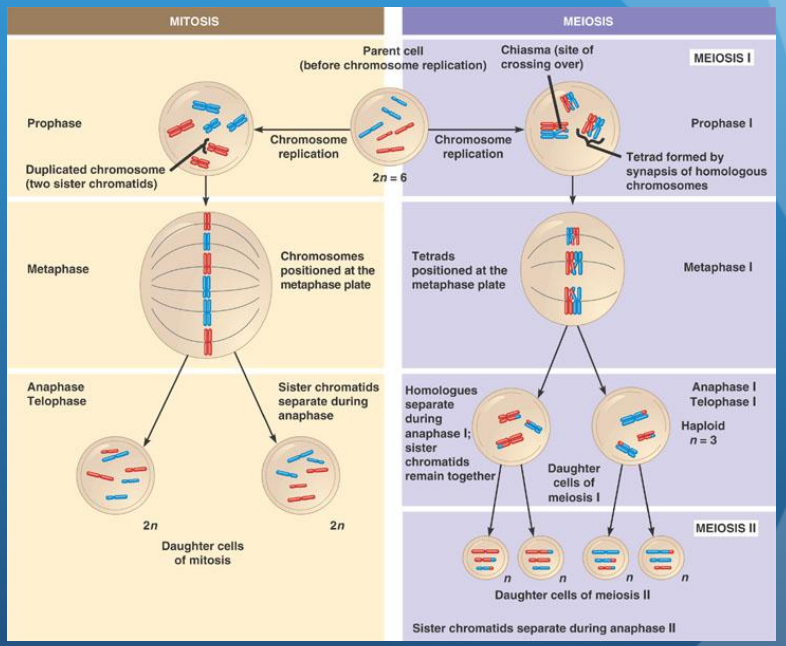
VERY Summarized Version…



Comparing Meiosis to the Cell Cycle

Comparison I

- Distinct Differences
  Key Concepts
- Meiosis = 4 progeny cells [1 = 2 = 4]... thus 2 divisions
- Mitosis = 2 daughter cells only... thus 1 cell division
- Meiosis = one-half number of chromosomes
- Mitosis = same # of chromosomes as parent cell
- Meiosis = new combinations of gene not in parents & chromosomes sort randomly of each other
- Mitosis = daughter cells are genetically identical

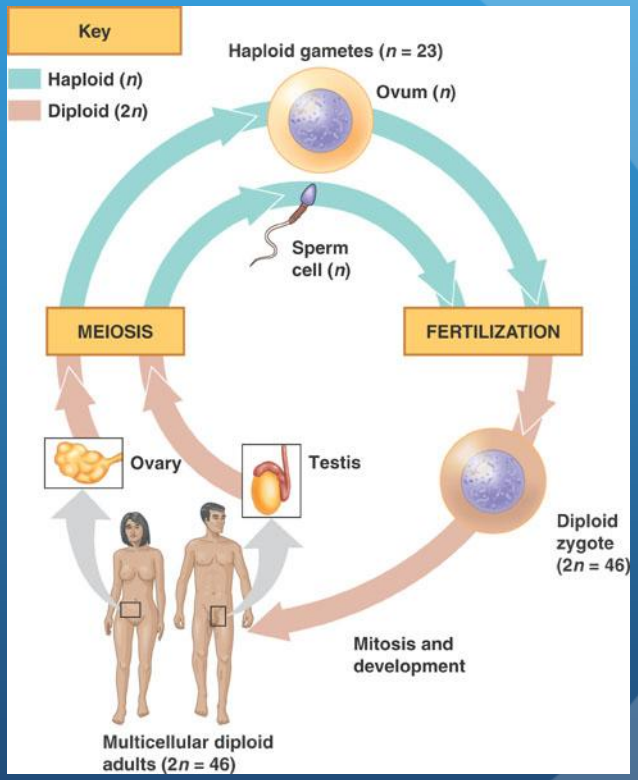


Linking Meiosis to Gametogenesis

Special Note: - We will NOT be investigating the reproductive anatomy of human males & females, the female monthly cycle, the releasing of male sperm, copulation and conception, the stages of pregnancy or childbirth at this point of the course.

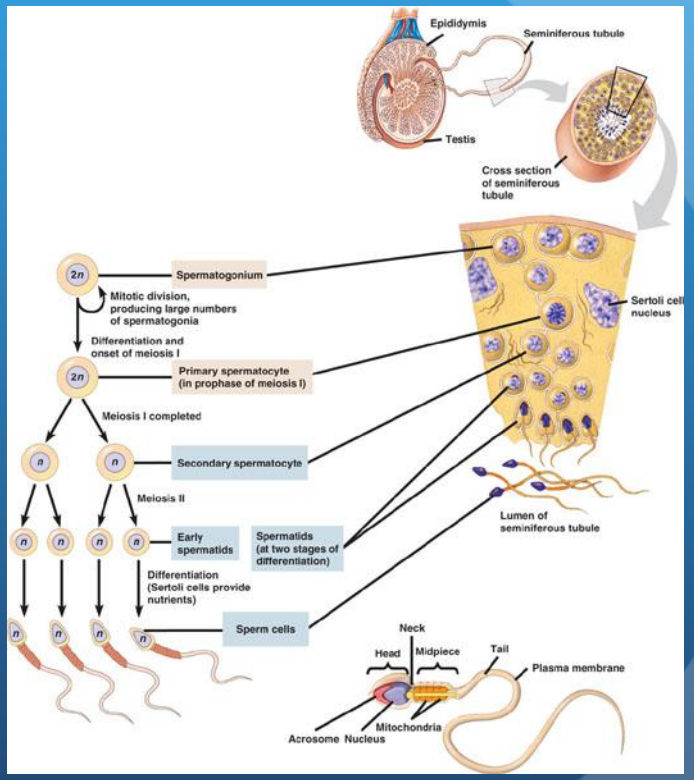
Remember…

- Gametogenesis is defined as the formation of gametes
  - Spermatogenesis (Males)
  - Oogenesis (Females)
- Both processes, in males and females respectively, occur due to meiosis.



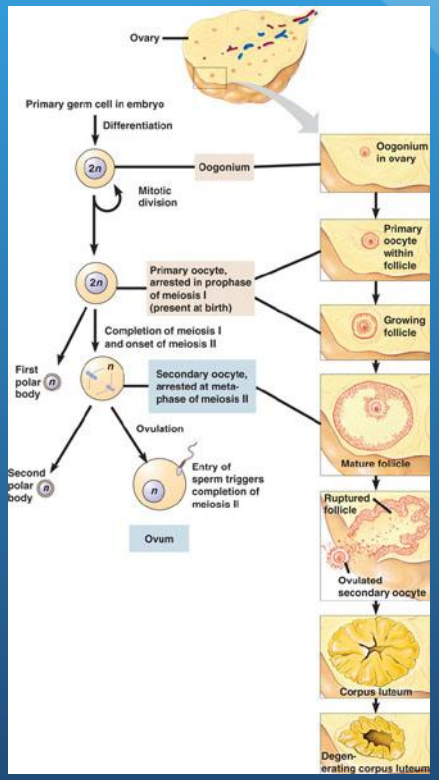
Spermatogenesis

- Spermatogenesis (Males)
  - Formation of four haploid sperm cells



Oogenesis

- Formation of egg cells (ovum)
  - Big difference when comparing to spermatogensis
    - **ONLY ONE EGG/OVEM IS PRODUCED ONCE MEIOSIS IS COMPLETED.**



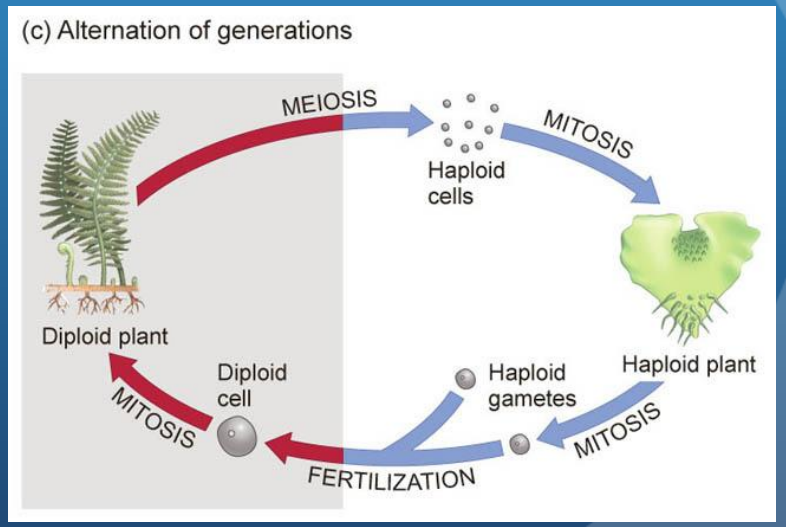
Linkage Continued…

- Organism Sexual Reproduction
  - Involves the fusion of *two haploid cells* to form a *diploid zygote*
    - Sperm and eggs are haploid cells that fuse together to give a diploid stem cell.
  - In the sexual life cycle, meiosis MUST occur before *gametes (sex cells)* can be formed.
    - *Germ line cells (stem cells)* are the cells that undergo meiosis to for sperm and eggs
    - Germ line cells, that do not undergo meiosis and destined to become specialized, multiply via mitosis (Cell Cycle)

Gametogenesis in Other Organisms

Gametogenesis
Alternation of Generations

- Many simple eukaryotes remain haploid throughout their entire live cycles
  - Rather than being predominantly diploid.
- Plants, some algae and some fungi have some of the most complicated life cycles.
  - Alternation of Generations
    - Diploid Stage
      - Sporophyte Generation
    - Haploid Stage
      - Gametophyte Generation
- More to come if time permits.



Review — Breathe!