Sexual Reproduction and Meiosis

Chapter 13

Outline

• Reduction Division
• Unique Features of Meiosis
• Prophase I
• Metaphase I
• Completing Meiosis
  – Second Meiotic Division
• Sexual Reproduction
  – Origin and Maintenance
  – Evolutionary Consequences

Random ??
fertilization
Maternal homologue
• Gametes fuse (fertilization) to produce a zygote
  – Meiosis - reduces the number of chromosomes to half that of somatic cells
  – Adult body cells are diploid.
  – Gamete cells are haploid.

Stem cells?

“Presidential” stem cells??
Meiosis I
- Like mitosis, meiosis begins after replication of DNA.
- Humans, 46 chromosomes would be present in duplicated state (92 sister chromatids)
- Like mitosis, four stages—prophase, metaphase, anaphase, and telophase.
- BUT prophase I very different from prophase of mitosis.
- Chromosomes condense—each homologous set paired together (tetrad)

Meiosis
- Synapsis
  - Homologues pair along their length.
- Homologous recombination
  - Genetic exchange (crossing over) occurs between homologous chromosomes.
- Reduction division
  - Meiosis involves two successive divisions, with no replication of genetic material between them.

Meiosis
- DNA replication
- 2 cell divisions
- 4 daughter cells
Unique Features of Meiosis

Figure 12.7
- Presence of a chiasma indicates crossing over has occurred.
- Tetrad - each homologous set paired together.

**Prophase I: Homologous Chromosome Pairing**
- Close proximity favors crossing over (recombination).
- Presence of a chiasma indicates crossing over has occurred.

*Chromosome homologues*
Meiosis I: Separation of Homologues

- Metaphase I—Tetrads line up—one pair bears no relationship to any other pair.

- Anaphase I—Homologous pairs separate and move to opposite poles

- Telophase I and cytokinesis creates two new cells haploid.
• **Meiosis II: Separation of Sister Chromatids**

- **Prophase II**—23 identifiable separate chromosomes (each still with two sister chromatids).
- **Metaphase II**—Chromosomes line up at metaphase plate, this time with one sister chromatid on either side.
- **Anaphase II**—Sister chromatids separate
- **Telophase II**—and cytokinesis create two new cells
- **Total of four haploid cells**
Second Meiotic Division

• Meiosis II resembles normal mitotic division.
  – prophase II - nuclear envelope breaks down and second meiotic division begins
  – metaphase II - spindle fibers bind to both sides of centromere
  – anaphase II - spindle fibers contract and sister chromatids move to opposite poles
  – telophase II - nuclear envelope re-forms
• Final result - four haploid cells

• Mitosis Compared to Meiosis
  – Meiosis reduces chromosome number by duplication of chromosomes followed by 2 divisions instead of 1.
    
    – Mitosis = “identical”
      • DNA is duplicated
      • identical sets (sister chromatids) are divided into two cells.
      • Result – One diploid cell (2n) becomes two diploid cells (2n)
    
    – Meiosis = “reductional”
      • DNA is duplicated
      • Each homologue must be separated to reduce the total number of chromosomes from 2n to n.
      • sister chromatids are separated
      • Two separate divisions—meiosis I and II.
      • Result – One diploid cell (2n) becomes four haploid cells (n).
• Meiosis and Diversity
  – combine desirable traits
  – increase genetic diversity

  – ALSO

  • Recombination -shuffles genes
  • Independent assortment (no two gametes are ever identical).

**Prophase I**: crossing over (recombination).

![Diagram of chromosomes during prophase I](image)

In prophase I of meiosis I, the chromosomes begin to condense, and the spindle of microtubules begins to form. The DNA has been replicated, and each chromosome consists of two sister chromatids attached at the centromere. In the cell illustrated here, there are four chromosomes, or two pairs of homologues. Homologous chromosomes pair up and become clockwise around each other. This is shown by chiasmata, which hold homologous chromosomes together.

**Independent Assortment**

For n chromosomes (haploid), possible combinations = 2^n.

For humans (23 chromosomes), possible combinations = 2^23 = 8.4 million
• **Meiosis and Sex Outcome**

  – Humans—22 pairs of autosomes and one pair of sex chromosomes; females (XX), males (XY)

  – Haploid cell after meiosis - either X or Y in males

  – Sex of offspring determined by the sperm

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**Why Sex ?**

• Asexual reproduction - individual inherits all its chromosomes from a single parent
  – parthenogenesis - development of an adult from an unfertilized egg

• Sexual reproduction - produces genetic variability.
  – Segregation of chromosomes tends to disrupt advantageous combinations.
    • Only some progeny maintain advantages.
• The Y Chromosome
  – recombination occurs infrequently with X.
  – Y chromosome from father is unchanged
  – hereditary marker (Thomas Jefferson’s descendants through Sally Hemings).
  – also migration across continents

• Gamete Formation in Humans
  – Four haploid spermatids mature into sperm with flagella tails, concentrated mitochondria, and a haploid nucleus (250 million sperm/day).
  – Oocyte division is unequal
    – one large cell (200,000 times bigger than the sperm) w/enough materials to drive and feed dividing embryonic cells (one secondary oocyte)
    – oocytes stay in meiosis 1 for years!
Factors that increase genetic variation

• independent assortment of chromosomes
• crossing over
• random fertilization

Independent Assortment

Evolutionary Consequences of Sex

• process is revolutionary and conservative.
  – pace of evolutionary change is accelerated by genetic recombination
  – evolutionary change not always favored by selection
  • may act to preserve existing gene combinations
Independent Assortment

Terms to Know

- haploid (n) – vs – diploid (2n)
- karyotype
- homologous chromosomes
- autosomes
- syngamy (union of gametes)
- gametes
- tetrads (4 chromatids, 2 homologous pairs)
- chiasmata (x region –crossed over chromatids)
Telophase II