Meiosis and the Sexual Life Cycle

Key Concepts

• Heredity → Transmission of traits from one generation to the next

• Genetic Variation

• Sexual Life Cycle: alternation between fertilization and meiosis

• Diploid vs Haploid

• Need to understand the difference between Mitosis and Meiosis
Asexual Reproduction  “CLONES”

Involves Mitosis:  1 →  2 identical progeny

Sexual Reproduction  Provides “Diversity”

2 genetically distinct cells →  1 unique offspring
(involves meiosis)

Gametes: reproductive cell
Haploid:  1 complete set of chromosomes

1n = 1 set of chromosomes

2n = 2 sets of chromosomes (Diploid)

2 gametes (1n each)  fuse  fertilization  Zygote (2n)
Chromosomes

Humans: \( n = 23 \) each with a unique in shape and size

- 22 autosomes
- 1 sex chromosome \( X \) or \( Y \)

\[ \text{Diploid (2n) = 46 chromosomes} \]

Somatic cells: 2n

Gametes: 1n
Chromosomes

Karyotype

• Ordered visual representation of the chromosomes in a cell

• Characteristics: based on length, centromere position, and staining pattern!

Normal: 46, X Y

Abnormal: 47, X Y, +21
Chromosomes

Using Karyotype: to Scan for genetic abnormalities using FISH (Fluorescent in situ hybridization)

Fluorescent DNA probes - which hybridize to chromosomal DNA

5'-AGTCTCCGAC-3'
3'-TCAGAGGCTG-5'

Abnormal: 47, X Y, +21
Chromosomes

Somatic Cells:
- 22 pairs of autosomes (non-sex chromosomes)
- 2 sex chromosomes (XX or XY)

Homologous Chromosomes (Very similar but not identical!)

- Same order of genes (important!!!)
- Length is the same
- Position of centromere is the same

DNA is not identical - WHY?

Maternal and paternal contribution

What's the advantage of having 2 copies? Increase Diversity, Redundancy promotes Viability
Meiosis: Overview
process to make Haploid Gametes

• 2n → 1n
• 1 set of all chromosomes in gametes
• Increase diversity

![Sister chromatids](image)

2 identical progeny

• Meiosis I
  • Homologs line up at Metaphase (I) plate
  • Cross-over

• Meiosis II (very similar to mitosis)
  • Sister chromatids separate

![Cross over](image)

4 cells - all 1n

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Meiosis increases DIVERSITY

(1) Independent Assortment of Chromosomes

**KEY** - In Metaphase I - each sister chromatids may line up randomly → maternal or paternal pair may orient facing different spindle poles

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2^n = 4
2^{23} = > 8 million
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**Key**
- Maternal set of chromosomes
- Paternal set of chromosomes

**Possibility 1**
- Two equally probable arrangements of chromosomes at metaphase I

**Possibility 2**
- Metaphase II

**Combination 1**
- Combination 2
**Combination 3**
- Combination 4

Daughter cells
Meiosis increases DIVERSITY

(2) Recombination “cross over” between homologous chromosomes.

Synapsis
(DNA exchange)

Tetrad (physical site of cross over)

Recombination

4 different Gametes
Meiosis increases DIVERSITY

Details of Synapsis in Prophase of 1 of Meiosis

1. Homologous chromosomes pair up

2. DNA info is traded between homologs
   • DNA intertwines : Chiasma
   • Cross over events
   • Enzyme cuts DNA at Chiasma and rejoins them back together

   “HOMOLOGOUS RECOMBINATION”

3. Recombinants are different from each other
   • Part maternal
   • Part paternal

4. Increases DIVERSITY!!!

5. 4 different Gametes
Stages of Meiosis

• **Meiosis I**
  • **Prophase I**
    • Chromosomes condensed
    • Pairing of homologs
    • Cross over/ intertwining at the Chiasma
    • Nuclear envelope is intact - *WHY?*
    • Enzymes cut DNA and rejoin (takes a long time – weeks!)
    • When completed: Recombinants made
    • At the end of Prophase I – nuclear envelope disassembles
  
  • **Metaphase I**
    • Homologs line up at the metaphase plate
  
  • **Anaphase I and Telophase I**
    • Homologs separated
  
  • Results in 2 daughters: different, with recombinant chromosomes
    • Does not go back into interphase
    • Does not reform nuclear envelope
    • Does not decondense DNA
  
  • Go directly to **Meiosis II**
Stages of Meiosis

- **Meiosis II** - no S Phase - Start with 2 cells
  - **Prophase II**
    - Another spindle assembles at a right angle to previous one
  - The rest is similar to Mitosis

**Metaphase II**
  - Sister chromatids line up at the metaphase plate

**Anaphase II and Telophase II**
  - Sister chromatids separated
  - Results in 4 cells (gametes): different, with recombinant chromosomes
  - Gametes all 1n!
Meiosis

**INTERPHASE**

**MEIOSIS I: Separates homologous chromosomes**

**PROPHASE I**

**METAPHASE I**

**ANAPHASE I**

- **Centrosomes (with centriole pairs)**
- **Sister chromatids**
- **Chiasmata**
- **Spindle**
- **Tetrad**
- **Chromatin**
- **Homologous chromosomes separate**
- **Sister chromatids remain attached**

**Figure 13.8**

- Chromosomes duplicate
- Homologous chromosomes
- Tetrads line up
- Pairs of homologous chromosomes split up
Meiosis

**Prophase II**
- Cleavage furrow

**Metaphase II**

**Anaphase II**
- Sister chromatids separate

**Telophase II and Cytokinesis**
- Haploid daughter cells forming

**Meiosis II**: Separates sister chromatids

During another round of cell division, the sister chromatids finally separate; four haploid daughter cells result, containing single chromosomes.

Two haploid cells form; chromosomes are still double.

Figure 13.8
**Compare and Contrast**

**Meiosis and Mitosis**

- DNA Replication
  
  Both start here
  
  *Meiosis:* no S phase between I and II

- # of Divisions
  
  *Mitosis:* 1 → cells identical
  
  *Meiosis:* 2 → cells different

- Synapsis
  
  Not in Mitosis, only in Meiosis I (Prophase I)

- Line up at plate
  
  *Mitosis:* sister chromatids
  
  *Meiosis I:* homologs
  
  *Meiosis II:* sister chromatids

- Daughter cells
  
  *Mitosis:* → 2 identical cells
  
  *Meiosis:* → 4 unique (haploid – 1n)

*When 2 unique gametes fuse: Zygote – Increases Diversity!!*