Chapter 11.4 – 11.5
Meiosis

Cell Division / Asexual Reproduction
- Mitosis
  - produce cells with same information
    - identical daughter cells
  - exact copies
    - clones
  - same amount of DNA
    - same number of chromosomes
    - same genetic information

Asexual reproduction
- Single-celled eukaryotes reproduce asexually
  - yeast
  - Paramecium
  - Amoeba
- Simple multicellular eukaryotes reproduce asexually
  - exceptions... like Hydra
    - budding

Asexual reproduction
- budding in yeast
- mitosis in amoeba

Sexual Reproduction / Fertilization
- in sexual reproduction, a gamete from each parent fuses (called fertilization)
  - joining of egg + sperm
- Do we make egg & sperm by mitosis?
- How do we make sperm & eggs?
  - Must reduce 46 chromosomes → 23
    - must half the number of chromosomes
    - diploid (2n) to haploid (n) (meiosis)
**Meiosis: Production of Gametes**

- Alternating processes, alternating stages
  - Chromosome number must be reduced
    - Diploid → Haploid
    - $2n \rightarrow n$
    - **Meiosis** reduces chromosome number
  - Fertilization restores chromosome number
    - Haploid → Diploid
    - $n \rightarrow 2n$

**Differences across Kingdoms**

- Not all organisms use haploid & diploid stages in the same way
  - Which one is dominant ($2n$ or $n$) differs
  - But still alternate between haploid & diploid
    - Have to for sexual reproduction

**Paired Chromosomes**

- Both chromosomes of a pair carry "matching" genes
  - Control same inherited characters
  - Homologous = same information

**Sexual Reproduction: Fertilization**

- 1 copy - haploid - 1n
- 2 copies - diploid - 2n
Making Gametes for the Next Generation

- 2 copies - diploid - 2n
- 1 copy - haploid - 1n

Meiosis = Reduction Division

- Meiosis
  - special cell division in sexually reproducing organisms
  - reduce 2n → 1n
  - diploid → haploid
  - half
  - makes gametes
    - sperm, eggs

Meiosis evolved from mitosis, so stages & "machinery" are similar but the processes are radically different. Do not confuse the two!

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2 Divisions of Meiosis

DNA replication

1st division of meiosis separates homologous pairs

2nd division of meiosis separates sister chromatids

Preparing for meiosis

- 1st step of meiosis
  - Duplication of DNA
  - Why bother?
    - meiosis evolved after mitosis
    - convenient to use "machinery" of mitosis
    - DNA replicated in S phase of interphase of MEIOSIS (just like in mitosis)

Meiosis 1

- 1st division of meiosis separates homologous pairs

Meiosis 2

- 2nd division of meiosis separates sister chromatids
Steps of Meiosis

- **Meiosis 1**
  - interphase
  - prophase 1
  - metaphase 1
  - anaphase 1
  - telophase 1

- **Meiosis 2**
  - prophase 2
  - metaphase 2
  - anaphase 2
  - telophase 2

1st division of meiosis separates homologous pairs
(2n → 1n)

2nd division of meiosis separates sister chromatids
(1n → 1n)
JUST LIKE MITOSIS

Mitosis vs. Meiosis

- **Mitosis**
  - 1 division
  - daughter cells genetically identical to parent cell
  - produces 2 cells
  - 2n → 2n
  - produces cells for growth & repair
  - no crossing over

- **Meiosis**
  - 2 divisions
  - daughter cells genetically different from parent
  - produces 4 cells
  - 2n → 1n
  - produces gametes
  - crossing over

Crossing Over

- During prophase 1
  - homologous pairs swap pieces of chromosome
  - sister chromatids intertwine
  - called “crossing over”
**Crossing Over**
- Involves 3 steps
  - cross over
  - breakage of DNA
  - re-fusing of DNA
- New combinations of traits

**Genetic Variation**
- Meiosis & crossing over introduce great genetic variation to a population
  - drives evolution

**Sources of Genetic Variability**
- Genetic variability in sexual reproduction!
  - independent assortment
    - homologous chromosomes in Meiosis 1
  - crossing over
    - between homologous chromosomes in prophase 1
  - random fertilization
    - random ovum fertilized by a random sperm

**The Value of Meiosis**
- Meiosis introduces genetic variation
  - gametes of offspring do not have same chromosomes as gametes from parents
  - genetic recombination
    - random assortment in humans produces $2^{23} \times 2^{23}$ (8,388,608) different combinations for one gamete!
    - This does not even include new combos due to crossing over!

**Random fertilization**
- Any 2 human parents will produce a zygote with over 70 trillion ($2^{23} \times 2^{23}$) diploid combinations (of chromosomes!)
Nondisjunction
- Problems with meiotic spindle cause errors in daughter cells
  - tetrad chromosomes do not separate properly during Meiosis 1
  - sister chromatids fail to separate during Meiosis 2
  - too many or too few chromosomes

Alteration of Chromosome Number

Nondisjunction
- Zygote has wrong chromosome number
  - trisomy
    - cells have 3 copies of a chromosome
  - monosomy
    - cells have only 1 copy of a chromosome

Human Chromosome Disorders
- High frequency in humans
  - most embryos are spontaneously aborted
  - alterations are too disastrous
  - developmental problems result from biochemical imbalance
- Certain conditions are tolerated
  - upset the balance less = survive
  - characteristic set of symptoms = syndrome

Down Syndrome
- Trisomy 21
  - 3 copies of chromosome 21
  - 1 in 700 children born in U.S.
  - Chromosome 21 is the smallest human chromosome
  - but still severe effects if affected
  - Frequency of Down syndrome correlates with the age of the mother

Down Syndrome & Mother’s Age

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**Genetic Testing**
- **Amniocentesis in 2nd trimester**
  - sample of embryo cells
  - stain & photograph chromosomes
- **Analysis of karyotype**

**Rate of miscarriage due to amniocentesis:**
- 1970s data: 0.5%, or 1 in 200 pregnancies
- 2006 data: <0.1%, or 1 in 1600 pregnancies

**Human Sex Chromosomes**
- **Human development more tolerant of wrong numbers in sex chromosome**
- **But produces a variety of distinct conditions in humans**
  - XXY = Klinefelter’s syndrome male
  - XXX = Trisomy X female
  - XYY = Jacob’s syndrome male
  - XO = Turner syndrome female

**Klinefelter’s Syndrome**
- **XXY male**
  - one in every 2000 live births
  - have male sex organs, but are sterile
  - slight “feminine” characteristics
  - tall
  - normal intelligence

**Jacob’s Syndrome**
- **XYY Males**
  - 1 in 1000 live male births
  - extra Y chromosome
  - somewhat taller than average
  - more active
  - slight learning disabilities
  - delayed emotional immaturity
  - normal intelligence, normal sexual development

**Trisomy X**
- **XXX**
  - 1 in every 2000 live births
  - produces healthy females
  - Why?

**Turner Syndrome**
- **Monosomy X or X0**
  - 1 in every 5000 births
  - varied degree of effects
  - normal intelligence
  - webbed neck
  - short stature
  - immature sterile females