Honors Biology Chapter 9 – The Cellular Basis of Inheritance p. 178-203
(How does 1 fertilized egg become the trillions of diff. types of cells in our bodies?)

Concept 9.1: All Cells come from Cells
(Char. of life- all orgs reproduce their own kind. Virchow)
(Division of cells into more cells allows orgs to repair, grow and produce offspring.)

I. Repair and Growth
- A. Ex. Skin Growth and Repair (See Fig. 9.1, p. 180) – Read
- B. Cellular reproduction allows for-
  1. Growth: development from 1 fertilized egg, the trillions of cells in our body (more stars than in the Milky Way!
  2. Maintenance – as old cells wear out, new ones replace them
  3. Repair – if injured, can replace damaged cells with new

II. Reproduction (See Fig. 9.2, p. 181)
- A. **Asexual Reproduction =** single cell or group of cells each duplicates its genetic material and then splits into two new genetically identical cells (done by simple cell division)
  1. 1 parent – all offspring genetically identical to parent and each other
  2. Ex. *Paramecium* = unicellular protistan that reproduces this way
  3. Ex. Bacteria, yeast, other protistans
  4. Ex. Plants (leaf cuttings) and Sea Stars
- B. **Sexual Reproduction =** genetic material from each of two parents combines, producing offspring that differ genetically from either parent
  1. Involves union of sex cells
  2. Sex cells produced by special type of cell division
  3. Ex. Some unicellular, most multicellular orgs.

*Regardless of which form of reproduction used to produce offspring, all multicellular orgs depend on asexual repro. for growth, repair, and maintenance.

Concept 9.2: The Cell Cycle multiplies Cells
(Every minute millions of cells in our bodies are dividng, while the other 200 trillion are doing regular activities)

I. Chromosomes and Cell Division
- A. Genetic Material –
  1. Location for Eukaryotes – in nucleus
     a. Forms
        1.) **Chromatin =** Most of the time, genetic material exists as a mass of very long fibers that are too thin to be seen under a light microscope.
            a.) Made of DNA and proteins
        2.) **Chromosomes =** condensed, compacted chromatin, visible as the cell prepares to divide
            a.) No. of chromo. – depends on species
                1.) Ex. Humans – 46 chrom. per cell
                2.) Ex. Pea plants – 14 chrom. per cell
                3.) Ex. *Drosophila melanogaster* (Fruit fly) – 8 chrom.
            b.) Each chrom. contains hundreds of genes
- B. Duplication of all Chromosomes
  1. Occurs before cell division
  2. Result: Each chromosome now consists of two identical joined copies called <u>sister chromatids</u>, joined together by a <u>centromere</u> (See Fig. 9.3, p. 182)

C. During Cell Division (terminology gets confusing – be careful!)
1. Pairs of duplicated chromosomes divide at centromere, separating sister chromatids
2. Each single sister chromatid is now called a chromosome
3. Result: 2 offspring nuclei, each with correct number of single chromosomes
4. See Fig. 9.4, p. 183

II. The Cell Cycle
A. How often cells divide – depends on type
1. Some 1x/day, some more often, some not at all (Ex. Mature muscle cell)
B. **Cell Cycle =** orderly sequence of events in dividing eukaryotic cells
1. lasts from "birth" of new cell, until it reproduces by division
2. helps us understand cell function and some cell cycle related diseases
3. See Fig. 9.5, p. 183
C. Parts of Cell Cycle
1. Interphase – up to 90% of its life
a. the stage during which a cell carries out its metabolic processes and performs its functions
b. Parts of Interphase
1.) **G_1 Phase** – Growth – Cell grows in size, ↑ its proteins, and # of organelles
2.) **S Phase** – Synthesis – Cell duplicates its DNA to prepare for cell division
3.) **G_2 Phase** – Duplicated chrom. stay loosely packed as chromatin fibers, now ready for mitosis
2. **Mitotic Phase (M Phase)** = when cell is actually dividing (see Fig. 9.6, p. 184)
a. Parts:
1.) **Mitosis = division of the nucleus -** the nucleus and the duplicated chrom, divide and are evenly distributed, forming two "daughter" nuclei.
2.) **Cytokinesis = division of cytoplasm** –(dividing up all organelles and cytoplasmic material between the newly forming daughter cells) - begins before mitosis is completed
b. Result: two genetically identical daughter cells with a single nucleus, some surrounding cytoplasm, and a plasma membrane
c. Accuracy – really good!
1..) Ex. Yeast expt. – chrom. division error only 1x/100,000 cell divisions
d. Unique to eukaryotes – prokaryotes use a simpler type of cell division

<u>Concept 9.3: Cells Divide during the Mitotic Phase</u>
(Mitosis – "dance" of the chromosomes – to ensure equal distribution in daughter nuclei)

I. The Mitotic Dance
A. **Spindle =** football-shaped framework of microtubules that guides the chrom. mvmts..
1. **Centrosomes =** regions of cytoplasmic material from which spindle grows
a. Animal Cells - contain structures called centrioles.
b. Centrioles a mystery – can remove them, and spindle still forms
B. Events of Mitosis – See Fig. 9.8, p. 186, and 187
1. 4 main "Stages" (Mitosis is continuous, but distinct events let us give it names)
a. Preceeded by Interphase – can't see chromosomes yet, nucleolus still present
b. Prophase -"dancer" chromosomes appear, Read p. 186
c. Metaphase –Read p. 186
d. Anaphase – Read p. 187
e. Telophase – Read p. 187
(f. .Cytokinesis concludes cell division, following completion of telophase)

II. Cytokinesis in Animals vs. Plants (concludes Telophase, not nec. a distinct phase of its own)

A. Animal Cells (See Fig. 9.8, p. 186—187)

1. Starts with indentation between 2 nuclei
2. Caused by a ring of microfilaments in the cytoplasm just under the plasma membrane
3. Ring contracts (like pulling drawstring) "pinching" the parent cell in two
4. B/c nuclei at opp. ends of cell, result in 2 new cells

B. Plant Cells (see Fig. 9.9, p. 188)

1. **Cell Plate =** disk containing cell wall material forms inside the cell and grows outward
2. New piece of cell wall divides the cell in two
3. Result: 2 daughter cells

Concept 9.4: Cancer Cells Grow and Divide out of Control

(Cell division regulated by a protein "control system" – a malfunction causes errors in cell reproduction.)

I. Tumors and Cancer

A. **Tumor =** mass of cells caused by out-of control cell repro.

1. **Benign tumor =** abnormal mass of essentially normal cells
   a. may cause health problems due to location
   b. usually can be completely removed by surgery
   c. do not spread
2. **Malignant tumor =** masses of cells that result from the reproduction of cancer cells
   a. **Cancer =** disease caused by the severe disruption of the mechanisms that normally control the cell cycle.
      1.) causes uncontrolled cell division
      2.) can spread– dangerous char., can cause death if trmt. Fails
         a.) invades surrounding tissue, replaces normal cells (See Fig. 9.11, p. 191)
         b.) **metastasis =** spread of cancer cells beyond their original site
            1.) may break off orig. tumor and spread to other parts of body growing tumors in other places
      3.) Caused by many diff. things – so no single "cure" or trmt. for cancer

II. Cancer Treatment

A. Surgery – to remove tumor – difficult to remove all cancer cells, though

B. Radiation Therapy – attempt to stop cancer cells from dividing

1. expose cancerous tumor areas with high energy radiation
2. minimal damage to normal cells, that are not dividing as quickly as cancer cells do

C. Chemotherapy – attempt to stop cancer cells from dividing

1. drugs used to disrupt cell division
2. variety of ways they work
   a. **antimitotic drugs =** prevent cell division by interfering with the mitotic spindle
      1.) 1 even prevents spindle from forming at all
      2.) another "freezes" the spindle after it forms, keeping it from functioning

D. Side effects of cancer trmt.

1. usually in body cells that divide often
   a. Ex. Ovaries, testes – can cause sterility
   b. Ex. Intestinal cells and hair follicle cells – affected by chemotherapy – nausea and hair loss

Concept 9.5: Meiosis functions in Sexual Reproduction

(Sexual reprod. allows members of same species to inherit unique combinations of genes, thus unique traits, from 2 parents while maintaining species char., too.) (see Fig. 9.12, p. 192)

I. Homologous Chromosome

A. Sexual reproduction depends on **meiosis**

1. Meiosis = type of cell division that produces four cells, each with ½ chrom. # of parent cell

a. In Animals – occurs in testes and ovaries

(b. In Plants – in ovary and anther (male plant part))

B. Chromosome Number and Pairs (See Fig. 9.13, p. 193)

1. Each member of a species – has similar looking chrom., and same # of chrom. / cell

2. **Karyotype =** A display of the chromosomes of an individual (in humans, 46 chrom.)

a. Each chrom. has a "twin" that looks like it – size, shape, centromere, bands, etc.

1.) Inherit 1 of each pair of twins from mom, 1 from dad

b. **Homologous Chromosomes = t**he two chromosomes of each matching pair

1.) each in pair carries same sequence of genes controlling same inher. char.

2.) Genes may vary, but gene for same trait (read p. 193) (ex. Blue + brown eyes)

3.) **Not** same as sister chromatids – they are identical in every way!

c. Humans

1.) 23 homologous pairs in females

2.) 22 homologous pairs in males, plus 1 pair that differs

a.) (**Autosomes =** all of the matching pairs except the sex chromosomes))

b.) **Sex Chromosomes =** chromosomes that determine gender

1.) two forms: X and Y

2.) Females – have 2 X chrom. for the 23rd pair

3.) Males – have 1 X and 1 Y chrom. for the 23rd pair

4.) only small parts of the X and Y are homologous (see Fig. 9.14, p. 193)

II. Diploid and Haploid Cells

A. Inheriting two sets of chrom., 1 from each parent key factor in sexually reprod. orgs.(See Fig. 9.15, p.194)

B. **Diploid Cells =** contain two homologous sets of chromosomes (most cells in body – "somatic cells")

1. **Diploid Number = 2n = t**he total number of chromosomes, 46 in humans

C. **Haploid Cells =** egg and sperm cells, known as sex cells, or <u>gametes</u>

1. Gametes have a single set of chrom, 1 from each aprent

2. **Haploid number** = **n =** ½ the total number of chrom. for the species (23 in humans)

3. produce haploid cells (gametes) by Meiosis

D. Why Haploid cells?

1. **Fertilization =** process of nucleus of a haploid sperm cell fusing with the nucleus of a haploid egg cell

a. **Zygote =** fertilized egg, diploid

2. If sperm and egg **not haploid but diploid, what would happen? (do the math!)**

a. Fert. restores the diploid chrom. # of the species

III. The Process of Meiosis

A. Life cycles of all sexually reproducing organisms involve alternating diploid and haploid stages

1. Alt. fert. And meiosis makes possible

2. Keeps the chrom . # of a species from changing

B. Meiosis keeps the chromosome number from doubling in every generation

C. Meiosis vs. Mitosis

1. Two main differences

Difference	Meiosis	Mitosis
#1	4 new haploid offspring cells produced	2 new diploid offspring cells produced
#2	Involves exchange of genetic info between homol chrom.	No exchange of genetic info

D. Stages of Meiosis (pay attention to differences b/t sister chromatids and homologous chromosome)
1. Read p. 195

E. The Two Meiotic Divisions
1. Meiosis I Summary - homologous chromosomes, each composed of two sister chromatids, are separated from one another.
2. Meiosis II Summary – sister chromatids are separated much as they are in mitosis.
3. Final Result – 4 haploid, genetically dissimilar daughter cells

F. Specific Events – Follow Diagram on p. 196-197
1. Interphase – same as regular cell cycle
2. Prophase I – unique events
a. Tetrads of homologous chromosomes form
b.C**rossing over =** exchange of genetic info between homol. – allows for new gene comb
(c. Follow the different colors to see.what is happening with this.)
3. Metaphase I – similar to mitosis, except line up in tetrads
4. Anaphase I – homol. chrom. separate as they migrate to opp. poles – completely random which goes where
Sister chromatids stay attached, unlike Mitosis
5. Telophase I – similar to Mitosis
6. Cytokinesis – similar to mitosis, but daughter cells haploid with duplicated chrom. still
7. Prophase II – spindles attach to centromeres to move chrom.
8. Metaphase II - chromosomes line up in the middle of the cell with spindle microtubules attached to each sister chromatid.
9. Anaphase II - sister chromatids separate and move to opposite poles
10. Telophase II and Cytokinesis – like Mitosis
End Result – 4 haploid genetically different daughter cells

Concept 9.6: Meiosis Increases Genetic Variation among Offspring

(Genetic variation, resulting from meiosis and fertilization is raw material for natural selection,)

I. Assortments of Chromosomes (see Fig. 9.18, p. 198)
A. Ex. Org. with diploid # of 4
1.How the chrom.in each homol.pair line up and separate at metaphase I is a matter of chance
2. So, the assortment of chromosomes that end up in the resulting cells occurs randomly.
a. in this example = 4 comb.possible
3. Can calculate # of possible comb.in gametes if know haploid # = 2^n
a. n = number of chrom. pairs
b. Ex. Humans n = 23; 2^{23} = about 8 million + possible comb. (= 8,388,608!!)

II. Crossing Over (see Fig. 9.19 p. 199)
A. 2^{nd} factor causing genetic variation = **crossing over =** exchange of genetic material b/t homologues
B. During tetrad formation of Prophase I
C. Can occur at 1 or more sites per tetrad, with each affecting multiple genes
D. **Genetic Recombination =** new combination of genetic information from different parents

III. Review: Comparison of Mitosis and Meiosis
A. See Fig. 9.20, p. 200, and read p. 201