Cell division: mitosis and meiosis

I. Cell division -- introduction

- roles for cell division:

  - reproduction -- unicellular organisms (mitosis)
  - growth and tissue repair in multicellular organisms (mitosis)
  - production of gametes, sex cells, for sexual reproduction (meiosis)

- for an eukaryotic cell to divide a few events required:

  - reproductive signal -- signal from outside the cell (but w/in organism) stimulates cell to divide/not divide
    - signals for cell division related to needs of entire organism
    - some cells mitotically active, others not
  - replication of DNA within nucleus
  - distribution of replicated DNA into two nuclei
  - cytoplasmic division

II. The cell cycle

- describes existence of cell -- interplay between periods of growth, periods of preparation for mitosis, periods of mitosis, relative to one another

- has two main phases, interphase and mitosis

A. Interphase

- a cell spends most of its life in interphase

  - G1 phase
  - S phase
  - Gap 2 phase

1. G1 phase
   - cell is performing its function in organism
   - some cells arrested in G1 -- muscle, nerve
   - other cells under appropriate stimulation begin preparations for S
2. S-phase
   - DNA replication

3. G2 phase

- cell is making preparations for mitosis

B. Mitosis -- M phase of cell cycle

- phase of nuclear division
- sorts genetic information into two cells
- ensures both contain exactly same genetic information

III. Chromosomes

- basic unit is a gigantic linear, double stranded molecule of DNA complexed with many proteins

- after replication (S-phase) each chromosome consists of two chromatids joined at centromere

- complex of DNA and proteins referred to as chromatin

- during interphase chromatin is very diffuse:
  - cell activity requires that portion of DNA unwound to interact with enzymes
- prior to and during mitosis chromatin condenses:
  - easier to achieve separation of replicated genetic material if DNA arranged in compact units rather than tangled and diffuse

III. Mitosis

- distributes exact copies of genetic information to two daughter cells

- recall that DNA replicated in S-phase

- also during S-phase the centrosome (microtubule organizing center) duplicates

- still in interphase -- nuclear membrane visible, chromatin diffuse

A. Prophase

- microtubules (MT) emanate from centrosomes (mitotic centers)
  - spindle develops
- chromatin coils and compacts
  - chromosomes visible
  - each consists of identical, paired chromatids
  - chromatids joined at centromere

- kinetochores develop in centromere region, one on each chromatid

B. Prometaphase -- transition to metaphase

- nuclear membrane disintegrates into small vesicles
  - spindle invades the nuclear region
- microtubules attach to chromatids at kinetochore -- microtubules
  - kinetochore of one chromatid attached to MT coming from one pole
  - kinetochore of sister chromatid attached to MT coming from other pole
- some microtubules extend from pole to pole and do not attach to chromatids

C. Metaphase

- centromere regions connecting paired chromatids become aligned in a plane at cell equator

D. Anaphase

- centromere pairs separate

- new chromosomes -- each containing one of paired chromatids begin to move toward poles
  - kinetochores move along microtubules
  - microtubules shorten from poles
- microtubules that extend from pole to pole slide past each other pushing poles of spindle farther apart
  - thus achieve separation of one set of daughter chromosomes from the other
- 10 - 60 minutes to complete journey to poles

E. Telophase

- chromosomes stop moving - reach poles

- chromatin becomes diffuse

F. Cytokinesis -- technically not part of mitosis

- division of the cytoplasm
  - initiated by microfilaments of actin and myosin beneath plasma membrane
  - proteins interact to form a contraction -- cell pinches in two

Summary:

- two daughter cells with identical genetic makeup
- thus reproduction by mitosis results in genetic constancy -- clone of offspring genetically identical to parent
    - any variation among offspring due to mutation

IV. Homologous chromosomes

- a cell from a specific organism contains a given number of paired chromosomes
    - human -- 23 pairs
    - potato -- 24 pairs
    - frog -- 13 pairs

- in a given pair, one chromosome comes from one parent, other chromosome comes from other parent

- members of homologous pair similar in size, appearance, location of centromere

- a cell that contains two homologs of each chromosome -- diploid cell

- a cell that contains one homolog of each chromosome -- haploid cell

VI. Meiosis

- meiosis and the human life cycle
    - two nuclear divisions that reduce the number of chromosomes to haploid number -- preparation for sexual reproduction
    - promotes genetic diversity among products

A. S-phase and late interphase
    - DNA replicated
    - centrosomes duplicated

B. Prophase I
    - chromatin condenses
    - homologs join together and pair up -- synapse
        - chiasmata -- areas of crossing over between chromatids of adjacent homologous chromosomes
        - due to chiasmata exchange of genetic material between homologous chromosomes

- nuclear membrane disintegrates
- spindle in formation

C. Metaphase I

- homologous chromosome pairs line up at equatorial plate
  - MT from one pole attaches to kinetochore of one chromosome
  - MT from opposite pole attaches to kinetochore of homologous chromosome

D. Anaphase I

- homologous chromosomes move to opposite poles of cell
  - same mechanism as in mitosis
  - poles of cell move apart
  - each chromosome still comprised of two joined chromatids
  - each daughter cell haploid -- contains one set of chromosomes

E. Telophase
  - reformation of nucleus
  - chromatin become diffuse
  - cytokinesis occurs at some point

F. Prophase II
  - spindle formation
  - disintegration of nuclear membrane
  - MT attach themselves to kinetochores of sister chromatids

G. Metaphase II
  - chromosomes align themselves at equatorial plate

H. Anaphase II

- chromatids separate and move towards opposite poles

I. Telophase II

- chromosomes gather into nuclei, cells divide – cytokinesis

J. Summary of meiosis:

1. formation of haploid cells -- allows for sexual reproduction to occur

2. leads to genetic diversity:

- sex cells produced by process different from each other
    - synapsis allows maternal chromosome of a pair to interact with paternal one
        - after crossing over two sister chromatids of a given pair not genetically identical.
    - which member of a homologous chromosome pair goes to which daughter cell is a matter of chance