Chapter 12: The Cell Cycle

I. Cell division in prokaryotes

- A. typically, a prokaryotic cell divides by **binary fission**, **<u>splitting</u>** into two nearly equal halves
  - 1. the main circular DNA molecule of the cell is replicated (replication begins **<u>at a replication origin)</u>**
- B. prokaryotic cells can have a **generation time** (the period from start of one cell division to start of next cell division; 20min.)

II. Eukaryotic DNA molecules are organized in **chromosomes**

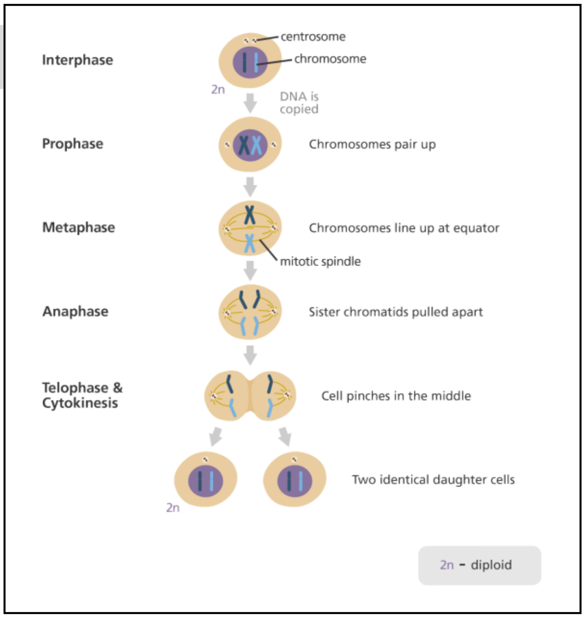
- A. each chromosome is made of **chromatin**, **a long DNA molecule with associated proteins**
  - 1. chromatin is packaged into **<u>dense chromosomes</u> during cell division**
  - 2. the chromosomes are unpacked ("**<u>decondensed</u>**") when cells are not dividing
- B. each chromosome contains hundreds to thousands of **genes**
  - 1. the complete DNA sequence for an organism is the **genome**; it contains the complete set of instructions for that organism
  - 2. humans apparently have ~40,000 genes in the now-sequenced human genome
  - 3. each species has a characteristic number of chromosomes (number varies between species)
  - 4. chromosome number does not reflect the complexity of the organism
  - 5. the assortment of chromosomes for an individual is the **karyotype (**humans have 46 chromosomes)
- C. chromosomes carry the genetic information: from one cell generation to the next, and from one organism to its offspring

III. The eukaryotic cell cycle

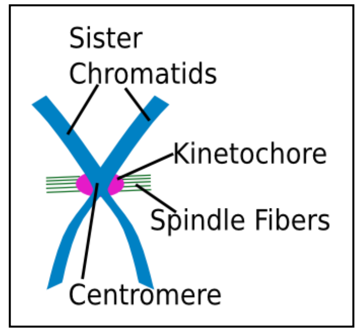
- A. the **cell cycle** describes the status of cells in relationship to growth and division
  - **1. when cells reach a certain size, growth either stops or the cell must divide**
  - 2. most, ***<u>but not all</u>***, eukaryotic cells are capable of dividing
  - 3. cell division is generally ***<u>a highly regulated process (OTHERWISE CANCER)</u>***
  - 4. the generation time for eukaryotic cells varies widely, but is usually 8-20 hours
- B. cell cycle has two main phases – **interphase** and **cell division** (mitosis + cytokinesis)
- C. **interphase** is divided into ***<u>three parts</u>***, defined **<u>with respect to DNA replication</u>**
  - 1. the DNA is completely replicated (genetic information duplicated) during the synthesis phase or **S phase**
    - the period before the S phase is a "gap" phase, **G_1 phase (**most cellular growth occurs in this phase)
    - this phase is usually the most variable with respect to time, and is **<u>typically longest</u>**
    - **<u>cells that do not divide become arrested in this phase, then called G_0</u>**
  - 2. the period between the S phase and cell division is the **G_2 phase**
    - the G_2 phase is usually short; cells in this phase are committed to and preparing for cell division
- D. **cell division** has two main parts – **mitosis** and **cytokinesis**
  - 1. **mitosis** is the process that **<u>distributes a complete copy of the duplicated genetic information to each daughter cell</u>**
  - 2. **cytokinesis** is the process of **<u>dividing the cytoplasm</u>** into two separate cells
  - 3. some cells can have **<u>mitosis without cytokinesis</u>** (most common in fungi)= **Dikaryotic**
- E. the current model of **cell cycle regulation** involves a **<u>highly conserved, genetically-controlled program</u>** that can be influenced by external signals
  - 1. there are three major **checkpoints**, found in **G_1**, **G_2** and **mitosis**
  - 2. key regulatory components for checkpoints are **cyclins** and **cyclin-dependent protein kinases**
  - 3. hormones such as **cytokinins** in plants and various protein **growth factors** in animals can stimulate progression through checkpoints in the right cells under the right conditions
  - 4. other factors can serve as **<u>suppressors</u>** of cell division
  - 5. **cancer cells** generally grow without needing stimulation by external growth factors and fail to respond to normal suppressors of cell division

IV. **mitosis** is generally be divided into 4 stages: **prophase**, **metaphase**, **anaphase**, and **telophase** (**PMAT**)

- A. be aware that mitosis is a continuous process,
  - the stages are defined only for our convenience
- B. **prophase** – chromatin condenses to form chromosomes
  - 1. each chromosome (duplicated during S phase) forms a pair of **sister chromatids**
    - sister chromatids are joined at a **centromere** by protein tethers
    - centromeres contain a **kinetochore** where microtubules will bind
    - each sister chromatid has its own kinetochore
  - 2. a system of microtubules, called the **mitotic spindle**, organizes between the two poles (opposite ends) of the cell
    - each pole has a **<u>microtubule organizing center</u>** (MTOC)
    - in animals and some other eukaryotes, centrioles are found in the MTOC; their exact role, if any, is unclear



3. by the end of prophase:
   - the **nuclear membrane has disappeared** (actually divided into many small vesicles)
   - ***nucleoli have disintegrated***
   - the sister chromatids are attached by their **kinetochores** to microtubules from opposite poles
4. some call the later part of prophase **prometaphase**, usually defined to include vesicularization of the nuclear membrane and attachment of kinetochores to microtubules



C. **metaphase** – chromosomes line up along the **midplane** of the cell (**metaphase plate**)

1. ***chromosomes are most condensed, most visible, and most distinguishable***
2. the **mitotic spindle**, now complete, has two types of microtubules
   - **kinetochore microtubules** extend from a pole to a kinetochore
   - **polar microtubules** extend from a pole to the midplane area, often overlapping with polar microtubules from the other pole
3. the mitosis **checkpoint** appears to be here; *progress past metaphase is typically prevented until the kinetochores are all attached to microtubules*

Centromere: the primary constriction تَضَيّق of a chromosome.
Kinetochores: two discs of proteins located at the centromere, on opposite sides of the chromosome. *Microtubules attach to the chromosomes actually attach to the kinetochores (called* ***kientochore microtubules****).*

D. **anaphase** – sister chromatids ***separate*** and are moved toward opposite poles

1. protein tethers حبال at the centromere between the chromatids are **broken**
2. ***each former sister chromatid can now be called a chromosome***
3. model for the mechanism that moves chromosomes to the poles
   - **motor proteins** move the chromosomes towards the poles **along the kinetochores microtubules**
   - kinetochore microtubules **shorten** as behind the moving chromosomes
   - polar microtubules **lengthen** the entire spindle
     - motor proteins on the polar microtubules slide them past each other, **pushing them apart** (the microtubules may grow a bit, too)
     - this pushes the **MTOCs (microtubule organizing centers) away from each other**, and thus has the effect of **pushing kinetochore microtubules from opposite poles away from each other**
4. this process assures that each daughter cell will receive one of the duplicate sets of genetic material.

E. **telophase** – ***the processes of prophase are reversed***

1. the ***mitotic spindle is disintegrated***
2. the chromosomes **decondense**
3. nuclear membranes ***reform*** around the genetic material to form two nuclei
4. nucleoli ***reappear***, and interphase cellular functions resume

V. **cytokinesis** divides the cell into two daughter cells

A. **cytokinesis** usually ***begins in telophase*** and ends shortly thereafter

1. in animals, a **cleavage furrow** develops – usually close to where the metaphase plate was
   - a microfilament (**actin**) ring ***contracts*** due to ***interactions with myosin molecules***, forming a deepening ***furrow***
   - eventually, the ring closes enough for spontaneous separation of the plasma membrane
2. in plants, a **cell plate** develops – usually close to where the metaphase plate was
   - ***vesicles that originate from the Golgi line up in the equatorial region***
   - vesicles fuse and add more vesicles, growing outward until reaching the plasma membrane ~ separating the cells
   - the vesicles contain materials for making the **primary cell wall** and a **middle lamella**

B. cytoplasm (and with it most organelles) is usually distributed randomly but roughly equally between daughter cells