CELL DIVISION

\[ 7 \]
\[ 294 \]
\[ 28 \]
\[ 14 \]
\[ 7 \]
Cell division functions in 1. reproduction, 2. growth, and 3. repair

- What do you think you are looking at here???
- Can something like you or I do this???
• How did you start out?
• How did you grow?
• Are you still growing?
2. Cell division distributes identical sets of chromosomes to daughter cells

- A cell’s entire set of genetic information, packaged as DNA, is called its **genome**.
  - Eukaryotic genome vs. prokaryotic??

- How are all of your cells basically the same??? How did this come to be??

- Oops, update time. Seems your cells aren’t identical after all, for two different reasons. Recent studies have shown that two things might be different about your cells.
• DNA molecules are packaged into **chromosomes**.
  
  • Every eukaryotic species has a characteristic number of chromosomes in the nucleus.
    
    • **Human somatic cells** (body cells) have 46 chromosomes.
    
    • **Human gametes** (sperm or eggs) have 23 chromosomes, half the number in a somatic cell.

*Fig. 12.2*
• DNA, chromatin, chromosome, gene: how do these relate?
• Prokaryotic cells have less protein associated with their circular chromosome.
• Chromatid – just what we need, another chroma-word.

• How about another centro-word?

• What will happen to these two chromatids??

Fig. 12.3
1. The mitotic phase alternates with interphase in the cell cycle: an overview

- The **mitotic (M) phase** of the cell cycle alternates with the much longer **interphase**.
  - The M phase includes mitosis and cytokinesis.
  - Interphase accounts for 90% of the cell cycle.
  - Realize that if a cell never divides, it spends its whole life in interphase.

*Fig. 12.4*
• Interphase has three subphases:
  • the $G_1$ phase
  • the $S$ phase ("synthesis")
  • the $G_2$ phase ("second gap")
• By late interphase, the chromosomes have been duplicated but are loosely packed.

• The centrosomes have been duplicated and begin to organize microtubules into an aster (“star”).

• Let’s watch the entire process.

Fig. 12.5a
• In prophase, the chromosomes are tightly coiled, with sister chromatids joined together.

• The nucleoli disappear because the DNA which is concentrated there is coiling.

• The mitotic spindle begins to form and appears to push the centrosomes away from each other toward opposite ends (poles) of the cell.

Fig. 12.5b
• During prometaphase (or late prophase), the nuclear envelope fragments and microtubules from the spindle interact with the chromosomes.

• Microtubules from one pole attach to one of two kinetochores, special regions of the centromere, while microtubules from the other pole attach to the other kinetochore.

Fig. 12.5c
• The spindle fibers push the sister chromatids until they are all arranged at the **metaphase plate**, an imaginary plane equidistant between the poles, defining metaphase. This is also called the equator of the cell.
• At anaphase, the centromeres divide, separating the sister chromatids.

• Each is now pulled toward the pole to which it is attached by spindle fibers.

• By the end, the two poles have equivalent collections of chromosomes (we don’t call them chromatids anymore).

Fig. 12.5e
• At telophase, the cell continues to elongate as free spindle fibers from each centrosome push off each other.

• Two nuclei begin to form, surrounded by the fragments of the parent’s nuclear envelope.

• Chromatin becomes less tightly coiled.

• Cytokinesis, division of the cytoplasm, begins.
Fig. 12.5 left
• Assembly of the spindle microtubules starts in the centrosome.

• The centrosome (*microtubule-organizing center*) of animal cells has a pair of centrioles at the center, but the function of the centrioles is somewhat undefined.

• Remember that plant cells often lack centrioles, but still have a functioning centrosome.

Fig. 12.6a
• Each sister chromatid has a **kinetochore** of proteins and chromosomal DNA at the centromere.

• The kinetochores of the joined sister chromatids face in opposite directions.

• During prometaphase, some spindle microtubules attach to the kinetochores.

Fig. 12.6b
• One hypothesis for the movement of chromosomes in anaphase is that motor proteins at the kinetochore “walk” the attached chromosome along the microtubule toward the opposite pole.

• The excess microtubule sections depolymerize (by what chemical process?).

Fig. 12.7a
3. Cytokinesis divides the cytoplasm:  
*a closer look*

- Cytokinesis, division of the cytoplasm, typically follows mitosis.

- In animals, the first sign of cytokinesis *(cleavage)* is the appearance of a *cleavage furrow* in the cell surface near the old metaphase plate.

![Fig. 12.8a](image-url)
• On the cytoplasmic side of the cleavage furrow a contractile ring of actin microfilaments and the motor protein myosin form.

• Contraction of the ring pinches the cell in two. This happens on what was the metaphase plate, the equator of the parent cell.
• Cytokinesis in plants, which have cell walls, involves a completely different mechanism.

• During telophase, vesicles from the Golgi coalesce at the metaphase plate, forming a **cell plate**.

  • The plate enlarges until its membranes fuse with the plasma membrane at the perimeter, with the contents of the vesicles forming new wall material in between.

• Watch [book animation](#).
Let’s do the onion root tip lab

• Before we get on the microscopes, let’s look at these…

• Look here
4. **Mitosis in eukaryotes may have evolved from binary fission in bacteria**

- Prokaryotes reproduce by **binary fission**, not mitosis. Know this term.

- Most bacterial genes are located on a single **bacterial chromosome** which consists of a circular DNA molecule and **fewer and different associated proteins** than those of eukaryotic chromosomes.
The frequency of cell division varies with cell type.

- Some human cells divide frequently throughout life (skin cells), others have the ability to divide, but keep it in reserve (liver cells), and mature nerve and muscle cells do not normally appear to divide at all after maturity, but current research is showing they are still able.

- Muscles get bigger when the cells that make them up get bigger; they don’t grow by making more cells.
The distinct events of the cell cycle are directed by a distinct cell cycle control system involving what are called checkpoints.

Fig. 12.13
For many cells, the $G_1$ checkpoint, the restriction point in mammalian cells, is the most important.

- If the cells receives a go-ahead signal, it usually completes the cell cycle and divides.

- If it does not receive a go-ahead signal, the cell exits the cycle and switches to a nondividing state, the $G_0$ phase.

- Most human cells are in this phase.

- Liver cells can be “called back” to the cell cycle by external cues (growth factors), but highly specialized nerve and muscle cells rarely divide.
• Rhythmic fluctuations in the abundance and activity of control molecules pace the cell cycle.
  • Some molecules are protein kinases that activate or deactivate other proteins by phosphorylating them.

• The levels of these kinases are present in constant amounts, but these kinases require a second protein, a cyclin, to become activated.
  • Level of cyclin proteins fluctuate cyclically.
  • The complex of kinases and cyclin forms cyclin-dependent kinases (Cdk5).
• MPF ("maturation-promoting factor" or "M-phase-promoting-factor") triggers the cell past the G₂ (not G₁ this time) checkpoint to the M phase.

• MPF promotes mitosis by phosphorylating a variety of other protein kinases.

• MPF stimulates fragmentation of the nuclear envelope.

• It also triggers the breakdown of cyclin, dropping cyclin and MPF levels during mitosis effectively inactivating itself.
• Cyclin levels rise sharply throughout interphase, then fall abruptly during mitosis.

• Peaks in the activity of one cyclin-Cdk complex, MPF, correspond to peaks in cyclin concentration.

• Let’s analyze what this graph tells.

Fig. 12.14a
• Growth factors appear to be a key in density-dependent inhibition of cell division.

• Cultured cells normally divide until they form a single layer on the inner surface of the culture container.

• If a gap is created, the cells will grow to fill the gap.

• At high densities, the amount of growth factors and nutrients is insufficient to allow continued cell growth.

Fig. 12.16a
3. Cancer cells have escaped from cell cycle controls

- Cancer cells divide excessively and invade other tissues because they are free of the body’s control mechanisms.
  - Cancer cells do not stop dividing when growth factors are depleted either because they manufacture their own, have an abnormality in the signaling pathway, or have a problem in the cell cycle control system.
- If and when cancer cells stop dividing, they do so at random points, not at the normal checkpoints in the cell cycle.
• Cancer cells may divide indefinitely if they have a continual supply of nutrients.

• In contrast, nearly all mammalian cells divide 20 to 50 times under culture conditions before they stop, age, and die.

• Cancer cells may be “immortal”.

• Cells (HeLa) from a tumor removed from a woman (Henrietta Lacks) in 1951 are still reproducing in culture.

• Watch this new therapy, a great example of science in action. (15:36).
Let’s read

• Chapter 8 in Survival of the Sickest introduces us to a model called the Hayflick Limit. So read away, and then look at this.

• [http://www.nature.com/news/medical-research-cell-division-1.13273](http://www.nature.com/news/medical-research-cell-division-1.13273)
It’s test time!!

• So make every minute count, like young Shane for his pre-K anatomy exam.