5.1 The Cell Cycle

I. The Cell Cycle

A. Cells have distinct phases of growth, reproduction, and normal functions.

B. The cell cycle has three main stages.
   1. Interphase – cell carries out normal functions and grows to its full size
   2. Mitosis – cell division
   3. Cytokinesis – evenly divides cytoplasm
5.1 The Cell Cycle

C. **Interphase** – divided into 3 stages

1. **Gap 1** – (G\(_1\)) – longest phase of cell cycle
   
   a. cells grow
   
   b. carry out normal functions for that type of cell
   
   c. replicate organelles

2. **Synthesis** – (S) – copies DNA in preparation for cell division

3. **Gap 2** – (G\(_2\)) – additional growth and development of spindle fibers for cell division
5.1 The Cell Cycle

D. **Mitosis** – (M) – cell division that occurs when cell is large enough and DNA is undamaged

a. division of the cell’s nucleus – evenly divides the DNA between the 2 new cells *(daughter cells)*

b. broken into 4 stages:
   1. prophase
   2. metaphase
   3. anaphase
   4. telophase

E. **Cytokinesis** – evenly divides cytoplasm between 2 daughter cells
II. Cell Division and Size

A. Cells divide at different rates.
B. Every kind of cell has a built-in timer to signal when and how often to divide. (See Fig. 5.2 in book)

<table>
<thead>
<tr>
<th>CELL TYPE</th>
<th>APPROXIMATE LIFE SPAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin cell</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Red blood cell</td>
<td>4 months</td>
</tr>
<tr>
<td>Liver cell</td>
<td>300–500 days</td>
</tr>
<tr>
<td>Intestine—internal lining</td>
<td>4–5 days</td>
</tr>
<tr>
<td>Intestine—muscle and other tissues</td>
<td>16 years</td>
</tr>
</tbody>
</table>

C. If the timer stops working, cells divide without stopping and a tumor develops.
D. Cell size is limited.

1. Cell size must stay small in order to efficiently exchange materials with their environments.

2. Everything cell needs to live must enter through cell membrane and wastes must also be able to exit.

   a. Cells must have a high ratio of surface area compared to the cytoplasm – smaller cells are the best! (See Fig. 5.3 in book)

<table>
<thead>
<tr>
<th>Relative size</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface area</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(length × width × number of sides)</td>
<td>6</td>
<td>24</td>
<td>54</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(length × width × height)</td>
<td>1</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td><strong>Ratio of surface area to volume</strong></td>
<td>(\frac{6}{1} = 6:1)</td>
<td>(\frac{24}{8} = 3:1)</td>
<td>(\frac{54}{27} = 2:1)</td>
</tr>
</tbody>
</table>
b. Volume increases faster than surface area, so when a cell gets too big, it divides. (think of a balloon…if it gets too big, it pops)
c. Cells that must be large have unique shapes.
5.2 Mitosis and Cytokinesis

III. Preparing DNA for copying

A. Chromosomes condense at the start of mitosis to make it easier to divide between the 2 daughter cells.

B. DNA wraps around proteins (histones) that condense it.
5.2 Mitosis and Cytokinesis

C. Important terms for chromosomes

1. **chromatin** – DNA plus proteins
2. **chromatid** – one half of a duplicated chromosome
3. **centromere** – place where sister chromatids are pinched and held together
4. **telomeres** – protect DNA and do not include genes (they are lost during mitosis)
IV. Cell Reproduction – creation of daughter cells

A. Interphase – prepares the cell to divide
   1. DNA and organelles are duplicated
5.2 Mitosis and Cytokinesis

B. Mitosis

1. **Prophase**
   a. Nucleolus disappears
   b. Nuclear envelope breaks apart
   c. Chromatin changes to chromosomes
   d. Centrioles (bundled microtubules) begin moving toward poles
   e. Spindle fibers begin stretching between the centrioles
2. **Metaphase**
   a. Spindle fibers attach to the centromere of each chromosome
   b. Spindle fibers align the chromosomes (pairs of chromatids) at the equator (middle)
5.2 Mitosis and Cytokinesis

3. **Anaphase**
   a. Chromatids separate from each other
   b. Spindle fibers shrink pulling the sister chromatids toward opposite poles (sides)
5.2 Mitosis and Cytokinesis

4. **Telophase**
   a. Complete set of identical chromosomes are positioned at each pole
   b. Nuclear envelope begins to develop around each group of chromosomes
   c. Chromosomes uncoil changing back into chromatin
   d. Spindle fibers fall apart
C. **Cytokinesis** – divides cytoplasm evenly between 2 daughter cells

1. differs in animal and plant cells
   
a. Animal cells - the membrane pinches closed
   
b. Plant cells – a cell plate forms because the cell wall is too rigid to pinch
V. Regulation of the Cell Cycle

A. Internal and external factors regulate cell division.
   1. Internal – growth factors (proteins that stimulate division)
      a. kinases – enzyme that transfers phosphate group
      b. cyclins – proteins that are rapidly made then destroyed
   2. External – physical and chemical signals trigger the internal factors
      Ex) platelets, erythropoietin, hormones

Normal cell growth
B. **Apoptosis** – programmed cell death
   1. normal feature of healthy organisms
   2. caused by a cell’s production of self-destructive enzymes
   3. occurs in development of infants (webbed fingers/toes)
5.3 Regulation of the Cell Cycle

C. **cancer** – uncontrolled cell division

1. **tumor** - disorganized clumps of cancer cells
   a. **benign tumor** – remain clustered and can be removed
   b. **malignant tumor** – metastasize (break away) and can form more tumors

2. Cancer cells do not carry out necessary functions.
3. Cancer cells come from normal cells with damage to genes involved in cell-cycle regulation.

4. Carcinogens are substances known to promote cancer.
5. Standard cancer treatments (radiation and chemotherapy) typically kill both cancerous and healthy cells.
### 5.4 Asexual Reproduction

#### VI. Asexual reproduction vs. Sexual Reproduction

<table>
<thead>
<tr>
<th></th>
<th><strong>ASEXUAL</strong></th>
<th><strong>SEXUAL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single organism creates offspring</strong></td>
<td><em>Single organism creates offspring</em></td>
<td><em>Two parents create offspring</em></td>
</tr>
<tr>
<td><strong>No egg or sperm cells involved</strong></td>
<td><em>No egg or sperm cells involved</em></td>
<td><em>Egg and sperm cells unite in fertilization</em></td>
</tr>
<tr>
<td><strong>Offspring identical to parent (clone)</strong></td>
<td><em>Offspring identical to parent (clone)</em></td>
<td><em>Unique combination of parents genes</em></td>
</tr>
<tr>
<td><strong>All organisms can produce offspring – results in rapid population growth</strong></td>
<td><em>All organisms can produce offspring – results in rapid population growth</em></td>
<td><em>Only females give birth – results in slower population growth</em></td>
</tr>
<tr>
<td><strong>Can occur in minutes to hours</strong></td>
<td><em>Can occur in minutes to hours</em></td>
<td><em>Can take months to years</em></td>
</tr>
<tr>
<td><strong>Gives advantage when environmental conditions are constant</strong></td>
<td><em>Gives advantage when environmental conditions are constant</em></td>
<td><em>Gives advantage when environmental conditions change</em></td>
</tr>
<tr>
<td><strong>No time/energy investment for reproduction</strong></td>
<td><em>No time/energy investment for reproduction</em></td>
<td><em>May require a lot of time/energy (finding a mate, courtship, nesting, defending territory)</em></td>
</tr>
</tbody>
</table>
VII. Types of asexual reproduction

A. **Binary fission** – the splitting of bacteria into 2 daughters
   1. Daughters are identical to parent (identical DNA)
B. **Budding** – forms a new organism from a small projection growing on the surface of the parent

1. Bud grows through mitosis and eventually breaks off
5.4 Asexual Reproduction

C. **Fragmentation** – the splitting of the parent into pieces that each grow into a new organism

- Ex) starfish can be cut up and each piece grows into a new starfish

D. **Vegetative reproduction** – forms a new plant from the modification of a stem or underground structure on the parent plant

- Ex) taking a cutting from one plant and rooting it in a glass of water
VIII. Cellular organization

A. **tissues** – groups of cells that perform a similar function

B. **organs** – groups of tissues that perform a specific or related function

C. **organ systems** – groups of organs that carry out similar functions

**cells → tissues → organs → organ systems**
D. **cellular differentiation** – process where cells express different combinations of genes and begin to take on specific roles.

- Cells develop into their mature forms through the process of cell differentiation.
- Cells differ because different combinations of genes are expressed.
- A cell’s location in an embryo helps determine how it will differentiate.
5.5 Multicellular Life

VI. Stem Cells

A. Stem cells have not begun the process of specialization so they have the ability to:
   1. divide and renew themselves
   2. remain undifferentiated in form
   3. develop into a variety of specialized cell types
B. Stem cells are classified into three types.

1. **totipotent** – can grow into any other cell type
2. **pluripotent** – can grow into any cell type but a totipotent cell
3. **multipotent** – can grow into cells of a closely related cell family

<table>
<thead>
<tr>
<th>Class</th>
<th>totipotent</th>
<th>pluripotent</th>
<th>multipotent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of cell</td>
<td>fertilized egg</td>
<td>embryonic stem cell</td>
<td>adult stem cell (example from blood)</td>
</tr>
<tr>
<td>Can give rise to</td>
<td>all cells</td>
<td>almost any cell</td>
<td>closely related cells</td>
</tr>
<tr>
<td>Example</td>
<td>new organism</td>
<td>neurons, skin, muscle, kidney, cartilage, bone, liver, pancreas</td>
<td>red blood cells, platelets, white blood cells</td>
</tr>
</tbody>
</table>
C. Stem cells come from adults and embryos which can be hard to isolate and grow.

1. Adult stem cells may prevent transplant rejection.

2. The use of embryonic stem cells raises ethical issues.

3. Embryonic stem cells are pluripotent and can be grown indefinitely in culture.
D. The use of stem cells offers many currently realized and potential benefits.
   Ex) treat leukemia and lymphoma
   Ex) cure disease or replace damaged organs
   Ex) revolutionize the drug development process