10.1 - CELL GROWTH

BIOLOGY
1. Why do cells need to divide?
   - Too much demand on its DNA (DNA overload)
   - As it grows it doesn’t make extra DNA
   - Exchanging materials (food and oxygen in) (wastes out) is much more simple with a smaller cell.
### RATIO OF SURFACE AREA TO VOLUME IN CELLS

<table>
<thead>
<tr>
<th>Cell Size</th>
<th>Surface Area (length x width x 6)</th>
<th>Volume (length x width x height)</th>
<th>Ratio of Surface Area to Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cm x 1 cm x 1 cm</td>
<td>1 cm x 1 cm x 6 = 6 cm²</td>
<td>1 cm x 1 cm x 1 cm = 1 cm³</td>
<td>6 / 1 = 6 : 1</td>
</tr>
<tr>
<td>2 cm x 2 cm x 6</td>
<td>2 cm x 2 cm x 6 = 24 cm²</td>
<td>2 cm x 2 cm x 2 cm = 8 cm³</td>
<td>24 / 8 = 3 : 1</td>
</tr>
<tr>
<td>3 cm x 3 cm x 6</td>
<td>3 cm x 3 cm x 6 = 54 cm²</td>
<td>3 cm x 3 cm x 3 cm = 27 cm³</td>
<td>54 / 27 = 2 : 1</td>
</tr>
</tbody>
</table>
As the cell grows its volume increases much more rapidly than its surface area, therefore...

The surface area to volume ratio decreases.
Cell division is the process by which a cell divides into "daughter cells"

- Reduces the *volume* and increases overall *surface area*
WHY DOES IT MATTER?

Every living cell is in contact with a **capillary**. By touching the “surface” **blood can deliver** efficiently to cell and also **pick up wastes**.
LET'S TALK ABOUT DNA

DNA and how it is packaged
DNA

• Genetic information – your own code
  • Unique to each individual (unless you are an identical twin)
• When packaged DNA takes on different names.

Figure 12.3
DNA AND ITS’ PACKAGING

- **Chromosomes** = Condensed DNA you can only see when the cell is ready to **divide**

- **Sister Chromatid** = Pairs of Identical Chromosomes held together to make cell division **more accurate**
  - There are **2 copies** of every chromosome because you get **one from mom** and **one from dad**.
CHROMOSOME TYPES

Homologous

You can also refer to sister chromatids as homologous.

- Look the same (homo)
- Control the same traits
- May code for different forms of each trait
  - Independent origin - each one was inherited from a different parent
CHROMOSOME TYPES

Non-Homologous

• Look different
• Control different traits
• Example: Sex chromosomes
  • Are represented as X and Y
  • Determine the sex of the individual, XX being female, XY being male
DNA AND CHROMOSOMES

• Chromosomes are **not** the same for all **organisms**.
  • An average eukaryotic cell has about 1,000 times more DNA than an average prokaryotic cell.
  • The DNA in a **eukaryotic** cell is organized into several linear **(straight line)** chromosomes.
  • **Circular** DNA molecule is found in a **prokaryotic** cell.
CHROMOSOMES

- All eukaryotic cells store genetic information in chromosomes.
  - Most eukaryotes have between 10 and 50 chromosomes in their body cells.
  - **Human** cells have **46** chromosomes.
  - **23** nearly-identical pairs
PHASES OF THE CELL CYCLE

- The cell cycle consists of
  - Interphase – **normal cell activity**
  - The mitotic phase – **cell division**
In preparation for cell division, **DNA is replicated** and the **chromosomes condense**.

Each duplicated chromosome has two sister chromatids, which **separate during cell division**.
• Because of duplication, each condensed chromosome consists of 2 identical **chromatids** joined by a **centromere**.

• Each duplicated chromosome contains 2 identical DNA molecules (unless a mutation occurred), one in each chromatid:
THE CELL CYCLE AND HOW CELLS DIVIDE
1. **Reproduction.** An amoeba, a single-celled eukaryote, is dividing into two cells. Each new cell will be an individual organism (LM).

2. **Growth and development.** This micrograph shows a sand dollar embryo shortly after the fertilized egg divided, forming two cells (LM).

3. **Tissue renewal.** These dividing bone marrow cells (arrow) will give rise to new blood cells (LM).
CELL DIVISION

- An important part of the cell cycle
- Start with 1 cell
- Results in 2 genetically identical daughter cells
INTERPHASE

- $G_1$ - Cells undergo majority of growth

- $S$ - Each chromosome replicates (Synthesizes) to produce sister chromatids

- $G_2$ - Chromosomes condense - Assemble machinery for division such as centrioles
Cells divide by **mitosis**.
- Each new cell receives **one copy** of every chromosome that was present in the original cell.
- Produces **2 new cells** that are both genetically identical to the original cell.
CYTOKINESIS

- **NOT** a stage of mitosis
- Cleavage of cell into two halves…
  - In animals division begins along the **cleavage furrow**
  - In plant cells this begins along the **cell plate**.
RESULT OF MITOSIS

• You end up with 2 Diploid cells
• **Diploid** - A cell possessing **two copies** of each chromosome (human body cells).

https://www.youtube.com/watch?v=f-IdPgEfAHl
WHAT IS CANCER?

- Cancer is **uncontrolled** cell growth and **division**.
  - There is **no one cure or treatment** because there is **no single cause**.
  - Your **own cells** lose the ability to **control when/how often** they divide.

- Cyclins= **proteins** that control the progression of cells through the **cell cycle**.
  - If these cyclins stop working, there is a **greater** chance of cancer occurring in an organism.
Loss of Normal Growth Control

Normal cell division

Cell damage—no repair

Cell Suicide or Apoptosis

Cancer cell division

First mutation
Second mutation
Third mutation
Fourth or later mutation

Uncontrolled growth
Meiosis – A Source of Distinction

Why do you share some but not all characters of each parent?

What are the rules of this sharing game?

At one level, the answers lie in meiosis.
Meiosis Does Two Things -

1) Meiosis takes a cell with **two copies** of every chromosome (diploid) and makes cells with a **single copy** of every chromosome (haploid).

- This is a good idea if you’re going to combine two cells to make a new organism.
- This trick is accomplished by **halving chromosome number**.
- In meiosis, one diploid cell produces **four haploid cells**.
2) Meiosis scrambles the specific forms of each *gene* that each *sex cell* (egg or sperm) receives.

- This makes for a lot of *genetic diversity*.
- This trick is accomplished through *independent assortment and crossing-over*.

- Genetic diversity is important for the evolution of populations and species.
WHY DO WE NEED MEIOSIS?

• Meiosis is necessary to half the number of chromosomes going into the sex cells.

• Why halve the chromosomes in gametes?

• At fertilization the male and female sex cells will provide ½ of the chromosomes each – so the offspring has genes from both parents.
**Meiosis**

Parent cell – chromosome pair

Chromosomes copied

1st division - pairs split

2nd division – produces 4 gamete cells with $\frac{1}{2}$ the original no. of chromosomes
MEIOSIS - MOUSE TESTES

Parent cell

1st division

2nd division

4 gametes
MEIOSIS

• Before Meiosis, cells must go through **interphase.**
  • Same as interphase in Mitosis.
    • G1
    • S
    • G2

• Something unique to meiosis is **crossing over.**
  • Crossing over: 2 homologous pairs of sister chromatids **kick over and exchange genetic information.**
  • One way of producing **genetic diversity.**
    • you are not completely similar to your parents or your siblings (unless you are an identical twin).
CROSSING OVER - VARIATION

nonsister chromatids

chiasmata: site of crossing over

variation

Tetrad
Another Way Meiosis Makes Lots of Different Sex Cells (Gametes) – **Independent Assortment**

Independent assortment produces $2^n$ distinct gametes, where $n = \text{the number of unique chromosomes}$.

- In humans, $n = 23$ and $2^{23} = 6,000,000.0$
- That’s a lot of **diversity** by this mechanism alone.
Meiosis produces **four genetically different** haploid cells.

- **Haploid** - A cell possessing a **single copy** of each chromosome (human sex cells).
In Spermatogenesis, each complete cycle of meiosis produces 4 viable gametes. Tend to be more errors in making sperm than eggs. (more cells = more chances for mistakes).
In oogenesis, only **1 viable egg** is produced for each one complete cycle of meiosis.

- Steals all of the **cytoplasm** from the other cells during division.

- Remaining cells are useless **polar bodies**.

https://www.youtube.com/watch?v=toWK0flyFlY
MEIOSIS - DIVISION ERROR

Chromosome pair
MEIOSIS ERROR - FERTILIZATION

Should the gamete with the chromosome pair be fertilized then the offspring will not be ‘normal’.

In humans this often occurs with the 21\textsuperscript{st} pair – producing a child with Down Syndrome.
21 TRISOMY – DOWNS SYNDROME

Can you see the extra 21st chromosome?

Is this person male or female?
The Key Difference Between Mitosis and Meiosis is:

1. the Way Chromosomes Uniquely **Pair** and **Align** in Meiosis

![Mitosis](image1)

Mitosis

![The first (and distinguishing) division of meiosis](image2)

The first (and distinguishing) division of meiosis
2. Another Way Meiosis Makes Lots of Different Sex Cells – **Crossing-Over**

- **Crossing-over** multiplies the already huge number of different gamete types produced by independent assortment.
FIGURE 13.7 THE STAGES OF MEIOTIC CELL DIVISION: MEIOSIS I

MEIOSIS I:
Separates homologous chromosomes

INTERPHASE

PROPHASE I

METAPHASE I

ANAPHASE I

Centrosomes (with centriole pairs)

Chiasmata

Microtubule attached to kinetochore

Sister chromatids remain attached

Nuclear envelope

Chromatins

Sister chromatids

Tetrad

Centromere (with kinetochore)

Homologous chromosomes separate

Chromosomes duplicate

Homologous chromosomes pair and exchange segments

Tetrads line up

Pairs of homologous chromosomes split up
FIGURE 13.7 THE STAGES OF MEIOTIC CELL DIVISION: MEIOSIS II

MEIOSIS II: Separates sister chromatids

TELOPHASE I AND CYTOKINESIS

PROPHASE II METAPHASE II ANAPHASE II TELOPHASE II AND CYTOKINESIS

Cleavage furrow

Two haploid cells form; chromosomes are still double

During another round of cell division, the sister chromatids finally separate; four haploid daughter cells result, containing single chromosomes

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Possibility 1

Two equally probable arrangements of chromosomes at metaphase I

Possibility 2

Metaphase II

Gametes

Combination 1

Combination 2

Combination 3

Combination 4
Mitosis vs. Meiosis

**Mitosis**

- **Prophase**
  - Duplicated chromosome (two sister chromatids)

- **Metaphase**
  - Chromosomes align at the metaphase plate

- **Anaphase**
  - Sister chromatids separate during anaphase

- **Telophase**
  - Daughter cells of mitosis
  - Daughter cells of mitosis

- **MEIOTIS**
  - Parent cell (before chromosome replication)
  - Chromosome replication
  - 2n = 4

  - **Metaphase**
    - Tetrads align at the metaphase plate

  - **Anaphase**
    - Homologous chromosomes separate during anaphase I; sister chromatids remain together

  - **Telophase**
    - Daughter cells of meiosis I
    - Daughter cells of meiosis II

    - Haploid
    - n = 2

    - Daughter cells of meiosis II
    - No further chromosomal replication; sister chromatids separate during anaphase II

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<table>
<thead>
<tr>
<th>Event</th>
<th>Mitosis</th>
<th>Meiosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA replication</td>
<td>Occurs during interphase before nuclear division begins</td>
<td>Occurs once, during the interphase before meiosis I begins</td>
</tr>
<tr>
<td>Number of divisions</td>
<td>One, including prophase, metaphase, anaphase, and telophase</td>
<td>Two, each including prophase, metaphase, anaphase, and telophase</td>
</tr>
<tr>
<td>Synapsis of homologous</td>
<td>Does not occur</td>
<td>Synapsis is unique to meiosis: During prophase I, the homologous</td>
</tr>
<tr>
<td>chromosomes</td>
<td></td>
<td>chromosomes join along their length, forming tetrads (groups of four</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chromatids); synopsis is associated with crossing over between</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nonsister chromatids</td>
</tr>
<tr>
<td>Number of daughter cells</td>
<td>Two, each diploid (2n) and genetically identical to the parent cell</td>
<td>Four, each haploid (n), containing half as many chromosomes as the</td>
</tr>
<tr>
<td>and genetic composition</td>
<td></td>
<td>parent cell; genetically nonidentical to the parent cell and to each</td>
</tr>
<tr>
<td>Role in the animal body</td>
<td>Enables multicellular adult to arise from zygote; produces cells for</td>
<td>Produces gametes; reduces chromosome number by half and introduces</td>
</tr>
<tr>
<td></td>
<td>growth and tissue repair</td>
<td>genetic variability among the gametes</td>
</tr>
</tbody>
</table>

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Boy or Girl? The Y Chromosome “Decides”

X chromosome

Y chromosome

X chromosome

Y chromosome
Boy or Girl? The Y Chromosome “Decides”

Mother: XX

Father: XY

Meiosis I: X X → X Y

Meiosis II: X X → X X, Y Y

Fertilization: XX + XY → daughter (XX), son (XY)

Diagram illustrates the genetic process that determines gender.