Lab 7: Cell Division — Paper-Based Mitosis & Meiosis

BIOL-8

Name: ______________________ **Date:** ______________________

Name: [ ] **Date:** [ ]

Objectives

By the end of this lab, you will be able to:

- **Model mitosis** by physically moving paper chromosomes through each phase
- **Model meiosis I and II** by separating homologous chromosomes and sister chromatids
- **Trace alleles** through both types of cell division to see how they are distributed
- **Compare and contrast** mitosis and meiosis in terms of purpose, process, and outcomes
- **Demonstrate crossing over** and explain how it creates new allele combinations
- **Explain independent assortment** and its effect on genetic variation

Introduction

Cell division is essential for life. **Mitosis** produces new cells for growth and repair, while **meiosis** produces gametes (sex cells) for reproduction. Although both processes involve dividing a cell's chromosomes, they differ in critical ways.

```
                 CELL DIVISION
                       |
         ┌─────────────┴─────────────┐
      MITOSIS                     MEIOSIS
   (for growth)               (for reproduction)
        |                             |
   1 division                    2 divisions
        |                             |
 2 diploid cells               4 haploid cells
  (identical)                 (genetically unique)
```

In this lab, you will use **paper chromosomes with labeled alleles** to physically walk through both mitosis and meiosis. By tracing specific alleles, you will see exactly how genetic information is distributed to daughter cells.

Key Terms:

Term	Definition
Diploid (2n)	A cell with two complete sets of chromosomes (one from each parent)
Haploid (n)	A cell with one set of chromosomes
Homologous chromosomes	Matching chromosome pairs (one maternal, one paternal)
Sister chromatids	Two identical copies of a chromosome, joined at the centromere
Allele	A version of a gene (e.g., A = dominant, a = recessive)
Centromere	The region where sister chromatids are joined
Crossing over	Exchange of DNA segments between homologous chromosomes

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Materials

- Scissors
- Tape or glue stick
- Colored pencils or markers (at least 2 colors: one for maternal, one for paternal chromosomes)
- **Appendix A**: Printable chromosome cutouts — 2 pairs of homologous chromosomes
- Chromosome Pair 1: Gene A (alleles: **A** and **a**)
- Chromosome Pair 2: Gene B (alleles: **B** and **b**)
- **Appendix B**: Centromere connectors (small strips to join sister chromatids)
- **Appendix C**: Cell outline templates (circles representing cells)
- Blank paper or lab worksheet for staging chromosome movements

Safety Considerations

- Use scissors carefully
- Keep workspace organized — small pieces can be easily lost

Setting Up Your Cell

The Organism

We will model a simple organism with **2 pairs of chromosomes** (2n = 4):

```
Chromosome Pair 1 (Gene A):
┌──────────┐     ┌──────────┐
│ Maternal │     │ Paternal │
│   (A)    │     │   (a)    │
│  [RED]   │     │  [BLUE]  │
└──────────┘     └──────────┘

Chromosome Pair 2 (Gene B):
┌──────────┐     ┌──────────┐
│ Maternal │     │ Paternal │
│   (B)    │     │  (b)     │
│  [RED]   │     │  [BLUE]  │
└──────────┘     └──────────┘

Genotype of starting cell: AaBb (diploid, 2n = 4)
```

Procedure

1. **Cut out** 4 single chromosomes from Appendix A
2. **Color** maternal chromosomes RED and paternal chromosomes BLUE
3. **Label** each chromosome clearly with its allele: A, a, B, or b
4. Place all 4 chromosomes inside a cell outline — this is your starting **diploid cell (2n = 4)**

Record the genotype of your starting cell:

____

How many chromosomes are in this cell?

____

Is this cell diploid or haploid?

____

Part 1: Mitosis

> ***Learning Goal:*** *Walk a diploid cell through all phases of mitosis and verify that both daughter cells are genetically identical to the parent.*

Step 1: S Phase (DNA Replication)

Before mitosis begins, DNA is copied during S phase.

1. **For each chromosome**, cut out an **identical copy** (same color, same allele)
2. **Join** each pair of identical copies with a centromere connector — these are now **sister chromatids**
3. You should now have 4 duplicated chromosomes (8 chromatids total)

```
After S Phase:

┌─────╥─────┐   ┌─────╥─────┐   ┌─────╥─────┐   ┌─────╥─────┐
│  A  ║  A  │   │  a  ║  a  │   │  B  ║  B  │   │  b  ║  b  │
│ RED ║ RED │   │BLUE ║BLUE │   │ RED ║ RED │   │BLUE ║BLUE │
└─────╨─────┘   └─────╨─────┘   └─────╨─────┘   └─────╨─────┘
 (sister          (sister         (sister          (sister
 chromatids)     chromatids)     chromatids)      chromatids)
```

Step 2: Prophase

1. Chromosomes are now visible as condensed, X-shaped structures (sister chromatids linked by centromere)
2. Arrange all 4 duplicated chromosomes loosely in the cell
3. **Note**: In mitosis, homologous chromosomes do NOT pair up

Step 3: Metaphase

1. **Line up** all 4 duplicated chromosomes single-file along the middle of the cell (the metaphase plate)
2. Each chromosome lines up independently

Step 4: Anaphase

1. **Separate the sister chromatids** — pull each pair apart at the centromere

2. Move one chromatid from each pair to one side of the cell, and the other chromatid to the other side
3. Each side should now have 4 chromatids (one A, one a, one B, one b)

Step 5: Telophase & Cytokinesis

1. **Draw a line** down the middle of the cell to separate the two groups
2. Each group becomes a new daughter cell
3. Place each set of chromosomes into a new cell outline

Mitosis Results

Mitosis Results — Allele Tracking

#	Cell	Allele for Gene A	Allele for Gene B	Full Genotype	Diploid or Haploid?	# Chromosomes
1						
2						
3						

Analysis

1. Are the two daughter cells genetically identical to each other and to the parent cell?

2. Did the chromosome number change? How many chromosomes are in each daughter cell?

3. Why is mitosis described as producing "clones" of the parent cell?

Part 2: Meiosis I — Separating Homologous Chromosomes

> ***Learning Goal:*** *Walk a diploid cell through meiosis I, including crossing over and independent assortment.*

Reset Your Cell

1. Start with a fresh diploid cell (2n = 4) — same starting genotype: **AaBb**
2. Complete S phase: duplicate all 4 chromosomes into sister chromatids (same as in mitosis)

Step 1: Prophase I — Synapsis and Crossing Over

This is the critical step that makes meiosis different from mitosis!

1. **Pair up homologous chromosomes** (synapsis):
2. Pair the A chromosome (red) with the a chromosome (blue)
3. Pair the B chromosome (red) with the b chromosome (blue)
4. Each pair is called a **tetrad** (4 chromatids in close contact)
5. **Simulate crossing over** on Chromosome Pair 1:
6. Take one chromatid from the A (red) chromosome and one chromatid from the a (blue) chromosome
7. **Cut a segment** from each and exchange the pieces
8. Tape the exchanged segments onto the opposite chromatid
9. You now have **recombinant chromatids** — one red chromatid with some blue, and one blue with some red

```
Before Crossing Over:        After Crossing Over:

┌────╥────┐                  ┌────╥────┐
│ A  ║ A  │  RED             │ A  ║ A* │  RED (A* = recombinant)
└────╨────┘                  └────╨────┘
```

```
┌────┬┬────┐                    ┌────┬┬────┐
│ a  ││ a  │  BLUE              │ a  ││ a* │  BLUE (a* = recombinant)
└────┴┴────┘                    └────┴┴────┘
```

Describe what crossing over does to the alleles on the affected chromatids:

Step 2: Metaphase I — Independent Assortment

1. **Line up the tetrads** (homologous pairs) along the middle of the cell
2. **IMPORTANT**: The orientation is random. There are two possible arrangements:

```
Arrangement 1:              Arrangement 2:
Left     |    Right         Left     |    Right
A(red)   |  a(blue)         A(red)   |  a(blue)
B(red)   |  b(blue)         b(blue)  |  B(red)
```

1. **Choose one arrangement** — this is independent assortment in action!

Which arrangement did you choose? (1 or 2)

With 2 pairs of chromosomes, how many different arrangements are possible?

With 23 pairs (human), the formula is 2^n. How many possible arrangements?

Step 3: Anaphase I

1. **Separate the homologous pairs** — pull each tetrad apart
2. Move ONE complete (duplicated) chromosome from each pair to each side
3. **Important**: Sister chromatids stay together! Only homologs separate.

Step 4: Telophase I & Cytokinesis I

1. **Divide the cell** into two new cells
2. Each cell should have **2 duplicated chromosomes** (still sister chromatids joined)
3. Each cell is now **haploid** (n = 2), but chromosomes are still duplicated

Meiosis I Results

Meiosis I Results — Allele Tracking

#	Cell	Chromosome Pair 1 Allele	Chromosome Pair 2 Allele	Ploidy	# Chromosomes (duplicated)
1					
2					
3					

Part 3: Meiosis II — Separating Sister Chromatids

> ***Learning Goal:*** *Complete meiosis by separating sister chromatids in each haploid cell.*

For EACH of the Two Cells from Meiosis I

Step 1: Metaphase II

1. Line up the duplicated chromosomes along the middle of each cell

Step 2: Anaphase II

1. **Separate the sister chromatids** — pull each duplicated chromosome apart at the centromere
2. Move one chromatid to each side

Step 3: Telophase II & Cytokinesis II

1. **Divide each cell** into two new cells
2. You should now have **4 total cells**, each with **2 single chromosomes** (one from each pair)

Final Meiosis Results

Final Meiosis Results — Complete Allele Tracking

#	Cell	Gene A Allele	Gene B Allele	Genotype	Haploid?	# Chromosomes	Recombinant?
1							
2							
3							
4							
5							

Analysis

1. How many cells did you end up with? Are they diploid or haploid?

2. Are any of the four gametes genetically identical to each other? Explain why or why not.

3. Which gametes (if any) contain recombinant chromosomes from crossing over?

4. If you had chosen the other arrangement during metaphase I, how would the gamete genotypes be different?

Part 4: Mitosis vs. Meiosis — Side-by-Side Comparison

> ***Learning Goal:*** *Synthesize your observations into a comprehensive comparison.*

Comparison Table

Mitosis vs. Meiosis Comparison

#	Feature	Mitosis	Meiosis
1			
2			
3			
4			
5			
6			
7			
8			

Allele Distribution Summary

In mitosis, the parent cell (AaBb) produced daughter cells with genotype(s):

In meiosis, the parent cell (AaBb) produced gametes with genotype(s):

Which process produced more genetic variety? Explain why:

Part 5: Connecting to Genetics

> ***Learning Goal:*** *Understand how meiosis produces the gametes used in inheritance.*

Gamete Fusion Simulation

Choose one gamete from your meiosis results. Imagine it fuses with a gamete from another individual who is also **AaBb**.

Your selected gamete genotype:

Partner's gamete genotype (choose one possibility):

Offspring genotype after fertilization:

Offspring phenotype (assuming A is dominant over a, and B is dominant over b):

Would a different combination of gametes produce a different offspring? Explain:

Conclusions

1. Summarize the key differences between mitosis and meiosis in your own words:

2. Explain why meiosis is essential for sexual reproduction:

3. How do crossing over, independent assortment, and random fertilization together produce genetically unique individuals?

4. If a human cell (2n = 46) undergoes mitosis, how many chromosomes are in each daughter cell? If it undergoes meiosis, how many are in each gamete?

5. A student says "Mitosis and meiosis are basically the same thing." How would you respond? What are the most important differences?

Quick Reference

Division Comparison

Feature	Mitosis	Meiosis I	Meiosis II
What lines up	Individual chromosomes	Homologous pairs (tetrads)	Individual chromosomes
What separates	Sister chromatids	Homologous chromosomes	Sister chromatids
Result	2 diploid cells	2 haploid cells (still duplicated)	4 haploid cells
Genetic outcome	Identical	Varied (crossing over + assortment)	Varied

Sources of Genetic Variation

Mechanism	When It Occurs	Effect
Crossing over	Prophase I	New allele combinations on chromosomes
Independent assortment	Metaphase I	Random mix of maternal/paternal chromosomes
Random fertilization	Conception	Any sperm can fuse with any egg

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Connection to Module 08: This lab directly applies the concepts of mitosis and meiosis from Module 08 (Cell Division). By physically tracing alleles through each stage, you can see how mitosis preserves genetic identity while meiosis creates genetic diversity — the raw material for inheritance (Module 09) and evolution.

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