

Name: \_\_\_\_\_

Date: \_\_\_\_\_

## Student Exploration: Meiosis

**Vocabulary:** anaphase, chromosome, crossover, cytokinesis, diploid, DNA, dominant, gamete, genotype, germ cell, haploid, homologous chromosomes, interphase, meiosis, metaphase, mitosis, ovum, phenotype, prophase, recessive, sister chromatid, sperm cell, telophase, zygote

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

1. During **mitosis**, a single cell divides to produce two daughter cells. What must happen in the original cell so that each of the daughter cells has a complete set of **chromosomes**?

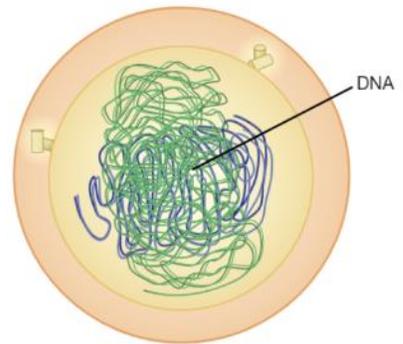
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2. During sexual reproduction, two sex cells fuse to create a fertilized cell with a complete set of chromosomes. What must be true about the number of chromosomes in each sex cell?

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### Gizmo Warm-up

**Meiosis** is a type of cell division that results in four daughter cells with half as many chromosomes as the parent cell. These daughter cells mature into **gametes**, or sex cells. In the *Meiosis* Gizmo, you will learn the steps in meiosis and experiment to produce customized sex cells and offspring.



On the STEPS tab, click **Male**. You are looking at a **germ cell**, or a cell that will undergo meiosis to become gametes.

1. Read the description of **interphase** at the bottom of the Gizmo. What happens to the cell at the beginning of interphase? \_\_\_\_\_

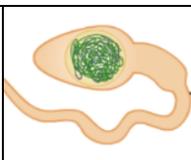
2. Click on the **DNA** in the nucleus of the cell. Describe what happens. \_\_\_\_\_

\_\_\_\_\_

3. Why is it necessary for the cell to grow and duplicate its DNA before the start of meiosis?

\_\_\_\_\_

\_\_\_\_\_

<b>Activity A:</b> <b>Steps in meiosis</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>• Make sure the STEPS tab is selected.</li> <li>• If necessary, choose the <b>Male</b> cell. Click on the DNA to copy it to proceed to prophase I.</li> </ul>	
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**Introduction:** Unlike mitosis, which produces two identical daughter cells from one parent cell, meiosis creates four unique daughter cells with half the amount of DNA as the parent cell.

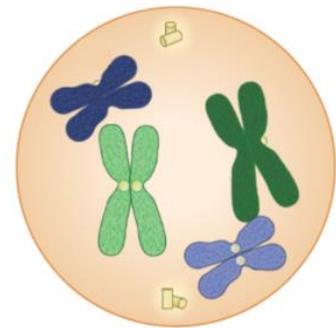
**Question: How does meiosis create four daughter cells from one parent cell?**

1. **Observe: (Prophase I)** Click on the nucleus to break it down then click on the DNA to condense it into chromosomes. Drag the centrosomes to the top and bottom of the cell.

A. How many chromosomes does this cell have? \_\_\_\_\_

Each chromosome consists of a pair of **sister chromatids**, two identical strands of DNA that formed when DNA replicated during interphase.

- B. On the image to the right, draw two lines connecting the pairs of **homologous chromosomes** (chromosomes of similar size with a matching set of genes).



In the Gizmo, drag the homologous chromosomes together. Click **Continue**. [Note: During prophase, all chromosomes undergo a process called *crossing over*, which will be discussed in activity C. You can skip this for now.]

2. **Observe: (Metaphase I and Anaphase I)** - Drag the groups of homologous chromosomes to the metaphase plate, then drag spindle fibers from each of the centrosomes to the chromosomes. Click the centrosome to pull the chromosomes apart.

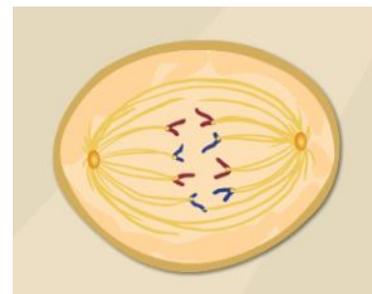
How do the chromosomes separate in anaphase I? \_\_\_\_\_

\_\_\_\_\_

3. **Compare:** An image of the anaphase step in mitosis is shown to the right.

A. How does anaphase I in meiosis differ from anaphase in mitosis? \_\_\_\_\_

\_\_\_\_\_



B. At the end of anaphase I (meiosis), how many chromosomes are on each side? \_\_\_\_\_

**(Activity A continued on next page)**

### Activity A (continued from previous page)

4. **Observe:** **Telophase I** and **cytokinesis** are the final steps of the first half of meiosis.

A. Describe what happens when you click on the chromosomes during telophase I.

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B. Click and drag on the contractile ring. Describe what happened during cytokinesis.

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5. **Observe:** Go through the steps of the second half of meiosis until you reach the end of telophase II, following the instructions at the top right corner. As you proceed, answer the questions below. Use the **Back** button if you need to see a step again.

A. Before prophase II begins, does the DNA in the cell duplicate itself? \_\_\_\_\_

B. During metaphase II, do homologous chromosomes pair up as in metaphase I? \_\_\_\_\_

C. How does anaphase II differ from anaphase I? \_\_\_\_\_

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D. At the end of anaphase II, how many chromatids are on each side of the cell? \_\_\_\_\_

E. After cytokinesis, how many cells have been formed from the parent cell? \_\_\_\_\_

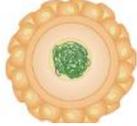
F. Are all of the cells the same size? \_\_\_\_\_

The original parent cell is called **diploid** because it contains a complete set of homologous chromosome pairs. Each of the four daughter cells is **haploid**, meaning that each contains half of the original parent cell's chromosomes. Each daughter cell contains one chromatid from each homologous pair.

6. **Observe:** Click on the spermatids. Spermatids that formed from meiosis will develop into mature male gametes called **sperm cells**. Sketch a mature sperm cell in the space to the right.

Mature sperm cells have only a small amount of cytoplasm and use their flagella, or "tails," to propel themselves forward. Sperm are designed for one purpose, to deliver genetic material to the egg cell during fertilization.



<b>Activity B:</b> <b>Comparing female and male gametes</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>• Make sure the STEPS tab is selected.</li> <li>• Click <b>Reset</b>.</li> </ul>	
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**Introduction:** Although both male and female gametes contain genetic material from the parent organism, they perform different functions. A male gamete delivers genetic material to a female gamete. The fertilized female gamete, called a **zygote**, then grows into the offspring.

**Question: What are the differences in meiosis between male and female cells?**

1. Compare: Click on the **Female** button. For the female cell, proceed through meiosis until you reach the end of anaphase I.

Up to this point, did you notice any differences between the development of male and female gametes? \_\_\_\_\_ Explain. \_\_\_\_\_

2. Compare: Proceed through telophase I and cytokinesis I.

A. What do you notice about the size of the two resulting cells? \_\_\_\_\_  
 \_\_\_\_\_

B. How does this compare to the two cells at the end of telophase I and cytokinesis I in male cells? \_\_\_\_\_

3. Compare: Continue through meiosis until you finish telophase II and cytokinesis II.

A. What do you notice about the four cells now? \_\_\_\_\_

B. What is the largest cell called? \_\_\_\_\_

The ovum is the largest cell in the human body. In contrast, the sperm cell is the smallest cell in the human body.

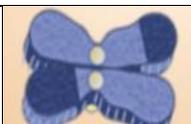
C. What are the small cells called? \_\_\_\_\_

Polar bodies are small cells that develop as a byproduct of meiosis in females. In humans and most other animals, these cells play no significant role and soon die.

4. Think and discuss: Why do you think egg cells are large and sperm cells are small? \_\_\_\_\_

\_\_\_\_\_  
 \_\_\_\_\_



<b>Activity C:</b> <b>Genetic diversity</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>• Make sure the STEPS tab is selected.</li> <li>• Click <b>Reset</b>.</li> </ul>	
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**Introduction:** The activities above shows that organisms can produce at least four different gametes. In reality, organisms can produce millions of genetically unique gametes.

**Question: How can meiosis create an unlimited number of unique gametes?**

1. Experiment: Use the following abbreviations for the chromosomes. Dark green – DG; Light green – LG; Dark purple – DP, Light purple – LP. Choose a **Male** or **Female** cell.

A. Proceed through meiosis to anaphase I. Which chromosomes went up and which went down? Up: \_\_\_\_\_ Down: \_\_\_\_\_

B. Click **Back** and run anaphase I again a few times. Did the results ever change? \_\_\_\_\_ Explain. \_\_\_\_\_

C. Chromosomes are distributed randomly during anaphase I. What are the possible chromosome combinations in the two daughter cells? (Use DG, LG, DP, and LP.)

\_\_\_\_\_

2. Experiment: Click **Reset**. Choose a **Male** or **Female** cell. Proceed through meiosis until the chromosomes are condensed in Prophase I.

Drag the LG (light green) chromosome to the **Allele map** on the left. This shows the alleles (or variations of a gene) that are present on the chromosome. A **genotype** is a list of alleles. The genotype of the LG chromosome, for example, is EEEFFGGHHJJ.

A. What are the genotypes of the remaining chromosomes? DG: \_\_\_\_\_  
 LP: \_\_\_\_\_ DP: \_\_\_\_\_

B. After moving the centrosomes, drag the pairs of homologous chromosomes together. Click on a chromosome. What happens? \_\_\_\_\_

When homologous chromosomes are paired up, they can exchange sections. This exchange of genes is called a **crossover**.

C. Click on several segments to create crossovers, and then click **Continue**. Proceed to anaphase I. Drag each chromosome to the Allele map and write its genotype.

LG: \_\_\_\_\_ DG: \_\_\_\_\_ LP: \_\_\_\_\_ DP: \_\_\_\_\_

**(Activity C continued on next page)**



**Activity C (continued from previous page)**

3. Think and discuss: In this Gizmo, only one crossover is allowed in each segment. In reality, crossovers can occur at almost any point along the chromosome. How do the random distribution of chromosomes and crossovers create more variation in the resulting gametes?

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4. Explore: Meiosis is a complicated process. What happens when something goes wrong?

A. Click **Reset** and choose a male or female cell. Click **Skip**. Describe what would happen if meiosis occurred without DNA replication.

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B. Click **Back**. Proceed through meiosis until the chromosomes are lined up along the metaphase plate. Click **Skip**. Describe what would happen if the chromosomes did not attach to spindle fibers during metaphase I.

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C. Click **Back**. Proceed through meiosis until the chromatids are connected to spindle fibers at Anaphase II. Click **Skip**. Describe what would happen if sister chromatids were not pulled apart at anaphase II.

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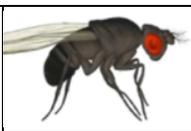
D. Click **Back**. Proceed through meiosis until cytokinesis II. Click **Skip**. Describe what would happen if cytokinesis did not occur.

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During meiosis, there are checkpoints that stop cell division if anything goes wrong. However, these checks do not always work. Abnormal cell division during meiosis can lead to genetic disorders. Trisomy 21 (Down syndrome), for example, occurs when there is an extra copy of chromosome 21 in one of the sex cells.



<b>Activity D:</b>  <b>Crossover challenge</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>• Select the EXPERIMENTATION tab.</li> <li>• Select the <b>Free explore</b> radio button.</li> </ul>	
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**Introduction:** Earlier, you learned how crossovers can result in genetically diverse gametes. In this activity, you will perform crossovers in parent cells undergoing meiosis and combine the resulting gametes to produce offspring with specific genotypes.

**Question: How can offspring be created that have a specific phenotype and genotype?**

1. Explore: The EXPERIMENTATION tab shows a simplified fruit fly genome, with a single pair of homologous chromosomes. Each chromosome has genes that control wing shape, body color, antenna type, and eye color. The uppercase alleles are **dominant** and the lower case alleles are **recessive**. The allele key is given at lower left. (Note that real fruit flies have eight chromosomes and many more genes.)

A. Click **Reset**. Without creating any crossovers, click **Divide into gametes**. What are the possible genotypes of the gametes? \_\_\_\_\_

B. Drag a gamete from each parent into the box below to create a zygote. What are the different combinations of possible offspring genotypes? \_\_\_\_\_  
\_\_\_\_\_

C. Click **Show phenotype** for each combination. What are the resulting phenotypes? \_\_\_\_\_  
\_\_\_\_\_

2. Experiment: Click **Reset**. You can create crossovers by clicking on the middle chromatids in each of the parent cells.

A. Create a gamete with the genotype C b l r. First, click on the c gene in one of the parent cells to create the crossover. Then, click **Divide into gametes**.

Did you create a gamete with the genotype C b l r? \_\_\_\_\_

B. Click **Reset**. Create a gamete with the genotype: c b L R. How many crossover were needed to create this gamete? \_\_\_\_\_

When a crossover occurs, the entire portion of genetic material is swapped between the two homologous chromosomes, so gene C is swapped along with gene B and gene R is swapped along with gene L.

C. Click **Reset**. Create a c B L r gamete. How many crossovers were needed? \_\_\_\_\_

**(Activity D continued on next page)**

**Activity D (continued from previous page)**

3. **Challenge:** Select the **Challenge** radio button. Make sure that **Target offspring 1** is selected in the dropdown menu.

Target offspring 1 is a fruit fly with normal wings (cc), a black body (bb), normal antenna (ll) and red eyes (Rr). Because the offspring receives one chromatid from each parent, each chromatid should come from a different parent.

- A. Using the Gizmo, create a fruit fly with the correct genotype. Explain how you did it.

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- B. Is there another way to get the correct phenotype, but not the correct genotype?

Explain. \_\_\_\_\_  
\_\_\_\_\_

4. **Challenge:** Use the dropdown menu to switch to the next target offspring. While creating target offspring 2-5, fill out the table below.

Target offspring	Genotype of chromatid 1	Genotype of chromatid 2	Number of crossovers Parent 1	Number of crossovers Parent 2
2				
3				
4				
5				

To produce target offspring 5, why were two crossovers needed on one chromatid arm?

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5. **Think and discuss:** Suppose there are two homologous chromosomes. Each chromosome contains a single mutant allele in different parts of the chromosome. How can crossovers be beneficial in this situation? (Hint: How can you create a single, mutation-free chromosome?)

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