Group Information:

Group member names			
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Project Information:

Title of Project:	Course & Level:	Length of lab/activity:
Identification of mitosis and meiosis, and estimation of crossing over rates in the fungus *Sordaria fimicola*	BIOL 2100	~2 hours

Project context –*Description of authentic context of activity.*

Meiosis and mitosis are critical phases during the life-cycle of cells. In this lab, students will model mitosis and meiosis with pop beads. Given their observations, students will perform a genetic mapping experiment of crossing over rates in the fungus *Sordaria fimicola*. Genetic mapping is a common practice that many geneticists use to determine the physical location of a gene on a chromosome. The mapping experiment and lab report will help solidify students' understanding of crossing over events and how they contribute to recombination.

Inquiry Structure and Strategies – *Inquiry structure (e.g., guided inquiry, POE) and strategies (e.g., group learning) that will be used during the activity and why.*

Inquiry Structure: Structured Inquire (level 2), Predict-observe-explain (POE)
Strategy: Group learning - learn how to collaborate with each other and design experiments based on prior information and observations.

Features of inquiry – *Identify the features of inquiry in your activity*

- Scientifically-oriented questions
- Prior knowledge with the observation for evidence
- Further explanation derived from the evidence
- Communicate and justify the explanations

Research Question – *This question guides your lab/activity and establishes a conceptual framework for students' learning.*

How do mitosis and meiosis differ? How does crossing over permit the exchange of genetic material among chromosomes?

Big idea – *Identify the big idea (e.g., patterns, structure & function)*

Students will learn to explain observed patterns in the context of their prior biological knowledge and make inferences using evidence.

Prior knowledge – *List the prior knowledge should students have coming in to the lab/activity*

- The function of mitosis and meiosis
- The tissue types within an organism where each process occurs
- General outline of steps in mitosis and meiosis.

Activity objectives - *Write objectives using action verbs from a variety of different Finks taxonomy levels. Indicate what activities during/after the activity align with each objective.*

- Test for foundational knowledge: students use beads to model the steps of mitosis and meiosis and demonstrate the differences between each process; identification of chromosomal structures in the models.
- Deduction of application: students must be able to give evidence that crossing over occurred in their fungus experiment based on observed patterns; use the rate of crossing over to calculate map units.
- Integration: associate problems with meiosis/crossing over to human disorders; the construction of a genetic mapping experiment, calculating

Alternate conceptions – *List at least two possible alternate conceptions students might have prior to beginning the activity/project. Indicate how the instructor could address each.*

- Confusion between the steps of mitosis and meiosis, and which process results in diploid/haploid daughter cells.
- Crossing over is the exchange of genetic material between two homologous chromosomes (not sister chromatid) that results in recombinant DNA in sexual reproduction. It occurs in prophase I of meiosis at the site of chromosome synapsis.

The TA should start with a short lecture to highlight the important differences between mitosis and meiosis, using discussion to gauge student understanding of biological implications of each process. By the end of discussion, students should understand that mitosis results in two genetically identical diploid (2n) daughter cells and meiosis results in four genetically unique haploid (n) daughter cells.

the physical distance between the centromere of the chromosome and the gene coding for spore color.

- Human dimension: communication of observed evidence of crossing over to other group members; collaborate with members at the same table to gather data to calculate crossing over frequency and communicate findings, as well as answering questions.

Nature of Science – *Write the NOS tenets addressed in this lab/activity. Indicate the types of questions the instructor could ask to explicitly teach each NOS tenet.*

- Scientific investigation uses various methods.
  - e.g. How can biological models (like modeling mitosis with beads) help inform scientific investigation?
- Scientific knowledge is based on both observation and inference.
  - e.g. How can we use observations of crossing over rates to infer the physical location of the color-coding gene on the *Sordaria* chromosome?
- Science is a human endeavor and scientific investigations require group work and communications.
  - e.g. How has group work improved your understanding of mitosis and meiosis?

Materials and Resources – *What equipment, chemicals, etc are needed for students to complete the lab/activity?*

Pop beads; dissecting microscopes; compound microscopes; sterile toothpicks; black and white mating types of *Sordaria fimicola* pre-grown in petri dishes; microscope slides and cover slips; sterile H20

Safety Considerations – *Are there chemical/instrumental safety concerns? How should waste be addressed?*

Glass microscope slide must be disposed in glass waste.
Fungal plates must be disposed in biohazard waste..

Project Assessment:

Formative Assessment Plan

Objectives:	How Assessed:	When Assessed:
Test students' prior knowledge to define each step in meiosis and mitosis, and when crossing over occurs.	Pre-lab quiz	Before experiments begin in lab

TA and students discuss possible ways to calculate map units based on observed crossing over rates in *Sordaria*.	Discussion	After students worked through mitosis, meiosis, and crossing over in their pop bead demonstrations.

Summative Assessment Plan		
Objectives:	**How Assessed:**	**When Assessed:**
A lab report stating findings from the genetic mapping experiment, which also links observed patterns in meiosis to a human genetic disease.	Lab report graded according to the rubric students receive ahead of time.	After lab, due in one week.
A self-reflection about pros/cons of collaboration with other students in the genetic mapping experiment.	Self-reflection	After lab, due in one week (with the lab report).

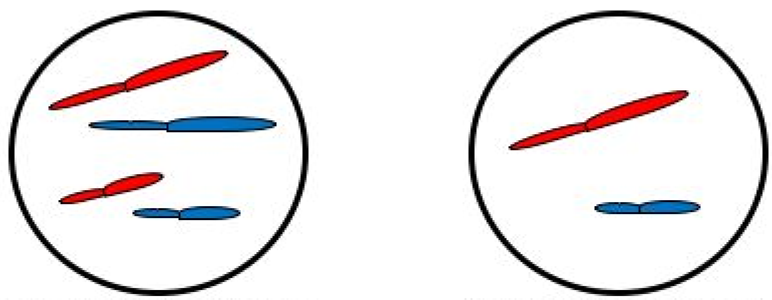
In addition to this cover page, submit the following:

- Inquiry lab/activity project document
- Summative assessment description and rubric
- Citations
- Additional resources for students (optional)

Mitosis and Meiosis Lab Activity

Today you will model mitosis and meiosis using blue and red pop beads. You will then design a study to estimate rates of crossing over in the fungus *Sordaria fimicola*. By the end of lab, you should understand the important differences between mitosis and meiosis. After the *Sordaria* experiment, you should understand how crossing over helps create genetically unique daughter cells

Recall **mitosis** occurs in **somatic** or non-reproductive cells. When a cell undergoes mitosis, it produces two **diploid** (2n) daughter cells that are genetically identical to the parent cell. Alternatively, **meiosis** occurs in specialized cells for sexual reproduction (for example, in the testes or ovaries of humans). When a reproductive cell undergoes meiosis, it produces four **haploid** (n) daughter cells (for example, sperm or eggs), which are all genetically unique.



Diploid (2n) daughter cell resulting for **Mitosis**

Haploid (n) daughter cell resulting for **Meiosis**

Activity 1 – Modeling Mitosis

Obtain 60 red and 60 blue pop beads per lab group of four students. Build two pairs of homologous chromosomes, one long pair and one short pair. Let the red beads represent maternally inherited chromosomes and the blue represent paternal chromosomes. Remember, you have one full set of chromosomes from your mother and one from your father.

Referring to your Cambell Biology textbook, use the pop beads to model the following steps of mitosis with your lab partner:

1) Interphase
2) Prophase
3) Prometaphase
4) Metaphase
5) Anaphase
6) Telophase

Be able to identify the following structures in your model:

Centrioles, centrosomes, chromosomes, centromeres, homologous chromosomes, sister chromatids, spindle fibers, kinetochores

Once you and your partner have worked through each step of mitosis, take turns teaching the entire process to each other.

Questions:
1) How many chromosomes are present in prophase? How about in each daughter cell after telophase?

2) Does crossing over occurring in mitosis?

Activity 2 – Modeling Meiosis
Use your two pairs of homologous chromosome to model the following steps of meiosis with your lab partner:

1) Interphase
2) Prophase I
3) Prometaphase I
4) Metaphase I
5) Anaphase I
6) Telophase I
7) Prophase II
8) Prometaphase II
9) Metaphase II
10) Anaphase II
11) Telophase II

Be able to identify the following structures in your model:
Centrioles, centrosomes, chromosomes, centromeres, homologous chromosomes, sister chromatids, tetrad, spindle fibers, kinetochores

Once you've worked through each step of meiosis, run through your model again, but this time include a crossing over event in the long pair of homologous chromosomes. Take turns teaching the entire process, with crossing over, to each other.

Questions:
1) In prophase I, is the cell diploid or haploid? After telophase II, are the four daughter cells diploid or haploid?

1) How many chromosomes do you have in prophase I? How many chromosomes does each daughter cell have after telophase II?

2) In which step does crossing over occur?

3) Examine the chromosomes in the four daughter cells after a crossing over event. How do these chromosomes differ compared to meiosis *without* crossing over?

4) List three differences between meiosis and mitosis.

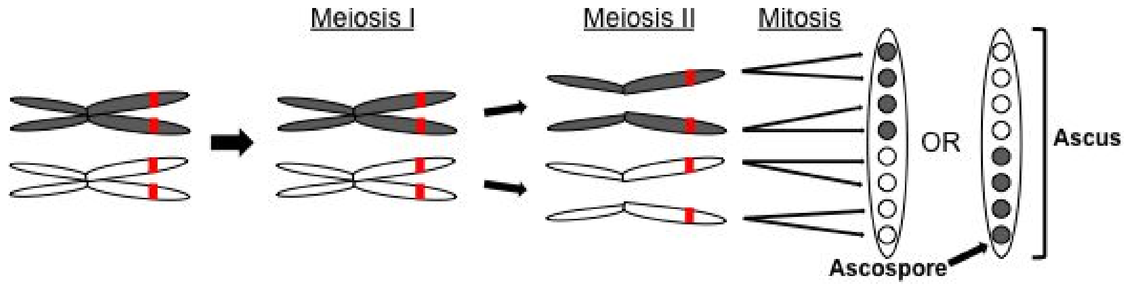
5) Imagine an error occurs in metaphase I of meiosis where the long pair of homologous chromosomes become stuck together in their tetrad and can not separate. How might this affect other steps downstream in meiosis? Will each of the four daughter cells still be haploid?

<u>Activity 3 – Crossing Over in *Sordaria*</u>

In this final activity, you will observe rates of crossing over in the fungus *Sordaria fimicola*. Recall that **crossing over** results in the exchange of genetic material between homologous chromosomes. *Sordaria fimicola* spends most of its life as a haploid (n) mycelium, a mass of cells arranged in filaments. When reproductive conditions are favorable, the filaments of two different mating types can fuse to form diploid (2n) zygotes within a structure called an **ascus** (or plural asci). Each 2n zygote then undergoes *meiosis*. Most importantly, the resulting haploid (n) cells (**ascospores**) remain aligned – the position of the ascospores within an ascus depends on the orientation of chromosomes on the equatorial plane of meiosis I. After meiosis, each resulting ascospore divides once again by *mitosis*, resulting in eight ascospores per ascus. This unique sequence of events means we can easily detect the occurrence of crossing over associated with chromatids carrying **alleles** that code for the color of spores.

If two mating types of *Sordaria*, one with black spores and one with white, are grown in the same petri dish, mycelia from the two types will fuse together and create 2n zygotes that contain a pair of homologous chromosomes, one chromosome with a “black spore” allele and another with a “white spore” allele. After meiosis takes place, and a round of mitosis, the result is eight haploid ascospores aligned within a single ascus: four black spores and four white spores. In the figure below, the red hash mark represents the **locus** that codes for spore color (either black or white).

Figure 1



Now assume crossing over occurs between the two homologous chromosomes, such that the two chromosomes swap their alleles that code for black and white spores, respectively. Below, illustrate how you expect the arrangement of eight ascospores to differ from the figure above?

You will use these arrangements of colored spores to identify when crossing over as occurred between the two homologous chromosomes.

Procedure:

1. Place a single small drop of water on a clean microscope slide.

2. Use a dissecting microscope to examine the ascocarps of *Sordaria* in the culture. The **ascocarps** are fruiting bodies that protect asci inside.

3. Open the lid of the *Sordaria* culture, and use a sterile toothpick to *carefully* remove several ascocarps near the edge of the dish where the two mating types (black and white) have grown together.

4. Place the ascocarps in the drop of water on your microscope slide and cover them with a coverslip.

5. Using the eraser of a pencil, apply light downward pressure to the coverslip until feel a small pop. The pop indicates that the ascocarps have burst open and released their asci from inside.

6. Use your compound microscope to find asci that contain four black and four white spores (i.e. those resulting from the fusion of black and white mating types). Try to find a minimum of 30 asci that contain both black and white spores. Fill out the following table.

Table 1

Asci type	**Number of asci in each category**
Crossing over absent	
Crossing over present	

7. Collaborate with the other members at your table and collect their data from Table 1. Calculate the total number of asci where crossing over was and wasn't present for your entire group.

8. Of all the asci tallied in Table 1, what proportion contained crossing over? Show your calculations below.

Lab Report Assignment: Geneticists estimate crossing over rates (just like you) in **genetic mapping** experiments. The goal of a mapping experiment is to determine the physical location of a gene on a chromosome. A **map unit** is a relative measure of the distance between the centromere and the gene of interest. The farther away the gene is from the centromere, the more likely crossing over is to occur between the two points; therefore, a larger map unit value denotes a higher rate of crossing over.

You will perform a genetic mapping study to determine the relative distance (in map units) on the *Sordaria* chromosome between the centromere and the locus for spore color (i.e. the red hash in Fig. 1). Based on your results in Table 1, you can first estimate the frequency of crossing over in *Sordaria*. These data can then be used to calculate map units that denote the relative location of the spore-color locus on the *Sordaria* chromosome. Work with your group members to determine how to use Table 1 to calculate map units. Write up your results in a formalized lab report. See grading rubric for specific requirements.

<u>Citations</u> - This activity was adapted from the following sources:

Reece JB, Urry LA, Cain ML *et al.* (2013) *Investigating Biology Laboratory Manual*. Pearson, Boston.

Urry LA, Cain ML, Wasserman SA, Minorsky PV, Reece JB (2016) *Campbell Biology*. Pearson, Boston.

Summative Assessment Description and Rubric

Description

After the lab, students must write a lab report about the *Sordaria fimicola* experiment. The report should include the following sections: introduction, methods, data and analysis, and self-reflection. Students should explain the process of meiosis, introduce the rationale of the experiment, present their genetic mapping results, and then link observed patterns in meiosis to a human hereditary disease. In the self-reflection, students should discuss the importance of observation and inference (as in the *Sordaria* experiment) to the process of scientific investigation, and then reflect on the quality of their collaborations with group mates and whether anything can be improved in future labs.

Rubric

	Excellent (5 pts)	**Good (4 pts)**	**Adequate (3 pts)**	**Needs Work (2 pts)**	**Not attempted (0)**
Introduction	1. Includes the experimental question. 2. Explains the process of meiosis. 3. Introduces the experiment rationale. 4. Links errors in meiosis to a human disease.	One of the "excellent" conditions is not met.	Two of the "excellent" conditions are not met.	Less than two "excellent" conditions is met.	
Methods	Includes description or step-by-step process about how crossing over rate was estimated and how the relative distance between the centromere and the locus for spore colors was calculated. Experiment could be repeated according description.	Description included, but some steps are vague or unclear.	The description is vague, but enough to understand how the experiment was conducted.	Reader must guess at how the data was gathered or experiment conducted.	
Data and Analysis	The number of crossing over events in *Sordaria* was clearly recorded. The results of crossing over rates and the relative distance were well presented and organized. All appropriate labels are included.	Results are clear and labeled, but there are minor errors in organization.	Results are unclear, missing labels, or disorganized, but enough to show the experiment was conducted.	Results are disorganized or poorly recorded, do not make senses; not enough data was taken to justify results.	

Self-Reflection	1. Summarizes own performance in the lab. 2. Reflects on the importance of observation and inference in scientific investigation. 3. Discusses what can be improved in next lab.	2 of 3 of the "excellent" conditions is met.	1 of the 3 excellent conditions met.	Does write something about self-reflection.	