

Mitosis, Meiosis and Fertilization -- Teacher Preparation Notes

By Drs. Ingrid Waldron, Jennifer Doherty, Scott Poethig and Lori Spindler, Department of Biology, University of Pennsylvania, 2010¹

Supplies:

Model chromosomes: sockosomes or cardboard models (1 model chromosome per student or 4 per group -- see chart on page 2)

Sockosome supplies:

--Small or medium children's crew socks (no more than half of any one color; even number of pairs of each color sock; eight pairs of socks for two groups of four students each (see chart on page 2); avoid black and dark blue socks typically found in packs of boys socks). To make the two different chromosomes different sizes, turn the cuffs of half of them down inside to make half the sockosomes smaller

-- Fiber fill

-- Self stick squares or circles of Velcro (If you are making more than 36 sockosomes it may be more cost effective to purchase a roll of Velcro and cut it into 1/2 " pieces.)

-- Needle and thread

-- Masking tape and Sharpies

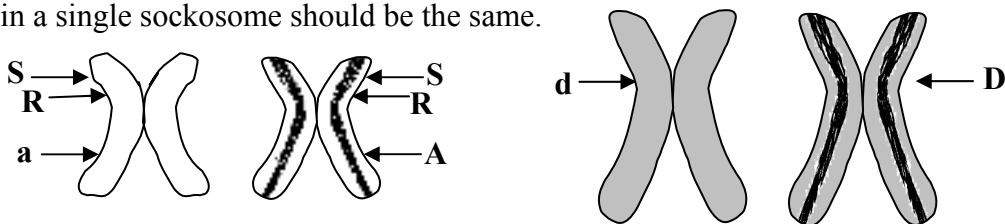
Cardboard models:

If you do not have the time and/or budget to prepare sockosomes, you can use cardboard models of the chromosomes made from card stock or posterboard available from stationery stores. You can use the pattern on page 6 to cut out individual chromatids and then use poster tack (or glue on pieces of Velcro) to attach the sister chromatids. (To simplify the preparation even further you could use rectangles with drawings of chromatids.) Follow the instructions below beginning with 4 in order to make the right number of chromosomes with the right labels for the activities.

Teacher Preparations:

To produce sockosomes



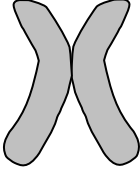

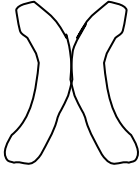
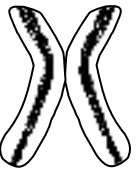
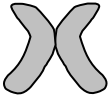

1. Attach and secure with staples or by sewing one part of a piece of self-stick Velcro (the fuzzy part) to the heel of one sock, and attach the other part (the part with hooks) to the heel of the other sock.
2. Fill each sock with fiber fill, and sew the end of each sock closed (sewing works much better than gluing for this step). This is the step at which you make half of each color shorter by folding the cuff down inside of the sock before stuffing.
3. Stick the socks together at the heels. You now have a chromosome with two chromatids, where each sock represents a chromatid. Note that a sockosome refers to the pair of socks attached by Velcro, not the individual socks.
4. Pairs of homologous chromosomes will be represented by two sockosomes of the same color, one with a stripe marked along the length of each sock with a permanent marker (representing the potentially different alleles on the two homologous chromosomes). Add a ring of tape around each sock in each sockosome to represent an allele of each of the genes as shown and explained further on the next page. The tape stays on best if it goes completely around the sock, overlapping at the ends. Obviously, for each gene the allele labeled on both socks in a single sockosome should be the same.



¹ These teacher preparation notes and the related student handout are available at http://serendip.brynmawr.edu/sci_edu/waldron.

Your students will work in groups of four and the chart below shows the sockosomes you will need for each pair of groups of four students each. Label two pairs of homologous sockosomes for each group with the alleles for skin pigmentation (**A** for pigmented skin or **a** for the albino allele) plus the **R** and **S** alleles (for normal hemoglobin and normal smell receptor protein). Label the other two pairs of homologous sockosomes for each group with the alleles for dwarfism versus normal height (**D** and **d**). The sockosomes with **A**, **R**, and **S** genes represent human chromosome 11. The sockosomes with the **D** gene represent human chromosome 4 (which is longer than chromosome 11). Therefore, if half of your socks are short and half long, then all of the short socks should be labeled with an **A** or **a**, **R** and **S**, and all of the long socks should be labeled with a **D** or **d**.

Eight Sockosomes Needed for Two Groups of Four Students Each

| | | | | |
|--|--|--|--|---|
| Mitosis & Meiosis Activities -- Group 1 | a (and R, S) sockosome in solid color 1  | A (and R, S) sockosome in solid color 1 but with a stripe  | d sockosome in solid color 2  | D sockosome in solid color 2 but with a stripe  |
| Mitosis & Meiosis Activities -- Group 2 | d sockosome in solid color 3*  | D sockosome in solid color 3* but with a stripe  | a (and R, S) sockosome in solid color 4*  | A (and R, S) sockosome in solid color 4* but with a stripe  |

*Solid color 3 can be the same as solid color 1, and solid color 4 can be the same as solid color 2. The specific colors used can vary for different sets of sockosomes.

The same sockosomes can be used for these two groups of students for the final activity which models meiosis followed by fertilization, but for this activity one group should have all the **a** and **A** sockosomes, and the other group should have all the **d** and **D** sockosomes. The pair of sockosomes in one color will represent the mother's chromosomes, and the pair of sockosomes in the other color will represent the father's chromosomes. The different colors for the mother's and father's sockosomes represent the fact that, although the labeled alleles are the same for the mother's and father's chromosomes, there are many genes on each chromosome and the mother's and father's chromosomes will have different alleles for many of these genes.

Instructional Suggestions

Students should learn basic information about DNA and proteins before this activity. You may want to use an introductory activity to motivate interest in learning about genes, chromosomes, mitosis and meiosis. Possibilities include an activity in which students evaluate traits which are presumed to be genetically determined (e.g. hitchhiker's thumb, which is the ability to bend the top part of your thumb backwards more than 45°) and/or a discussion of the effect of having an extra chromosome in each cell (e.g. Down Syndrome and Klinefelter Syndrome).

We recommend using two 50 minute periods for this activity, the first for mitosis (pages 1-7) and the second for meiosis and fertilization (pages 8-13).

Many students have difficulty understanding and distinguishing the concepts of DNA, genes and chromosomes. In this activity, almost all the student questions ask about the **A/a** and **D/d** alleles. We have included the **R** and **S** alleles on the sockosomes with the **A/a** alleles to counteract the tendency for some students to assume that each chromosome has only a single gene. One analogy that may be helpful is to compare each gene to a recipe which gives instructions about how to combine the right components to make a protein (comparable to a recipe for a soup, salad or cake). Each chromosome has hundreds of these recipes for different proteins, so you could compare each chromosome to a chapter in a cookbook. All the chromosomes together are like a cookbook which provides recipes for all the different proteins our bodies need to make (or all the different dishes we will want to cook). Each gene is part of a DNA molecule and each chromosome contains one DNA molecule, so the nucleotides in the DNA molecule are comparable to the words in a recipe and cookbook. Different alleles of a gene produce different versions of the same protein, which is comparable to different versions of a recipe (e.g. brownie recipes with different numbers of eggs produce brownies with different textures). We think this analogy is useful, but you should be aware that the explanation of the effects of trisomy at the end of the protocol uses the analogy differently and treats the whole genome as one recipe.

The Teacher Preparation Notes for our "Genetics" activity on this website provide additional information on sickle cell anemia, albinism and vitiligo (another condition in which lack of melanin pigment results in pale skin). Our activity, "From Gene to Protein -- Transcription and Translation" provides additional information on sickle cell hemoglobin and sickle cell anemia. For additional information on the inherited conditions discussed in this activity, search OMIM (Online Mendelian Inheritance in Man, <http://www.ncbi.nlm.nih.gov/omim/>) for 603903 (sickle cell anemia), 606952 (albinism) or 100800 (achondroplasia dwarfism).

When the students model mitosis and meiosis, they can use their arms as spindle fibers. To demonstrate fertilization (and in most of the other demonstrations), it works best to lay the chromosomes out on the table, so students can more easily see the multiple different possible combinations. Another possibility is to have the students carry out the sockosome modeling on two textbooks for mitosis and on four textbooks for meiosis and then push apart the books to represent cytokinesis.

We have focused this activity on understanding the processes of mitosis and meiosis and have omitted many technical terms. You may want to incorporate additional terminology by revising the Word document for this activity. For example, you can incorporate the names of the phases of mitosis in the "More about how mitosis occurs in real cells" section (page 6).

We recommend showing two short videos available on the web at http://iknow.net/cell_div_education.html. Specifically, we recommend that you first show Plant Cell Mitosis which has clear diagrams and then show Live Animal Mitosis which has good video of an actual cell undergoing mitosis with helpful explanations. These videos also demonstrate the difference in cytokinesis for plant versus animal cells.

Possible alternatives include:

Videophotography of dividing cells:

<http://www.youtube.com/watch?v=s1yIUTbXyWU>

<http://www.dnatube.com/video/328/Mitosis>

Animation: <http://www.youtube.com/watch?v=VIN7K1-9QB0>

Videotape: "Cell Division: Mitosis and Cytokinesis" which provides an excellent overview; available for purchase from <http://www.cytographics.com/>.

Teaching points:

- Each cell has DNA molecules (containing genes) organized in chromosomes.
- 46 chromosomes = 23 pairs of homologous chromosomes in each human cell²
- For each pair of homologous chromosomes, both chromosomes contain genes which control the same characteristics, but the two copies of each gene may be different on the two different chromosomes (e.g. the alleles for normal melanin production vs. not).
- Each cell needs a complete set of chromosomes to function properly.
- The body needs to be able to produce new cells for growth, development and repair.
- The purpose of mitosis is to produce two daughter cells, each containing a complete set of chromosomes.
- Basic steps of cell division:
 - replication of DNA → sister chromatids
 - mechanics of mitosis to separate sister chromatids
→ complete sets of chromosomes at opposite ends of cell
 - cytoplasm splits into two separate daughter cells
- The purpose of meiosis is to produce eggs and sperm with only 23 chromosomes, so fertilization can produce a fertilized egg (zygote) with 46 chromosomes.
- Meiosis 1 separates pairs of homologous chromosomes
and meiosis 2 separates sister chromatids → 23 chromosomes in each egg or sperm.
- Different eggs or sperm from the same person have different genetic makeup.
- Fertilization produces zygotes with different combinations of chromosomes, half each from mother and father.
- If the zygote does not have exactly the correct number of chromosomes, this results in abnormalities such as Down Syndrome or, more frequently, death of the embryo.
- Introduction to the idea that understanding meiosis and fertilization is the basis for understanding genetics (developed further in the next activity, Genetics).

Optional Additional Activity

The following activity can be inserted on page 2 of the protocol to help reinforce the concept of homologous chromosomes and the need for condensing the chromosome at the beginning of mitosis.

Prose for Student Handout:

As you probably know, most of the time, chromosomes are contained inside the nucleus in a cell. Chromosomes are very long and thin, much longer than the diameter of a nucleus. To mimic this real-life situation inside a cell, you will be given four long pieces of thread to represent two pairs of homologous chromosomes. Only a few of the genes on these chromosomes will be labeled. Use a piece of paper to represent a cell and draw a nucleus inside the cell. Pile your four pieces of thread inside the nucleus.

Separate the thread into the two pairs of homologous chromosomes. To keep the chromosomes inside the cell, keep the pieces of thread on the paper while you do this.

² There are a few exceptions (gametes, which are mentioned in the student handout, and red blood cells, which are not mentioned).

How can you tell which chromosomes are homologous and which chromosomes are not homologous?

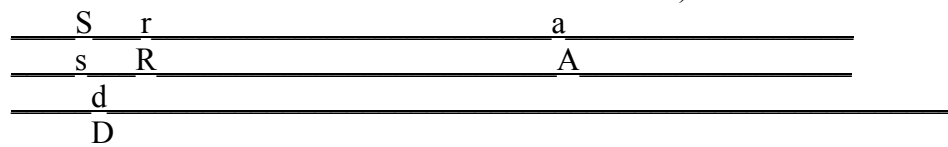
Did you have any problems while you were trying to sort out the chromosomes on the piece of paper which represents the cell?

Next, wrap each piece of thread around a piece of straw, put these on the nucleus, and separate them into two pairs of homologous chromosomes (while keeping them on the paper). Was it easier to sort out the pairs of homologous chromosomes after you wrapped them around the pieces of straw?

Supplies needed for each pair of students for this activity:

-- 4 long pieces of thread (24" for the first two chromosomes shown below and 36" for the second two chromosomes shown below; all the same color)

-- masking tape to label each piece of thread with alleles as shown below (the labels should be small and the alleles should be written on both sides):



-- piece of 8 1/2 x 11" paper

-- short pieces of plastic straw to roll the thread around for the second part of the activity

Additional Related Activities

We recommend that this activity be followed by our [Genetics activity](http://serendip.brynmawr.edu/sci_edu/waldron/) (available at http://serendip.brynmawr.edu/sci_edu/waldron/), so the students will develop a better understanding of how meiosis and fertilization provide the basis for understanding genetics. Sockosomes can be used to demonstrate how meiosis and fertilization provide the basis for understanding Punnett squares.

One of the major oversimplifications in the current activity is that our simulation of meiosis ignores crossing over which contributes greatly to genetic diversity. Sockosomes made with larger socks can be modified so they can be used to model crossing over and recombination. Using a larger pair of socks, cut off a portion of the top of the sock to be stuffed and sewed close separately. The top portion can then be reattached with Velcro, allowing it to be removed and swapped with the top portion of another sock. This can be particularly useful for teacher demonstrations.

Potentially useful related activities (e.g. on the lifespan of different types of cells in the human body, relating cell division to cancer, using yarn and pipe cleaner chromosomes to assess understanding of mitosis and meiosis, and using humans as chromosomes to model mitosis) are available via <http://groups.google.com/group/biology-pd/web/cell-cycle-cancer-mitosis-and-meiosis>. You must join the group to access materials stored there. To do so, simply go to <http://groups.google.com/group/biology-pd/subscribe> and send a request to join the group.

