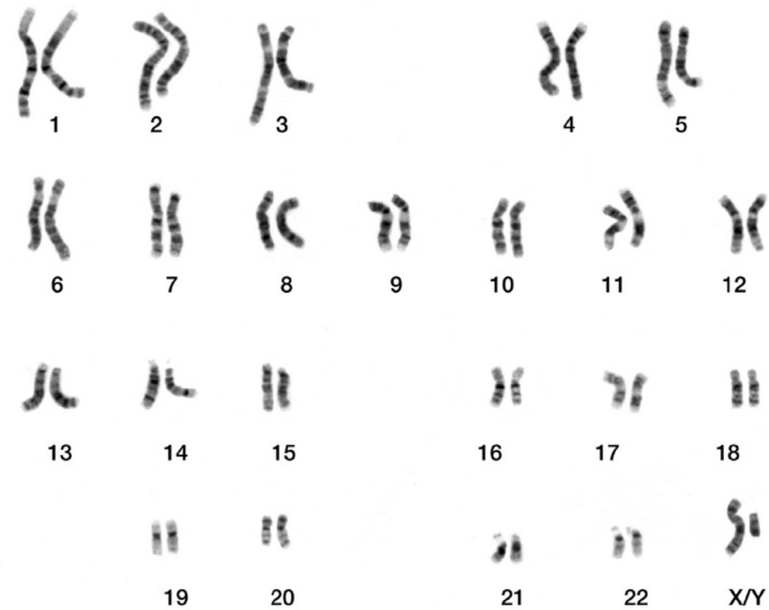
Lab 19. Meiosis: How Does the Process of Meiosis Reduce the Number of Chromosomes in Reproductive Cells?

Introduction

Sexual reproduction is a process that creates a new organism by combining the genetic material of two organisms. There are two main steps in sexual reproduction: (1) the production of reproductive cells and (2) fertilization. Fertilization is the fusion of two reproductive cells to form a new individual. During fertilization, chromosomes from the male and female combine to form homologous pairs (see the figure below). The number of chromosomes donated from the male and female are equal, and offspring have the same number of chromosomes as each of the parents.

A human karyotype depicting 23 homologous pairs of chromosomes.



If the reproductive cell from a male and the reproductive cell from a female each donate the same number of chromosomes that are found in a typical cell to the new embryo, then the chromosome number of the species would double with each generation. Yet that doesn't happen; the chromosome number within a species stays constant from one generation to the next. Therefore, a mechanism that reduces the number of chromosomes found in reproductive cells is needed to prevent the chromosome number from doubling as the result of fertilization. This mechanism is called meiosis.

It took many years of research and contributions from several different scientists to uncover what happens inside a cell during the complex process of meiosis. The German biologist Oscar Hertwig made the first major contribution in 1876, when he documented the stages of meiosis by examining the formation of eggs in sea urchins. The Belgian zoologist Edouard Van Beneden made the next major contribution in 1883. He was the first to describe the basic behavior of chromosomes during meiosis by studying the formation of eggs in an intestinal worm (Ascaris). Finally, the German biologist August Weismann highlighted the potential significance of meiosis for reproduction and inheritance in 1890. Weismann was the first one to publish an article that suggested that meiosis could half the number of chromosomes in reproductive cells and, as a result, keep the chromosome number within a species constant from one generation to the next. In this investigation, you will attempt to build on the work of these scientists by developing a model that explains how this type of cell division results in the production of reproductive cells that contain halve the number of chromosomes that are found in the other cells of that organism.

Your Task

Meiosis is the process in which chromosomes are duplicated and then separated into four reproductive cells that have exactly half the number of chromosomes of the original organism. In addition, this process ensures that there are no pairs of chromosomes found in the reproductive cells. In other words, there is only one copy of each chromosome in reproductive cells instead of two. Then during fertilization, a reproductive cell from a male (i.e., a sperm) and a reproductive cell from a female (i.e., an egg) will fuse to form an embryo that has the same number of chromosomes as the original organism. This process happens in all animals, plants, and fungi that reproduce sexually. Your goal is to develop a model that explains what happens to the chromosomes within a cell during each stage of meiosis.

The guiding question of this investigation is, **How does the process of meiosis reduce the number of chromosomes in reproductive cells?**

Materials

You may use any of the following materials:

- 8 Pop bead chromosomes (and extra pop beads if needed)
- Images of the stages of meiosis

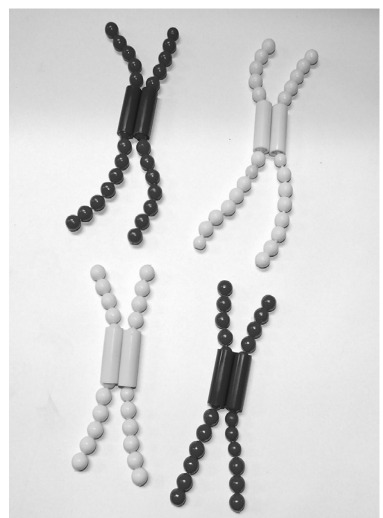
Safety Precautions

1. Safety goggles or glasses are required for this lab.
2. Wash hands with soap and water after completing this lab.
3. Follow all normal lab safety rules.

Getting Started

To answer the guiding question, you will need to develop a model that explains the process of meiosis. Your first step is to learn more about what a cell looks like as it goes through meiosis. You will therefore be given a series of pictures that show the different stages of meiosis as seen through a microscope. Your next step will be to figure out (a) the correct order of stages and (b) what you think may be going on during each stage. Use what you know about the stages of mitosis and how cells divided during mitosis to accomplish this task. From there, you can use pop bead chromosomes (see the figure to the right) to attempt to make sense of what is happening with the individual chromosomes during each stage of meiosis.

Pop bead chromosomes



Your model, once complete, should be able to explain (a) what happens to the chromosomes inside a cell as it goes though meiosis, (b) why reproductive cells have half the number of chromosomes of the individuals who produce them, and (c) why there are no pairs of chromosomes in reproductive cells. To be valid, your model must be able to explain all three of these issues.

Investigation Proposal Required? ☐ Yes ☐ No

Connections to Crosscutting Concepts and to the Nature of Science and Scientific Inquiry

As you work through your investigation, be sure to think about

- the importance of identifying and explaining patterns,
- how scientists develop and use models,
- the difference between theories and laws in science, and
- the role of creativity and imagination in science.

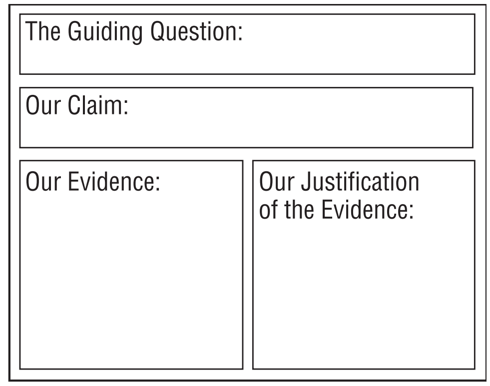
Argumentation Session

Once your group has finished collecting and analyzing your data, prepare a whiteboard that you can use to share your initial argument. Your whiteboard should include all the information shown in the figure on the following page.

To share your argument with others, we will be using a round-robin format. This means that one member of your group will stay at your lab station to share your group's argument while the other members of your group go to the other lab stations one at a time to listen to and critique the arguments developed by your classmates.

The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. In order to critique an argument, you will need more information than what is included on the whiteboard. You might, therefore, need to ask the presenter one or more follow-up questions, such as:

Argument presentation on a whiteboard



- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other models did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?
- How confident are you that your model is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!