

How a Dragon Gets its Wings

*A fanciful approach
to teaching meiosis*



I MAY HAVE MY FATHER'S EYES AND MY mother's chin, but we all know I possess a number of traits that are different from those of either parent. This variation results from the process of meiosis. Variation not only makes me look different from my parents but also contributes to natural selection, which shapes the course of evolution.

In nature, some variations are more advantageous than others because they result in superior adaptations to a particular environment or they give individuals increased mating opportunities allowing them to pass on their genes more often. For example, the male walrus with the longest tusks is given his choice of females in the harem. During the Industrial Revolution, population numbers of light and dark peppered moths changed as the environment changed. Before the Industrial Revolution, the population of light moths dramatically outnumbered that of the dark moths due to the camouflaging effect of light



Explore natural selection
at www.scilinks.org.
Enter code TST0452.

PAMELA ESPRÍVALO HARRELL

ILLUSTRATION BY JOANNE CUNHA

body color against tree trunks that were similar in color. As the Industrial Revolution progressed, the trees became covered with sulfur dioxide from the factories and gradually turned dark. The predation of light moths increased because of the contrast between the light-colored moths and the darkening tree trunks. The dark moths had the advantage of blending in with the darker tree trunks, and that factor increased the likelihood of them escaping predators. Over time, the moth population became predominantly dark because of the change in the environment (Kettlewell, 1955).

Many students wonder, then, why genetic variation exists if certain traits are more favorable. Students do not understand why successful populations still have so much variation. I tell them, first of all, that not all variation influences survival or reproductive success; there are lots of neutral traits. Also, many traits persist in populations because the more genetic variation there is within a population, the more likely it is that the species will survive. For instance, populations with little or no variation have the potential to be wiped out by a single disease. The cheetah population is an example of an endangered species for which biologists are especially concerned because of its lack of genetic variation. Of course, the ability of the cheetah to survive is also influenced by environmental factors such as habitat destruction.

The process of meiosis and its contribution to genetic variation are important concepts. But they are challenging for students, many of whom confuse meiosis with mitosis because of similar terminology and likenesses in how chromosomes align during the dividing process. For this reason, I designed a series of activities to help students form accurate conceptions of meiosis and how its process and purpose greatly differ from mitosis.

PUZZLING OVER MEIOSIS

For the first activity, I assemble a chart of the events occurring during meiosis. The chart lists cell parts (nucleus, chromosomes, centrioles, spindle, and cell membrane) across the top and the phases of meiosis (Interphase, Prophase I, Metaphase I, Anaphase I, Telophase I, Prophase II, Metaphase II, Anaphase II, and Telophase II) down the left side. Then I make a grid describing each

event that occurs in each cell part during each phase. In the activity, students put together a meiosis puzzle using a cut-apart version of the chart. The purpose of this activity is to provide students with a blueprint of the subtle and gross differences occurring at each stage of meiosis. Categorizing these events by phase, while specifically directing attention to the changes with regard to nuclear material, membrane, centrioles, and spindle, introduces students to the complex events comprising meiosis.

Depending on the desired level of complexity, teachers may cut the chart into any number of pieces. If the cell parts and phases of meiosis are left intact, the rest of the table could be divided into a maximum of 45 squares, and students could use their text or other reference materials to assemble the puzzle correctly. A modification of this activity would be color-coding various parts of the puzzle and limiting the total number of puzzle pieces to less than 10.

Once students have completed the meiosis puzzle, they begin a simulation of dragon meiosis. Each pair or group of students is given a simulation packet containing the following materials:

- Four 80 cm lengths of yarn representing spindle fibers in Metaphase I through Anaphase I;
- Eight 30 cm lengths of yarn representing spindle fibers in Telophase I and Prophase II through Anaphase II;

FIGURE 1.

Chromosome information table.

Chromosome pair number	Trait	Dominant/ Recessive	Genotype	Phenotype	Homozygous/ Heterozygous/ Hemizygous
1	Neck length				
	Eye color				
	Horn present?				
	Spike present?				
2	Tail length				
	Body color				
	Wing color				
	Toe number				
3	Belly color				
	Spike color				
	Freckles?				
4	Fire breathing?				
	Chromosome	N/A			

The process of meiosis and its contribution to genetic variation are important concepts. But they are challenging for students, many of whom confuse meiosis with mitosis because of similar terminology and likenesses in how chromosomes align during the dividing process.

- Eight 15 cm lengths of yarn representing spindle fibers in Telophase II.
- Four black construction-paper circles, approximately 9 cm in diameter, representing nuclei;
- Eight red construction-paper rectangles, measuring 1 x 3 cm, representing centrioles;
- Phase labels for Interphase and Meiosis I and II;
- Printout of the meiosis chart—puzzle for events occurring during meiosis;
- Printout of Figure 1—data table to record chromosome information;
- Dragon chromosomes with hook and loop fasteners (such as VELCRO®) attached to the ends for centromeres (Figure 2);
- Printout of Figure 3—dragon parts and dragon key;
- Self-adhesive notes (flags) for each gene—Students place one flag on each allele using pink flags for the mother's genes and blue flags for the father's and copy the trait for each gene shown on the chromosomes onto the flags; and
- Expandable cell membrane—four ribbons approximately 60 cm each with 5 cm of hook and loop fasteners attached to each end.

Using the information from the meiosis puzzle, students construct each phase of meiosis (such as the one pictured in Figure 4). Different sizes of yarn are used to differentiate the spindle formation during Meiosis I from that in Meiosis II. Hook and loop fastener strips unite homologous chromosomes, and four ribbons with hook and loop fastener ends are used to create the elongation or division of the cell membrane. The phase labels enable the teacher to quickly assess what students are doing and facilitates circulation among students as they move at their own pace during the simulation. Lamination of the nuclei, chromosomes, centrioles, and phase labels will extend the useful life of the simulation materials.

Formative assessment by the teacher occurs as students complete each stage of meiosis. Students must

accurately complete each stage before proceeding to the next. During summative assessment, each student is given four different phase labels and asked to demonstrate their knowledge of meiosis by accurately constructing the phases using the simulation materials.

CROSSING OVER

Pink and blue self-adhesive notes, or flags, are used to simulate crossing-over during Prophase I. The pink flags are used for the mother's genes, and blue flags represent the father's genes. To simulate crossing-over, students exchange flags between homologous nonsister chromosomes. The teacher should make sure the students understand that the exchange of genetic materials occurs between corresponding segments on the maternal and paternal chromosomes. It is also possible to show how genes may be linked by proximity on a chromosome and tend to travel together to the same gamete. This can be accomplished by placing both traits on a single self-adhesive note so the two traits will move as a unit.

The instructions students follow to simulate a crossing-over event involving the homologous pairs of maternal and paternal chromosomes that make up a tetrad are:

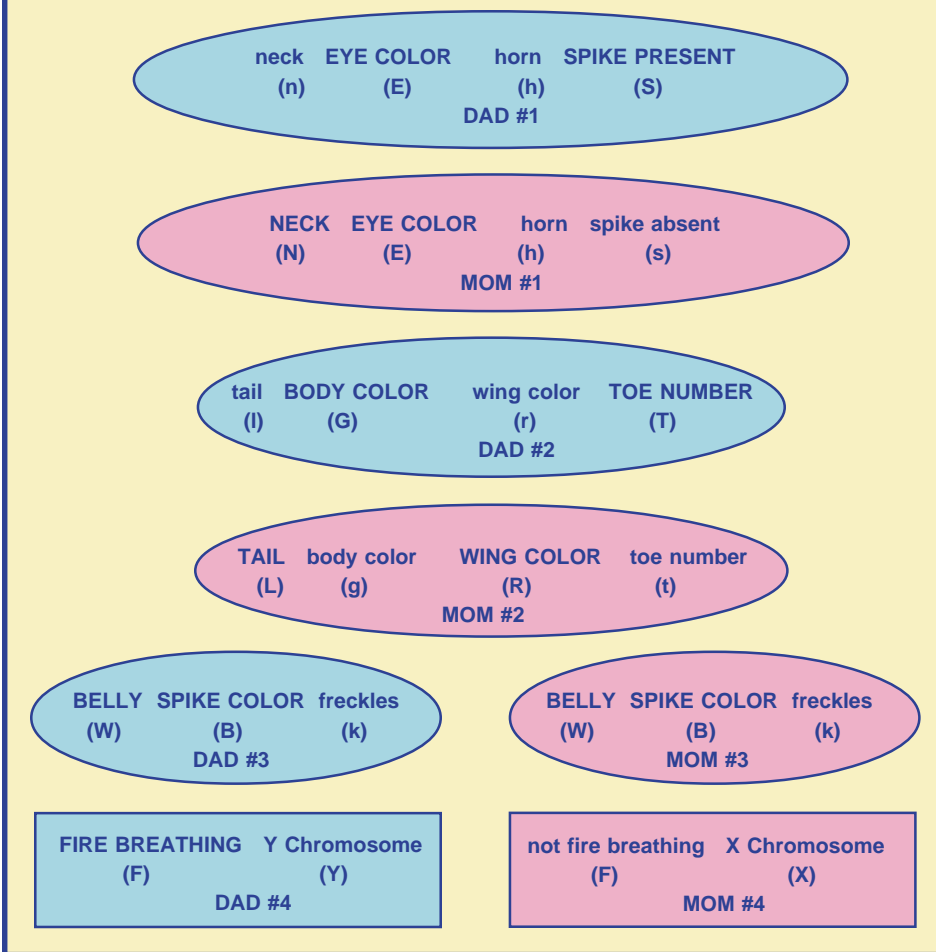
- Horizontally line up each of the homologous pairs of maternal and paternal chromosomes that form a tetrad. There are four tetrads in this activity.
- For each of the four tetrads, select a crossing-over point between two nonsister chromosomes, and mark it with a thin piece of paper.
- Exchange the self-adhesive notes between the two chromosomes. Exchange all of the notes either above or below the crossing-over point.
- Complete three crossing-over events for each tetrad.

One caution is in order. Students must be reminded that while the sequence of dragon meiosis is comparable to meiosis in human males, there are specific differences that occur in human females. For example, crossing-over during Prophase I occurs while the female is still an embryo, and her primary oocytes will become arrested in Prophase I until puberty. At the onset of puberty, the monthly release of a secondary oocyte from the ovary begins. Upon release of the egg, meiosis will progress to Metaphase II and stop unless fertilization occurs within a day or two. Only after fertilization will the mature fertilized egg complete the second meiotic division.

To complete understanding of meiosis in the female, the teacher should include a discussion of the role of polar bodies and how at the end of oogenesis there is only one egg and not four. In human males, primary spermatocytes are not formed until puberty, and then males have the capacity to produce sperm throughout the rest of their lifetimes. Unlike oogenesis in females, male meiosis results in four genetically different sperm.

FIGURE 2.

Dragon chromosomes.



on the concept of independent assortment, the meiosis activity can be completed for spermatogenesis using only the chromosomes and skipping the crossing-over activity. Because the chromosomes are colored pink (maternal) and blue (paternal), teachers can specifically direct students to analyze the effect of chromosome shuffling during independent assortment. There are actually 16 (2^4) possible gametes that could result from this simulation.

Tracking the movement of maternal and paternal chromosomes during the process of spermatogenesis allows students to critically analyze the four resulting sperm with regard to the many possibilities that may result from independent assortment alone. For example, if the act of crossing-over were eliminated, independent assortment would make it possible to produce gametes containing only maternal or paternal chromosomes. Finally, to assist students in the formation of appropriate conceptual ideas with regard to meiosis and how it differs from

mitosis, students should engage in a comparison of the processes of meiosis and mitosis. Students should understand that:

- Mitosis produces two identical cells, while meiosis produces cells that are genetically different. Spermatogenesis produces four different sperm, while oogenesis produces one egg and polar bodies.
- In mitosis, the chromosome number of the two daughter cells is the same as that of the mother cell. After meiosis is complete, the chromosome number of the resulting gametes is cut in half to allow the original chromosome number to be restored upon fertilization.
- Cells that complete mitosis contain two sets of chromosomes (maternal and paternal). Cells with two sets of chromosomes are referred to as diploid. Cells that complete meiosis contain one set of chromosomes and are called haploid.
- Crossing-over contributes to the reassortment of genetic material during Prophase I of meiosis. There is no reassortment of genetic material during mitosis.

At the conclusion of the simulation, students should clearly understand the type and number of cells formed at the end of each process, the chromosome number of the resulting cells, and the origin of variation.

In addition to learning about the concept of crossing-over, students should also understand that independent assortment of nonhomologous chromosomes (maternal and paternal homologues) during meiosis is another source of variation. Therefore, during meiosis there is a shuffling both of chromosomes and the genetic information they carry. To focus solely

FIGURE 3.

Dragon parts and key.



Key to dragon trait alleles

N—long neck
n—short neck

F—fire breathing
f—does not breathe fire

S—spikes on tail
s—no spikes on tail

T—three toes
t—four toes

E—red eyes
e—white eyes

G—green body
g—grey body

R—red wings
r—yellow wings

H—horn
h—no horn

L—long tail
l—short tail

K—freckles
k—no freckles

W—yellow belly
w—white belly

B—black spikes
b—red spikes

X—X chromosome
Y—Y chromosome

- During meiosis, homologous pairs of duplicated chromosomes synapse to form tetrads that line up on the spindle. In mitosis duplicated chromosomes line up individually on the spindle.

A Venn diagram may be used to assist students in a comparison of mitosis to meiosis. In addition to the differences described above, similarities between the two processes include sister chromatids, phase terminology (for example, Prophase, Metaphase, Anaphase, and Telophase), cell machinery used during mitosis and meiosis (for example, spindle fibers and centrioles), and general movement of the chromosomes. At the conclusion of the simulation, students should clearly understand the type and number of cells formed at the end of

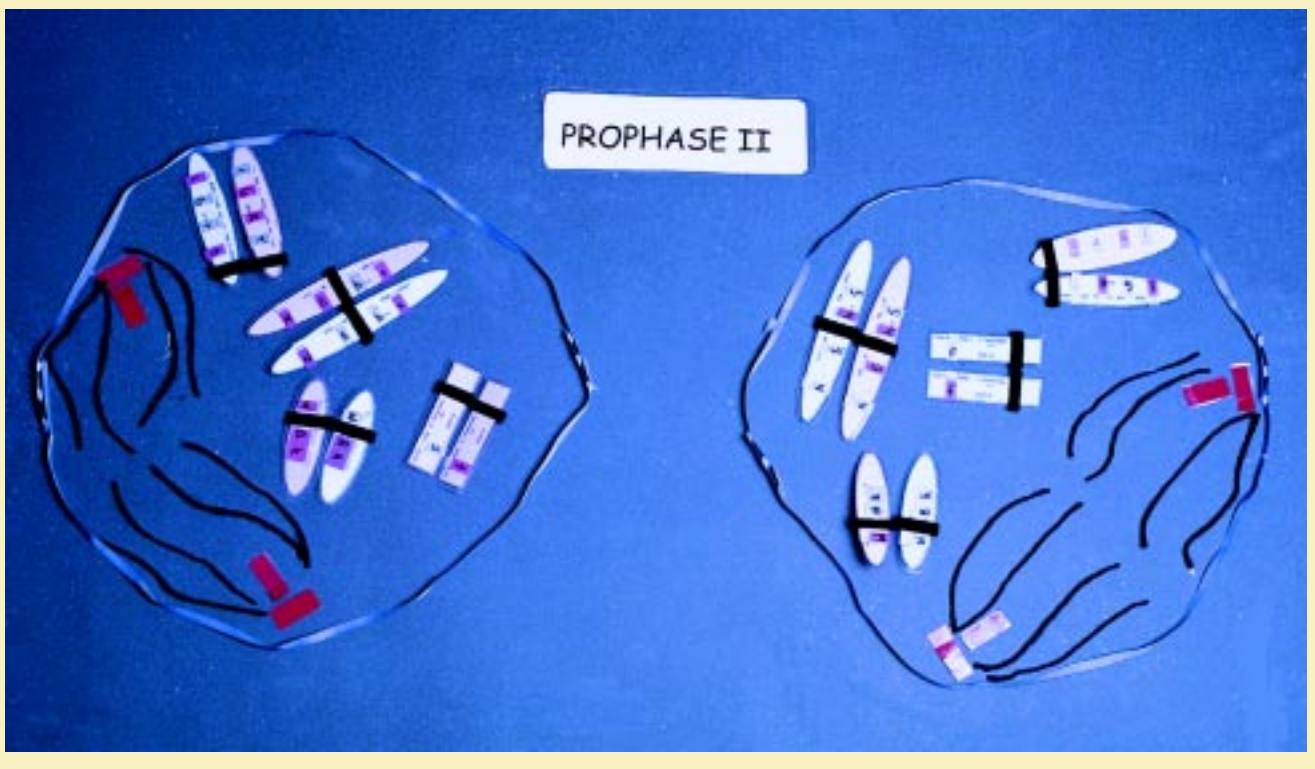
each process, the chromosome number of the resulting cell(s), and the origin of variation.

DRAGON EGGS AND SPERM

Once students understand how important gamete formation is to sexual reproduction and genetic variation, they are ready to engage in the fertilization activity. First, one student selects one of the four simulated sperm and places its chromosomes in a small plastic egg, like those used for Easter egg hunts. Then the teacher uses a hot glue gun to attach a ribbon to the end of the egg to represent the tail of the sperm. For students simulating oogenesis, large plastic eggs are used to hold the chromosomes of the resulting egg. The large plastic eggs need no alteration. The students are now ready to pair up with a

FIGURE 4.

Student construction of Prophase II.



partner and place the contents of the egg and sperm together to simulate fertilization.

Many teachers do not cover the concepts of Mendelian genetics at the same time as meiosis and mitosis. For teachers who teach mitosis and meiosis before Mendelian genetics, it is possible to save the eggs and sperm and use them at a later period of time after the students have been introduced to Mendelian genetics.

DRAGON FERTILIZATION

To simulate fertilization, students open their egg and sperm and remove the chromosomes. Next, using previous knowledge of dominant, recessive, and sex-linked inheritance patterns, they analyze and interpret which traits have been inherited as a result of the egg being fertilized by the sperm. After recording this information on a data table (Figure 1), students trace the correct body parts that correspond to their chromosomes by using Figure 3 and then assemble the dragon.

After the body parts corresponding to the chromosomes of the mother and father have been traced, map pencils are used to color the dragon's body parts to code the inherited traits. It is possible to use the dragon chromosomes from the fertilization activity to spawn a new generation of dragons by repeating

the meiosis simulation. Students can then compare the parent dragon to the new offspring.

As a classroom teacher, I find that students construct knowledge of new information in many ways, some of which are not valid. The more abstract the concept, the more students need to learn by doing. Thus, a simulation such as the one described here increases understanding of complex events. Manipulation of the materials increases understanding of both the mechanics of meiosis and how meiosis creates an organism that is genetically different from its parents and how that individual in turn produces gametes and begins the cycle again. ✧

Pamela Esprivalo Harrell is an assistant professor at the University of North Texas, P.O. Box 311337, Denton, TX 76201; e-mail: pamharrell@hotmail.com.

REFERENCE

Kettlewell, H.B.D. 1955. Results of a mark-recapture study in polluted wood of Rubery near Birmingham during 1953. *Heredity* 9:323-342.

NOTE

Parts of these activities have been adapted from "Dragon Genetics," on pages 33-37 of the January 1997 issue of *Science Scope*, also by Pamela Esprivalo Harrell.



Explore Mendelian genetics at www.scilinks.org. Enter code TST0453.