

Teacher Preparation Notes for Dragon Genetics Lab -- Understanding Inheritance¹

In this simulation activity students mimic the processes of meiosis and fertilization to investigate the inheritance of multiple genes and then use their understanding of concepts such as dominant/recessive alleles, incomplete dominance, sex-linked inheritance, and epistasis to interpret the results of the simulation. After you have introduced classical genetics, this activity can be used as a culminating activity and/or it can serve as a formative assessment to identify any areas of confusion that require additional clarification.

Before beginning this activity students should understand the processes of meiosis and fertilization and basic concepts of classical genetics. Recommended hands-on activities to provide needed background for this simulation activity are:

- Mitosis, Meiosis and Fertilization, available at http://serendipstudio.org/sci_edu/waldron/#mitosis
- Genetics, available at http://serendipstudio.org/sci_edu/waldron/#genetics

You may also want to include a vocabulary review as a pre-lesson assignment. Relevant vocabulary includes: homologous chromosomes, diploid, haploid, gamete, alleles, genotype, phenotype, homozygous, heterozygous, dominant, recessive, incomplete dominance, X-linked recessive allele (and/or sex-linked trait), Punnett squares, and epistasis. Student understanding of this vocabulary should be further reinforced during the activity.

We estimate that this activity will require two 50-minute periods, the first for pages 1-4 of the Student Handout (including the introductory review of relevant biological concepts, the simulation, and the completion of the data charts on page 4) and the second for the picture of the baby dragon and discussion of the questions on pages 5-6.

Learning Objectives:

- Students will understand how meiosis and fertilization result in transmission of genes from one generation to the next.
- Students will understand how meiosis and fertilization provide the biological basis for Mendel's Laws of Segregation and Independent Assortment.
- Students will understand homozygous and heterozygous alleles, dominant and recessive alleles, incomplete dominance, sex-linked inheritance, and epistasis.
- Students will evaluate the strengths and weaknesses of the simulation as a model for understanding inheritance. This will improve student understanding of the role of models in scientific thinking.

Materials and Instructions for Preparing Popsicle Stick Chromosomes

Each Popsicle stick should be prepared to represent a pair of homologous chromosomes. Each student in your class should have a complete set of three Popsicle sticks representing:

- two pairs of homologous autosomes (represented by a green Popsicle stick and a yellow Popsicle stick)
- a pair of sex chromosomes (represented by a red Popsicle stick for the mother or a blue Popsicle stick for the father).

You will need one of the following sets of supplies:

-- regular Popsicle sticks (3 for each student in your largest class) and small rubber bands (1 for each student in the class) + colored paper (1 each of green, yellow, red, and blue) and glue or rubber cement

or

-- regular Popsicle sticks (3 for each student in your largest class) and small rubber bands (1 for each student in the class) + green, yellow, red and blue permanent markers

or

-- colored Popsicle sticks (2 green, 2 yellow, 1 red, and 1 blue for each pair of students in your largest class) and small rubber bands (1 for each student in the class) + 4 pages paper for photocopying and glue or rubber

¹ By Ingrid Waldron, Department of Biology, University of Pennsylvania and Bob Farber, Central High School, Philadelphia, PA, copyright 2012. Based on the work of Dr. Pamela Esprivalo Harrell, University of North Texas, who developed an earlier version of "Dragon Genetics" described in the January 1997 issue of Science Scope, 20:4, 33-37 and the April 2001 issue of The Science Teacher, pages 52-57. The Student Handout, these Teacher Preparation Notes, comments, and the complete list of our hands-on activities are available at http://serendipstudio.org/sci_edu/waldron/.

cement

or

-- colored Popsicle sticks (2 green, 2 yellow, 1 red, and 1 blue for each pair of students in your largest class) and small rubber bands (1 for each student in the class) + a permanent marker

The instructions below describe two alternative methods for preparing the Popsicle sticks. These instructions will produce enough Popsicle sticks for 30 students (15 dragon mothers and 15 dragon fathers).

Method 1: Use the last four pages of these Teacher Preparation Notes to photocopy or print a copy of each page of genes on the appropriate color paper. For each page of genes, cut out the vertical strips, each with a column of letters representing the genes in one chromosome; keep each group of 15 vertical strips with the appropriate label. Apply rubber cement or Elmer's glue to both sides of a Popsicle stick. To prepare a Popsicle stick to represent a pair of autosomes or a pair of X chromosomes, glue the strip for chromosome 1 on one side of the popsicle stick and the strip for chromosome 2 on the other side. (Be sure to keep the mother's green and yellow autosomes separate from the father's green and yellow autosomes.) To prepare a Popsicle stick to represent the sex chromosomes for a male, glue the strip for the blue X chromosome on one side and the strip for the Y chromosome on the other side. Use rubber bands to make bundles that include either the three chromosomes for the mother or the three chromosomes for the father.

Method 2: Use the appropriate color marker or Popsicle sticks to write the alleles for each gene on the Popsicle sticks. Be sure to keep the mother's green and yellow autosomes separate from the father's green and yellow autosomes.

To prepare the green autosome Popsicle sticks:

- for the mother, write **W I A c** on one side of each popsicle stick and write **w l a c** on the other side
- for the father, write **W I a C** on one side of each popsicle stick and write **w l a c** on the other side.

To prepare the yellow autosome Popsicle sticks:

- for the mother, write **f T R** on one side of each popsicle stick and write **f t r** on the other side.
- for the father, write **F T R** on one side of each popsicle stick and write **F t r** on the other side.

For the mother's X/X chromosome Popsicle sticks, use red marker or red Popsicle sticks to write **H** on one side and **h** on the other.

For the father's X/Y chromosome Popsicle sticks, use blue marker or blue popsicle sticks to write **H** on one side and **M** on the other.

Use rubber bands to make bundles that include either the three chromosomes for the mother or the three chromosomes for the father.

Suggestions for Discussing Questions in Student Handout

The questions on page 1 of the Student Handout and the chart on the top of page 2 are important for ensuring that students understand the biological meaning of the simulation they will be carrying out. The questions also demonstrate how meiosis and fertilization provide the biological basis for the Punnett square.

The charts for recording the results of the simulation on page 4 of the Student Handout should be relatively straightforward to complete. We recommend that you use these charts to record the genotypes and phenotypes of mom and dad and the possible genotypes and phenotypes of the baby dragons before beginning the activity. We also recommend that you check your students' charts before they make the picture of their baby dragon and answer the questions on pages 5-6. One potential problem may occur when students enter the skin color and freckles phenotypic traits of the father, since they may ignore the epistatic effects of the **aa** alleles which make the father an albino.

The first two questions on page 5 of the Student Handout require students to use their understanding of inheritance and Punnett squares to interpret the results of the simulation. The alleles for the parents in this simulation have been chosen to ensure that at least one trait is the same in Mom, Dad and baby. In addition, it is highly unlikely (for male babies) or impossible (for female babies) that the baby will have exactly the same phenotypic traits as the same-sex parent.

Questions 3 and 4 require students to state Mendel's Laws of Segregation and Independent Assortment and relate them to this simulation. Your students may find it helpful to use a Punnett square to answer question 3c. The following quotes (from Concepts of Genetics, Sixth Edition by Klug and Cummings) give a helpful summary of Mendel's postulates:

"Genetic factors are controlled by unit factors that exist in pairs in individual organisms."

"When two unlike unit factors responsible for a single character are present in a single individual, one unit factor is dominant to the other, which is said to be recessive."

"During the formation of gametes, the paired unit factors separate, or segregate, randomly so that each gamete receives one or the other with equal likelihood."

"During gamete formation, segregating pairs of unit factors assort independently of each other."

This simulation is useful for helping students to understand inheritance of genes and traits, both because the simulation mimics the biological processes of meiosis and fertilization and because the simulation allows students to apply their understanding of genetics concepts to a model system that is intermediate in complexity between a Punnett square and the intricacies of the real genetics of biological organisms. However, like all models this simulation does not include important features of biological reality, e.g. crossing over during meiosis, codominant alleles, multiple alleles for a single gene, polygenic inheritance, and sex-limited and sex-influenced inheritance. Also, this simulation only hints at the complex relationships between individual genes and phenotypic traits.

To further develop your students' more sophisticated understanding of the role of models in scientific thinking, you may want to discuss the relative advantages of several different models of inheritance:

- this simulation, which is useful for reinforcing understanding of the roles of meiosis and fertilization in inheritance and concepts such as dominant and recessive alleles, incomplete dominance, and sex-linked inheritance and also useful for introducing some of the complexities of inheritance of multiple genes
- Punnett squares, which are useful for analyzing inheritance of one or two genes, including identifying all the possible combinations of alleles in offspring and the resulting phenotypes, and making quantitative predictions concerning the frequency of these genotypes and phenotypes in large samples of offspring
- pedigrees, which are useful for analyzing the genetic basis of inheritance of a phenotypic trait in multiple family members.

(The uses of Punnett squares and pedigrees are demonstrated in our "Genetics" hands-on activity (available at http://serendipstudio.org/sci_edu/waldron/#genetics).)

For question 6, you may want to have your students draw a Punnett square. You may want to link the discussion of this question to the generalization that traits due to X-linked recessive alleles (e.g. colorblindness and hemophilia) are generally much more common in males than in females.

Question 7 illustrates some of the complexities of genetics. For dominant/recessive alleles, heterozygous and homozygous dominant individuals have the same phenotypic trait. For incompletely dominant alleles, heterozygous individuals have a distinct phenotype that is intermediate between the two homozygous phenotypes. An absence of freckles could be due to being homozygous for the albino allele (**a**) or the no freckles allele (**r**).

Many phenotypic traits are influenced by multiple genes. One example is epistasis in the control of skin color, both in humans and in this simulation. If a person is homozygous for an allele that codes for a defective version of tyrosinase (a key enzyme to produce melanin), then the person will be an albino and other genes that influence skin color have little or no effect. (Additional information about human genes that influence skin color is available at <http://ghr.nlm.nih.gov/gene/TYR> and ghr.nlm.nih.gov/genes/MC1R.) Skin color also is a

Genes on Yellow Autosome 1 for Mother

f f f f f f f f f f f f f f f
T T T T T T T T T T T T T T T
R R R R R R R R R R R R R R R

Genes on Yellow Autosome 2 for Mother

f f f f f f f f f f f f f f f
t t t t t t t t t t t t t t t
r r r r r r r r r r r r r r r

Genes on Yellow Autosome 1 for Father

F F F F F F F F F F F F F F F
T T T T T T T T T T T T T T T
R R R R R R R R R R R R R R R

Genes on Yellow Autosome 2 for Father

F F F F F F F F F F F F F F F
t t t t t t t t t t t t t t t
r r r r r r r r r r r r r r r

Gene on X Chromosome 1 for Mother [red]

H H H H H H H H H H H H H H H

Gene on X Chromosome 2 for Mother [red]

h h h h h h h h h h h h h h h

Gene on X Chromosome for Father [blue]

H H H H H H H H H H H H H H H

Gene on Y chromosome for Father [blue]

M M M M M M M M M M M M M M M
