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Dragon Genetics

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Genetics is a topic that most students enjoy but also have trouble understanding. This set of laboratories teaches basic genetics concepts using a fun model, dragons. Groups of students create their own dragon using popsicle sticks as chromosomes, emphasizing the randomness of inheritance. These baby dragons are then used to answer guided question sets to help students learn some of the more difficult introductory genetics concepts. During the second lab students interact with other groups to find a mate for their dragon and to do an activity for understanding test crosses. This lab is based on "Dragon Genetics" by Dr. Pamela Esprivalo Harrell, updated with more reflective prompts to address common student misconceptions.

Keywords: genetics, active learning, homozygous, heterozygous, dominant, recessive, dragons

Introduction

Dragons are thought of as mystical creatures that do not exist; however, their existence in this exercise is very real. Many different possibilities exist for each group to make a unique dragon. Before presenting this material to students, instructors should cover mitosis, meiosis, homologous chromosomes, genes and alleles. This laboratory is meant for introductory level biology students to familiarize them with the basic concepts of heredity such as: homozygotes, heterozygotes, codominance, incomplete dominance, Mendel's principles and addition and multiplication rules. Students should be able to independently work inheritance problems after completing this laboratory exercise.

Very little time is needed to prepare for this set of lab exercises. The only preparation needed is writing the letters on the chromosomes (popsicle sticks/tongue depressors), making sure you have a packet for each student plus one for each group (so each student can keep their personal packet but turn in the group packet) and creating the stencils for the dragons. Part one of the Dragon Genetics exercises usually takes a little over two hours depending on the students' level of understanding. If this is their first exposure to inheritance then an extended explanation will be necessary to get them ready for this exercise. Students usually have many questions about procedure despite the detailed directions and adequate oral presentation. These concepts are new to them and so questions should be expected and marked as piqued interest instead of lack of effort. Part 2 of the dragon genetics exercise takes another 2 hours, unless the students are advanced. At the introductory level some students have had prior exposure to these concepts and so some groups may finish more quickly than others. It is good to have an extended practice exercise on hand to challenge these advanced students.

We've found that *Dragon Genetics* engages students and helps them remember the concepts. This exercise is a straightforward and enjoyable way to cover difficult genetics concepts.

Student Outline

Objectives

Teach basic genetics concepts using dragons as a model.

Introduction

A chromosome contains one long __________ molecule. Each gene in this molecule gives the instructions for making a __________________.

Both chromosomes in a pair of ______________________ chromosomes have the same ___________, but the two chromosomes may have different _________________.

Chromosomes that are not homologous have different ______________ which give the instructions for making different kinds of proteins.

Dragon Genetics

In this activity you will work with your group to carry out a simulation of meiosis and fertilization and produce a baby dragon. Each group will have a surrogate dragon mother and father who have the genes indicated on a set of three Popsicle sticks. Each side of a Popsicle stick represents one chromosome, and the two chromosomes for each parent together represent a pair of homologous chromosomes. This table explains how the simulation mimics the biological processes of meiosis and fertilization.

Biological Process	Simulation
The parents' diploid cells have pairs of homologous chromosomes. Meiosis separates each pair of homologous chromosomes, so each gamete receives only one from each pair of chromosomes. Thus, the parents' diploid cells have two copies of each gene, but each haploid gamete has only one copy of each gene.	Each dragon parent asks for outside help to select the Popsicle stick that will be used from each homologous pair in the gamete. The alleles from these chromosomes are recorded in the charts on page 3.
When a haploid sperm fertilizes a haploid egg, this produces a diploid zygote with one copy of each gene from the mother and one copy from the father. These genes determine the phenotypic traits of the baby dragon that develops from this zygote.	The dragon parents record the phenotypic traits of their baby in the Baby's Traits column in the charts on page 3.

Simulation Procedure

1. Each group should have a bundle of twelve Popsicle sticks -- four green autosomes, four red autosomes, and four sex chromosome sticks. The autosomes with blue spots at the bottom end are from the father. The sex chromosomes in your bundle will consist of two X chromosome Popsicle sticks (pink), an X chromosome Popsicle stick (blue) and a Y chromosome Popsicle stick (blue).
2. Record the alleles from each Popsicle stick for Mom in the first column of the charts on page 3 and the alleles from both sides of each Popsicle stick for Dad in the second column.
3. Use the decoding chart on page 2 to figure out the phenotypic effects of each parent’s genes. Record Mom's and Dad's phenotypic traits in the last two columns of the charts on page 3.
4. For each color autosome and then for the sex chromosomes, each parent will show their sticks (face down) to a member of a different group. The volunteer from the different group will randomly pick the chromosome that is passed onto the baby via meiosis and fertilization. Record the alleles from this chromosome in the Egg or Sperm columns in the charts on page 3.

5. Next, you must decode the genes inherited by your *bundle of joy* to determine the phenotype of your baby. Record the trait produced by each pair of alleles in the Baby's Traits column of the charts on page 3. If your baby dragon is **aa**, be sure to take this into account when assessing the phenotypic effects of the skin color and freckles genes.
6. There are stencils for short neck short tail dragons and stencils for long tail long neck dragons. Find the appropriate stencil(s) for your dragons. Use the stencils provided to draw pictures of your dragons and indicate their colors. If you are not artistic just do your best.

Dragon Genome – Decoding of the Genes

Chromosome	**Dominant alleles**	**Recessive alleles**
Green autosome	**W** has wings **L** long neck and tail **A** normal skin pigment **C** skin color dark green*	**w** no wings **l** short neck and tail **a** completely white, including no freckles **c** skin color light green*
Red Autosome	**F** fire breather	**f** not fire breather
	T and **t** (see below)	
	R and **r** (see below)	
X chromosome	**H** has horn on nose	**h** hornless
Y chromosome	**M** male sex (results in spike on tip of tail)	

Incompletely dominant alleles

TT five-toed	**Tt** four-toed	**tt** three-toed
RR lots of freckles* (draw 10)	**Rr** some freckles* (draw 5)	**rr** no freckles

*If a dragon is **aa** and therefore unable to make skin pigment, it will have white skin and it will not have any freckles (no matter what alleles it has for the skin color and freckles genes).

Green Autosomes

GENOTYPES			ALLELES in			PHENOTYPES		
Mom	Dad		Egg	Sperm		Baby's Traits	Mom's Traits	Dad's Traits

Red Autosomes

GENOTYPES			ALLELES in			PHENOTYPES		
Mom	Dad		Egg	Sperm		Baby's Trait	Mom's Traits	Dad's Traits

<u>Sex Chromosomes</u> (Use the first line for the alleles on the X chromosomes and the second line for the allele on the Y chromosome.

Remember that the sperm will have either an X chromosome or a Y chromosome.)

	GENOTYPES			ALLELES in			PHENOTYPES		
	Mom	Dad		Egg	Sperm		Baby's Traits	Mom's Traits	Dad's Traits
X									
Y								No spike on tip of tail	Spike on tail

<u>Mom</u> <u>Dad</u> <u>Baby</u>

Questions

1a. What is one phenotypic trait that is the same in Mom, Dad and baby dragon?

1b. Draw a Punnett square to show how your baby dragon inherited the genes that resulted in this trait. In the Punnett square, circle the genotype of your baby dragon.

1c. Suppose that Mom and Dad had a second baby. Would the second baby necessarily have this same trait? Explain why or why not.

2a. Does your baby dragon have exactly the same phenotypic traits as his or her same-sex parent?

2b. If not, choose one trait that differs between the baby and the same-sex parent, and explain the genetic reason for this difference.

Principle of Segregation –

3. Use an example from this simulation to demonstrate how segregation of two alleles during meiosis, followed by fertilization, can result in a baby that has a new phenotypic trait that is not observed in either parent.

4a. For the mom and dad in the simulation, will all of their daughters have horns? Explain why or why not.

4b. For this couple, will all of their sons have horns? Explain why or why not.

4c. Which sex will be more likely to have horns. How might horns be an advantage for this sex?

4d. For this couple, is there an example of an X-linked trait?

4e. What is an example of an X-linked trait in humans?

5a. What is a polygenic trait?

5b. Describe an example of a polygenic trait in this simulation.

6a.What is multifactorial inheritance?

6b. Propose an environmental factor that might influence phenotypic traits as the baby dragon grows up, e.g. how long the neck and tail grow or how dark the freckles in the skin become.

6c. What is an example of a multifactorial trait in humans?

7. What is a codominant trait?

7a. An example of a codominant trait in humans is blood type. Alleles A and B are expressed equally. However, the O allele is recessive to both A and B. In contrast, the Rh factor allele is inherited classically. Rh- is recessive; whereas Rh + is dominant. If Sally has type AB Rh+ (Rh+, Rh-) blood and Harry has type BO Rh- (Rh- Rh-) blood what kinds of blood types might their children inherit?

8. The P generation is the parental generation. Give the genotype of the parental generation for your dragons.

9. The F1 generation is the first generation after the parental generation. Give the genotype for wings and toes of your F1 generation. Enter the genotype of your F1 generation into the excel sheet. Once all groups have entered their babies into the spread sheet the instructor will make a graph to show numbers of dragons with different genotypes. Using the graph, make a hypothesis about what the F2 generation (the generation after the F1 generation) might look like using only this population of dragons. Keep your hypothesis focused and specific.

10. Find a group at another table with a baby dragon of the opposite sex and write down its genotype for wings and toes. Cross your now-mature dragon with the other group's now-mature dragon (using only the two genotypes). Write the possible genotypes for this generation.

11. Once you have all of the possible genotypes written out enter your new baby dragons' genotypes into the spreadsheet (on the computer up front). If you see that other babies have the same genotype then increase the number next to the genotype accordingly.

12. Once all groups have entered their babies into the spreadsheet, the instructor will make a graph to show numbers of dragons with different genotypes. Write a summary of what the graph means.

13. Did you accept or reject your hypothesis? What are your conclusions?

14. What is a test cross?

Partner with another group. Group A will decide on a trait (heterozygous or homozygous dominant) from their baby dragon. Group B then sets up a Punnett square with the appropriate genotype for a test cross. Group A writes in the results of the cross **but not the genotype of their baby dragon**. Group B discusses and proposes a genotype of Group A's baby dragon. Group A then gives the genotype of their dragon. The two groups then switch roles and do the whole procedure again.

Addition rule –

Multiplication rule –

15. Using the two parents you started with, what is the probability of getting a baby dragon that has normal skin pigment?

16. You have two dragons that are so in love and they want to breed. Both of these dragons are four-toed. Therefore, you are worried that they may end up with a baby dragon with three-toes (an undesired trait in show dragons). You want to know what the probability is that their baby will have either four-toes or five-toes. What is the answer to this important question?

17. Using the two parents you started with, what is the probability of getting a baby dragon with wings, normal skin pigment, fire breathing and no freckles?

18. The two parents want to have another baby dragon. What are the chances of getting a dragon either just like the one above (17) or a dragon just like the baby you created?

Principle of Independent Assortment –

19a. Two dragons breed that have the genotypes WWLL and wwll breed. What will the F1 generation look like? What will their genotypes be?

19b. If one of the dragons in the F1 generation breeds with a dragon of the genotype WwLl what will the resulting baby dragons look like? What will be their genotypes? Write their phenotypes out in ratio form.

19c. How does this example illustrate (or not) the principle of independent assortment?

19d. Explain how the principle of independent assortment is simulated by dropping the green and brown autosome Popsicle sticks.

19e. Explain why the principle of independent assortment does not apply to genes that are close together on the same chromosome.

Additional questions for those who finish early: Find information on crossing over. How would you incorporate this process into this dragon genetics simulation? What would happen if during meiosis, one of the gametes accidentally got 2 copies of one chromosome (the sister chromatids didn't properly separate during meiosis II)?

Materials

For this activity very little equipment is required. For the experiment three items are necessary. For 24 students, 2 per group, 144 Popsicle sticks labeled appropriately so that each group of two can have a set of twelve sticks (e.g., Figure 1). Each participant will also need a copy of the packet. For students they should get three packets per group (assuming two students per group) so they can turn in one and keep the other two. Stencils for the dragons are also necessary to allow students to customize the neck and tail length of their dragons. Etsy.com is a great place to find sellers willing to make custom stencils inexpensively. Make sure you consider the dimensions of the stencils. In order to fit on the page as given in this laboratory exercise they cannot be larger than 3.25” wide by 2.6” tall.

Possible pictures of the dragons to be made into stencils are provided in Figure 2. For the presentation, a computer with MS Excel and PowerPoint, a projector and a chalk board or dry erase board will be necessary.

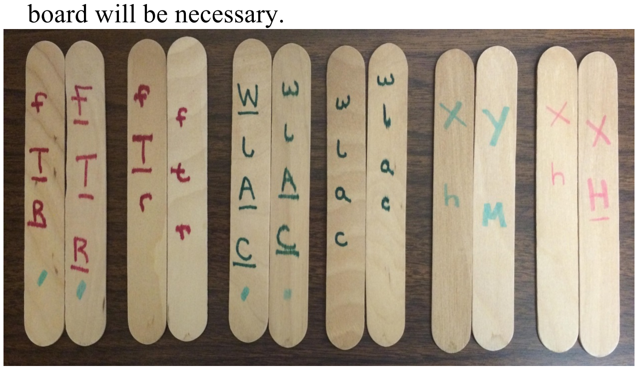

Figure 1. A set of sticks for one group. Note the underlining on capital letters and the blue dots designating the father’s chromosomes.

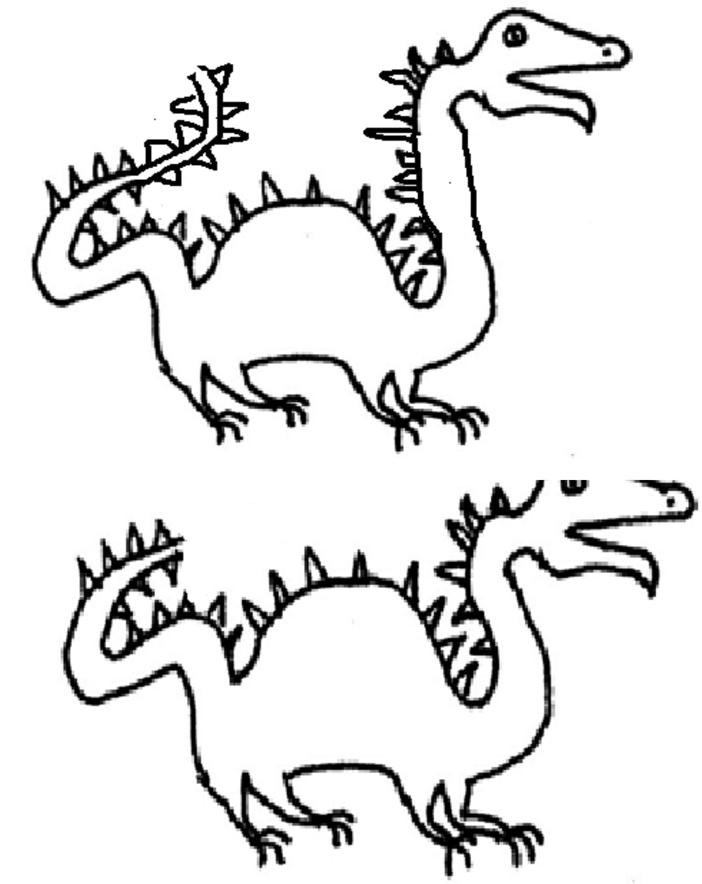

Figure 2. Possible images for making stencils of the two types of dragons.

Notes for the Instructor

Preparation for the simulation includes writing the alleles on the chromosomes. Each parent has two sticks for each chromosome representing a homologous pair of chromosomes. The green autosome should be written in green sharpie and the red autosome with a red sharpie. Mark the bottoms of the male’s autosomes with blue sharpie to indicate that it is his chromosome. The sex chromosomes should be written in blue and pink for the male and female respectively. Make sure your autosomes and sex chromosomes have a high amount of genetic variation. Be clear about capital letters and lower case letters by underlining capital letters. Each group of students will receive a packet of chromosomes including; four green autosomes (two from the mom and two from the dad), four red autosomes (two from mom and two from the dad) and four sex chromosomes.

Once all of the students have their sticks, explain the exercise to them. They will be picking sticks that represent homologous chromosomes by partnering with another group. For each color autosome and then for the sex chromosomes, each parent will show their sticks (face down) to a member of a different group. The volunteer from the different group will randomly pick the chromosome that is passed onto the baby via meiosis and fertilization. Use the chart on the first page to guide you through a simple explanation of the simulation. Talk briefly about the traits on page three and how they should approach the interpretation of each trait. Then explain how to fill in the chart on page 3 of their packet. The sex chromosomes are the most difficult to understand. The H allele goes in the top boxes for the egg and sperm. The M goes in the bottom box for sex chromosomes.

Filling in the chart properly is many times the most difficult part for the students. However, it helps them understand the process of meiosis and fertilization so be certain to include this in your explanations.

Part 1 is mostly done independently by the groups of students. Within the questions, the principle of segregation and numbers four through seven are meant to be done with instructor guidance. Part 2 is done independently through question number nine. The instructor will set up a simple spreadsheet for the students then create a bar graph to show the frequency of different genotypes in the dragon population. Further instructor guidance is needed to discuss the addition and multiplication rules and the principle of independent assortment.

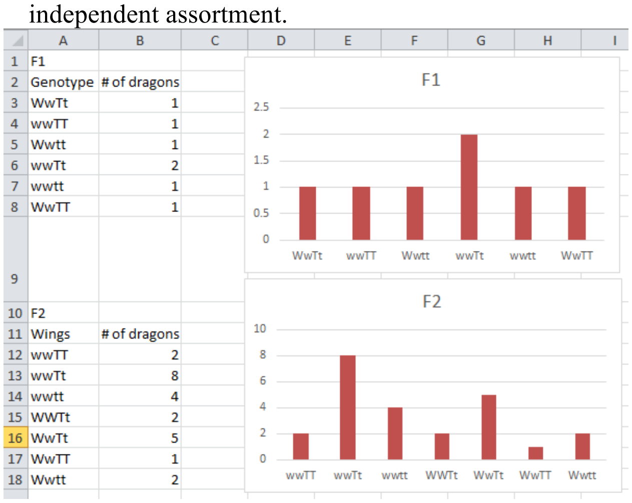

Figure 3. Excel spreadsheet set up for the data in questions nine and eleven.

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About the Authors

Rebecca Williams has been an Instructor at the University of Central Oklahoma since 2012, where she teaches introductory biology courses for majors and non-majors and upper level entomology, field biology and pollination biology.

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