

Rules

Teacher's Guide

1.0 Summary

The *Rules* activity contains three sections and should take students one class period of 45-50 minutes to complete. Some students may finish in less time.

2.0 Learning Goals

Driving Question: How do genes affect appearance?

The *Rules* activity introduces students to dominance relationships among alleles while helping them learn the rules of inheritance in dragons. The activity is divided into 3 parts, each of which can be accessed from the Table of Contents.

Part One: *Dominant and Recessive Relationships Among Alleles* focuses on which alleles are dominant and mask the presence of other alleles for a gene. The students identify all possible combinations of alleles that produce a particular trait in an organism.

Part Two: *Some Traits are X-Linked* focuses on genes that are part of the X chromosome. Students investigate the impact of different allele combinations for X-linked genes.

Part Three: *Color and Fatal Combinations* examines polygenicity and lethal alleles using the two Color genes of BioLogica's dragons. Students explore what happens when more than one gene contributes to a single characteristic and learn about allele combinations that are lethal.

Learning Goals

- Students will know that alleles are different forms of the same gene.
- Students will know that gene codes for specific traits are part of specific chromosomes.
- Students will manipulate the dragon's alleles to create changes in its phenotype.
- Students will observe changes in phenotypes when the genotype is changed.
- Students will understand that a genotype is an inherited combination of alleles.
- Students will identify a dragon's phenotype based on its genotype.
- Students will recognize that some traits are dominant and others are recessive.
- Students will understand that females have 2 X chromosomes.
- Students will understand that males have one X and one Y-chromosome.
- Students will recognize polygenic traits and their roles in coding for specific traits.
- Students will use relevant vocabulary to answer specific questions related to each section.

Additional Teacher Background

To understand the rules of dominant and recessive relationships among alleles, students must first understand that an allele is one of a number of different forms of a gene. The principle of dominance states that some alleles are dominant over other alleles while others are recessive. An organism with a recessive allele for a particular trait will only have the recessive trait when the dominant allele is not present.

Students should observe the third set of chromosomes for both the male and female dragons and understand that the sex chromosomes are different for gender. Males have one X and one Y-chromosome while females have two copies of the X chromosome.

In humans, the 23rd pair of chromosomes determines gender. Genes that are part of this pair of chromosomes are referred to as sex-linked genes. Over 100 known sex-linked genetic disorders have been linked to genes that are part of the X chromosome. This presents a problem for males because X-linked alleles are always expressed in males, since they have only one X chromosome. The human Y chromosome is much smaller than the human X chromosome and contains few genes.

Students should understand that the number of phenotypes produced for a single trait depends on how many genes control the trait. Two or more genes control polygenic traits and each gene has two or more alleles. One polygenic trait can have several possible genotypes and even more phenotypes. Most traits are polygenic traits and therefore provide great variations of a single trait. In the case of the dragons, color is a polygenic trait and certain combinations can be lethal.

3.0 Standards Alignment

Alignment to National Math and Science Standards (NCTM or NSES)

Objective	Standards
Students will explore the effects of changing alleles on phenotype.	Students should draw reasonable conclusions about a situation being modeled.
Students will learn different modes of inheritance.	Students should draw reasonable conclusions about a situation being modeled.
Students will formulate rules of inheritance.	Students should draw reasonable conclusions about a situation being modeled.

4.0 Activity Sections

The *Rules* activity has three activities. Each activity can be accessed from the table of contents by clicking the desired topic.

4.1 Table of Contents

Table of Contents

1. Dominant and Recessive Relationships among Alleles
How do alleles interact to determine a dragon's phenotype?
What are the rules for inheritance?

2. Some Traits are X-linked.
What about genes that are part of the X chromosome?

3. Color and Fatal Combinations
When can Color alleles kill a dragon?

4.1 Dominant and Recessive Relationships among Alleles

This section (10 screens) enables students to figure out the dominance relationships by changing alleles to produce specific traits. Students cannot go forward until they have identified all the combinations that produce a given trait.

Male Dragon

Chromosome: 1
h Horns

Chromosome: 2
w Wings
l Legs
t Tails

Chromosome: Y

Chromosome: 1
h Horns

Chromosome: 2
W Wings
L Legs
t Tails

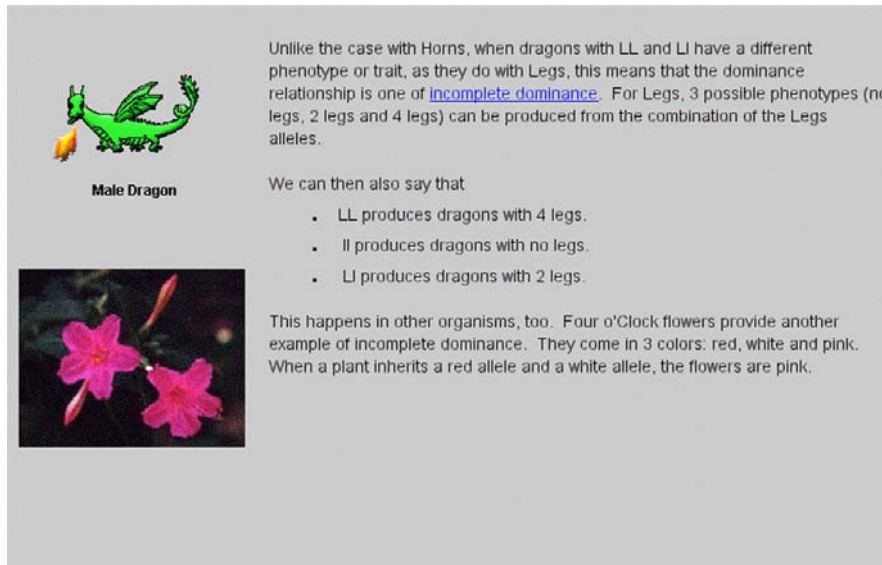
Chromosome: X
f Fire
A Color1
B Color2

hh
 Hh
 HH

Submit Answer

Change both Horns alleles that are part of Chromosome 1 until you figure out which allele combinations produce horns.
In the boxes on the left click ALL the combinations that produce horns.

As they work through all the dragon characteristics, they are encouraged to write down the rules in the notepad and are introduced to the vocabulary of dominance relationships. Please note that the contents of the notepad disappear when the session ends; students cannot save the contents.



Unlike the case with Horns, when dragons with LL and Ll have a different phenotype or trait, as they do with Legs, this means that the dominance relationship is one of incomplete dominance. For Legs, 3 possible phenotypes (no legs, 2 legs and 4 legs) can be produced from the combination of the Legs alleles.

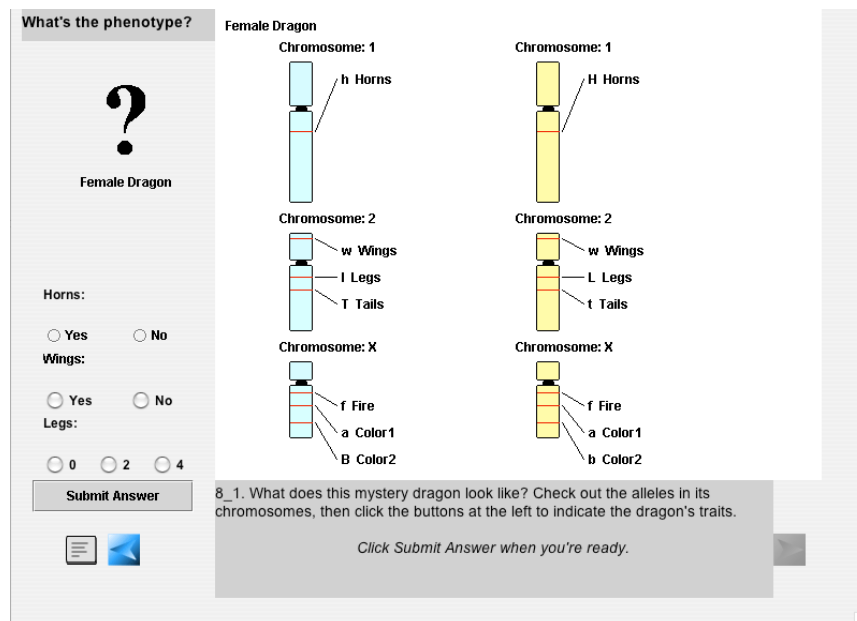
We can then also say that

- LL produces dragons with 4 legs.
- Ll produces dragons with 2 legs.
- ll produces dragons with no legs.

This happens in other organisms, too. Four o'clock flowers provide another example of incomplete dominance. They come in 3 colors: red, white and pink. When a plant inherits a red allele and a white allele, the flowers are pink.

Explanation screen of Incomplete Dominance.

After working out the dominance relationships among the autosomal characteristics, students are asked to predict the phenotype of a mystery dragon from the genotype given. Their answers are checked and must be correct before they can proceed.



What's the phenotype?

Female Dragon

Horns: Yes No

Wings: Yes No

Legs: 0 2 4

Submit Answer

Female Dragon

Chromosome: 1

h Horns

Chromosome: 2

w Wings

l Legs

t Tails

Chromosome: X

f Fire

a Color1

B Color2

Chromosome: 1

H Horns

Chromosome: 2

w Wings

L Legs

t Tails

Chromosome: X

f Fire

a Color1


b Color2

8_1. What does this mystery dragon look like? Check out the alleles in its chromosomes, then click the buttons at the left to indicate the dragon's traits.

Click Submit Answer when you're ready.

A second series of challenges asks students to hypothesize the possible genotypes of a visible dragon.

What's the genotype?



Male Dragon

Horns: hh Hh HH






Wings: ww Ww WW

Legs: ll Ll LL

Submit Answer

9_1. Look at the dragon above.

*Click ALL the allele combinations that COULD produce its traits.
When you think you've got them all, click Submit Answer.*

Note: The notepad button gives students access to the notes they have taken. The 'red dragon' button gives them a dragon to practice with if they've forgotten or didn't take notes.

After this experience, the terms heterozygous and homozygous are introduced and illustrated.

At the end of this section 11 questions elicit students' understanding of the content.

Questions 11-14 are essay questions about terminology.

Answers to other questions:

15. tt

16. Complete dominance

17. There are just 2 phenotypes

18. Fancy

19. It takes just one dominant T allele to give the dragon a fancy tail.

20. Hh

21. HH

22. ww.

4.3 Some Traits are X-Linked!

After reviewing sex chromosomes of male and female dragons and noting the differences, students review which genes are part of the X chromosome.

Students are introduced to autosomal vs. x-linked terminology.

As in the first part of *Rules*, students experiment to determine what the rules are for Fire and record them. Students are then given the same two types of puzzles as before: What is the phenotype? What is the genotype?

A quiz completes this section.

Characteristic	Ernest	Characteristic	Jill
1). Horns	<input type="checkbox"/> HH <input type="checkbox"/> Hh <input checked="" type="checkbox"/> hh <input type="checkbox"/> H- <input type="checkbox"/> h-	6). Horns	<input checked="" type="checkbox"/> HH <input checked="" type="checkbox"/> Hh <input type="checkbox"/> hh <input type="checkbox"/> H- <input type="checkbox"/> h-
2). Wings	<input type="checkbox"/> WWW <input type="checkbox"/> WWw <input checked="" type="checkbox"/> ww <input type="checkbox"/> W- <input type="checkbox"/> w-	7). Wings	<input type="checkbox"/> WWW <input type="checkbox"/> WWw <input checked="" type="checkbox"/> ww <input type="checkbox"/> W- <input type="checkbox"/> w-
3). Tail	<input checked="" type="checkbox"/> TT <input checked="" type="checkbox"/> Tt <input type="checkbox"/> tt <input type="checkbox"/> T- <input type="checkbox"/> t-	8). Tail	<input type="checkbox"/> TT <input type="checkbox"/> Tt <input checked="" type="checkbox"/> tt <input type="checkbox"/> T- <input type="checkbox"/> t-
4). Legs	<input checked="" type="checkbox"/> LL <input type="checkbox"/> Ll <input type="checkbox"/> ll <input type="checkbox"/> L- <input type="checkbox"/> l-	9). Legs	<input type="checkbox"/> LL <input checked="" type="checkbox"/> Ll <input type="checkbox"/> ll <input type="checkbox"/> L- <input type="checkbox"/> l-
5). Fire	<input type="checkbox"/> FF <input type="checkbox"/> Ff <input type="checkbox"/> ff <input checked="" type="checkbox"/> F- <input type="checkbox"/> f-	10). Fire	<input type="checkbox"/> FF <input type="checkbox"/> Ff <input checked="" type="checkbox"/> ff <input type="checkbox"/> F- <input type="checkbox"/> f-

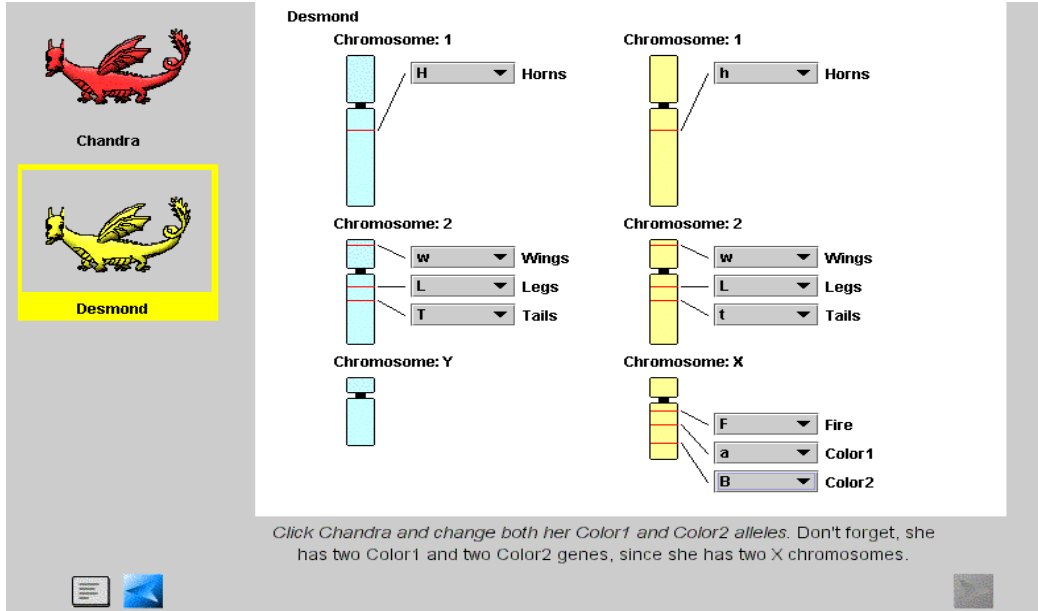
Answers to questions:

11. X and Y
12. because their genes are part of the X chromosome.
13. the genes for autosomal traits are part of chromosomes other than the sex chromosomes.
14. fire-breathing is a recessive trait because heterozygotes are not fire-breathing.
15. x-linked characteristics are fire and color.
16. Autosomal characteristics are horns, wings, legs, tail.
17. Homozygous

4.4 Color and Fatal Combinations

Because Color is a polygenic trait, it's very difficult for students (and adults) to grasp how the alleles combine to produce the different colors of dragons. Because females have two X chromosomes they have more colors. Since the male dragons have just one X chromosome, they have just 2 colors. The lethal b allele limits the number of possible male colors.

This part of *Rules* follows the same patterns as the previous two: Students experiment with the allele combinations for colors, figure out the specific combinations that produce specific colors, and take notes in the provided notepad.



Desmond

Chromosome: 1

Chromosome: 1

Chromosome: 2

Chromosome: 2

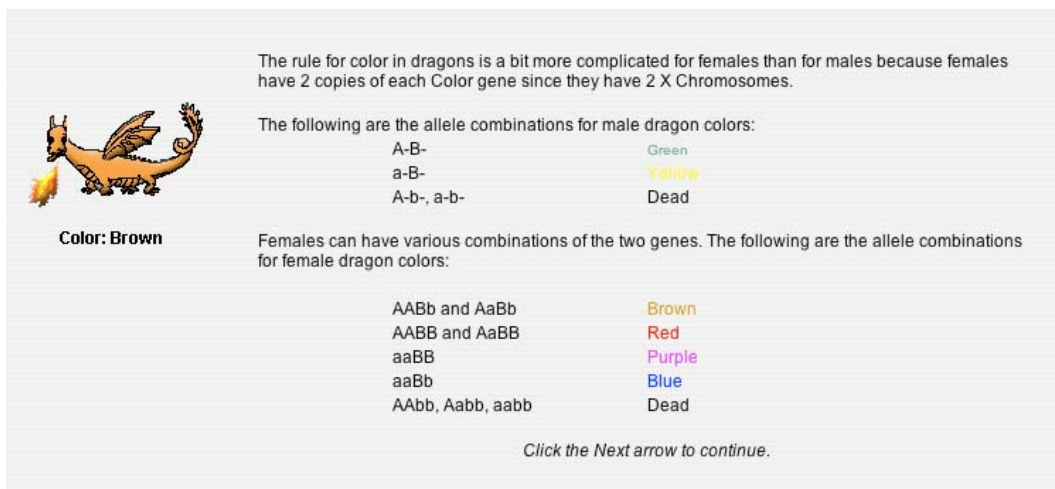
Chromosome: Y

Chromosome: X

Click Chandra and change both her Color1 and Color2 alleles. Don't forget, she has two Color1 and two Color2 genes, since she has two X chromosomes.

Note: Because the notepad doesn't yet persist between one session and the next, we recommend that after your students have completed *Rules*, you print out and distribute the dragon genome chart included in this guide.

Students need their notepads for solving the two types of puzzles: What color is this dragon? What is the genotype?



The rule for color in dragons is a bit more complicated for females than for males because females have 2 copies of each Color gene since they have 2 X Chromosomes.

The following are the allele combinations for male dragon colors:

A-B-	Green
a-B-	Yellow
A-b-, a-b-	Dead

Females can have various combinations of the two genes. The following are the allele combinations for female dragon colors:

AABb and AaBb	Brown
AABB and AaBB	Red
aaBB	Purple
aaBb	Blue
AAbb, Aabb, aabb	Dead


Click the Next arrow to continue.

This screen shows the color allele combinations for male and female dragons.

A quiz (5 Questions) completes this part of the *Rules* activity.

55. female, alive, brown
56. male, dead
57. male, alive, green
58. Color is inherited differently from horns in that it depends on 2 genes that are on the X chromosome.
59. The B allele for Color 2 is dominant and non lethal; the b allele is a lethal recessive.

The *Rules* activity concludes with a summary and the dragon genome chart icon.



Color: Blue

As you saw, Color is quite complicated in dragons, as it is in most animals. That's because Color is a polygenic characteristic, which means it is controlled by more than one gene. In dragons there is a Color1 and a Color2 gene.

Finally, one of the Color alleles can actually kill dragons -- it is called a recessive lethal. This can also be found among real animals - most white horses, for example, carry one copy of an allele that would kill them if they had two copies.

We don't expect you to memorize the allele combinations for each phenotype, so from now on, we'll provide a button that will pop up a dragon genome chart.

Check it out by clicking the Chart icon.

Done

Dragon Genome Chart

Having horns is dominant to no horns.
 HH or Hh = horns hh = no horns

Having wings is recessive to no wings.
 ww = wings WW or Ww = no wings

Legs are incompletely dominant.
 ll = no legs Ll = 2 legs LL = 4 legs

Fancy Tails are dominant to plain tails.
 TT or Tt = fancy tail tt = plain tail

Fire-breathing is recessive to non-fire-breathing and is an X-linked characteristic.

Males: F- = non-fire-breathing males
 f- = fire-breathing males

Females: FF, Ff = non- fire-breathing females
 ff = fire-breathing females

Color is a polygenic, X-linked characteristic.

Males: Green A-B-
 Yellow a-B-

Females: Red AABB or AaBB
 Blue aaBb
 Brown AABb or AaBb
 Purple aaBB

5.0 Student Reports

Your students' work with Rules is logged and viewable on the MAC Project Web Portal at <http://mac.concord.org>. For each student, you can view a report containing questions and answers.

The next activity that students should use is *Meiosis*, which focuses on meiosis and fertilization.