Genetics - X-linkage

Teacher's Guide

1.0 Summary

The *X-Linkage Activity* is the sixth core Genetics activity. This activity is comprised of three sections and designed to last one class period of approximately 45-50 minutes.

2.0 Learning Goals

Driving Question: What difference does it make if a gene is part of the X Chromosome?

In *X-linkage* students investigate differences between autosomal and X-linked inheritance patterns using pedigree analysis.

Part One: **Introduction to Genes that are part of the X Chromosome** reviews how a gene is inherited when it is part of the X-chromosome.

Part Two: **X-Linked Traits** links the fire-breathing gene to the inheritance of the sex chromosomes through the generations.

Part Three: **Determining if a Characteristic is X-linked** focuses on pedigree analysis as a tool for discriminating between autosomal and X-linkage inheritance.

Learning Goals

- Students will understand what an autosomal trait is and on which chromosomes they are located.
- Students will understand what a sex-linked trait is and on which chromosome they are located.
- Students will know that egg cells contain only x chromosomes.
- Students will know that sperm cells contain either one X or one Y chromosome.
- Students will understand that Y-chromosomes are much smaller than X chromosomes and carry few genes.
- Students will use pedigree charts to identify traits.
- Students will identify traits as either being sex-linked or autosomal.
- Students will identify traits as being either dominant or recessive.
- Students will interpret these charts to determine that a trait is X-linked.
- Students will know that all X-linked alleles are expressed in males, even if they are recessive.

Additional Teacher Background

Sexually reproducing organisms have a pair of chromosomes known as sex chromosomes, which are called this primarily because they determine gender. In humans, the 23rd pair of chromosomes is composed of sex chromosomes.

Males have one X chromosome and one Y chromosome. Females have two X chromosomes and no Y chromosome. Because males have just one X chromosome, all X-linked alleles are expressed in males, even recessive alleles.

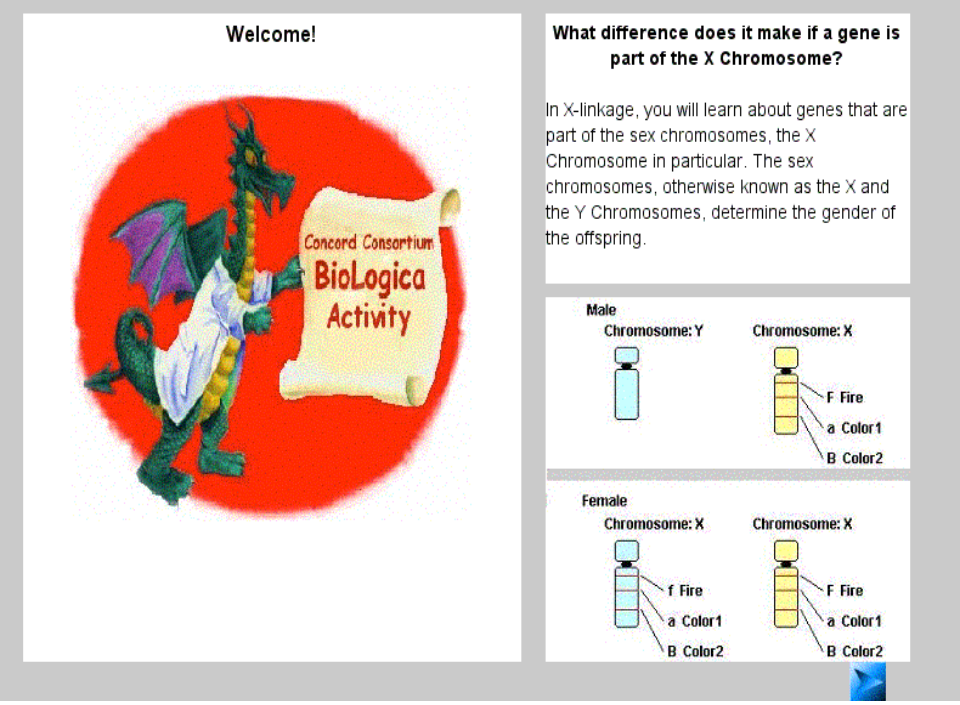
In determining human gender, all eggs carry a single X chromosome, while half of the sperm carry an X and the other half carry a Y. This means that the odds are approximately 50/50 of having either a boy or a girl when a sperm and an egg produce that offspring. That is of course without genetic intervention. It also means that a boy will inherit any genes that are part of that X chromosome. Over 100 genetic diseases have been discovered thus far on the X chromosome. Males are far more likely than females to evidence sex-linked traits; they only need one affected X chromosome. On the other hand, females can carry these genetic traits but rarely are afflicted; they need two copies of the diseased X chromosome in order to exhibit the trait.

3.0 Standards Alignment

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

Objective	Standards
Students will be able to distinguish between autosomal and sex-linked inheritance.	Students will know that hereditary information is contained in genes, which are located in the chromosomes.
Students will understand how x-linked genes are inherited.	Students will know that heredity is the passage of instructions from one generation to another generation.
Students will be able to determine through pedigree analysis whether a trait is X-linked or autosomal.	The students will use representations to model and interpret physical, social, and mathematical phenomena.

4.0 Activity Sections



Opening Screen

4.1 Table of Contents

This activity has 3 sections: *Introduction to Genes that are part of the X Chromosome*, *X-Linked Traits* and *Determining if a Characteristic is X-linked*.

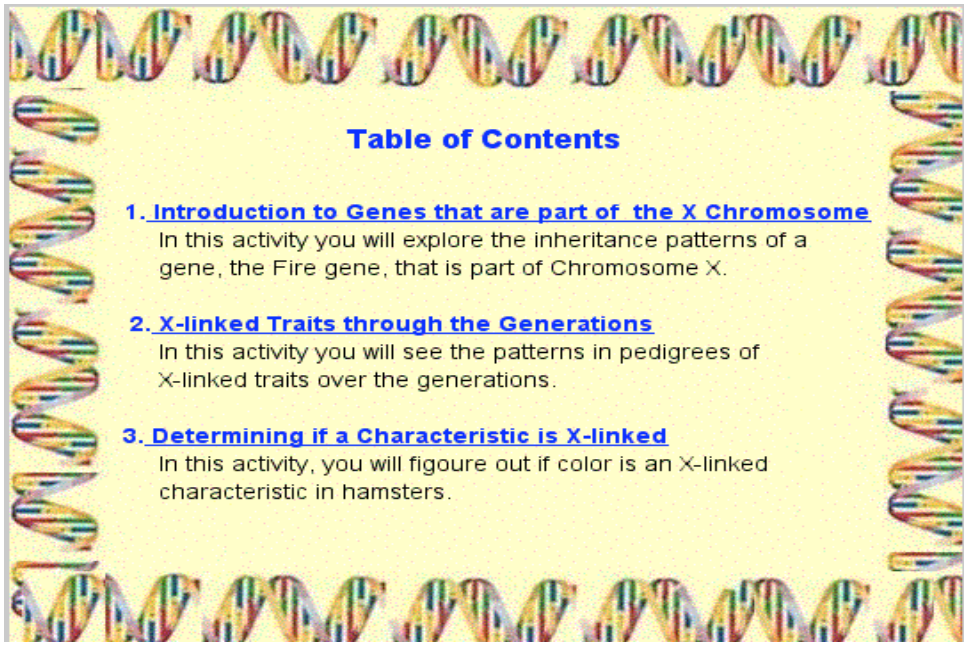


Table of Contents

4.2 1) Introduction to Genes that are part of the X Chromosome

Step 1: Remember that the fire-breathing characteristic is part of the X chromosome. State the rule and determine which allele is responsible for fire breathing for a male. (The answer is f.)

Step 2: Experiment with the female chromosomes and determine which allele(s) are responsible for fire breathing for a female. (The answer is ff.)

Step 3: Answer the questions as you proceed through the screens. For questions 6 and 7, the answers are that the daughters of these offspring will not be fire breathers and that the sons will all be fire breathers.

Step 4: Review questions and summary.

Note: Refer to the Genome chart if you get stuck; it's icon is a sheet of note paper which is located in the lower left of the screen.

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

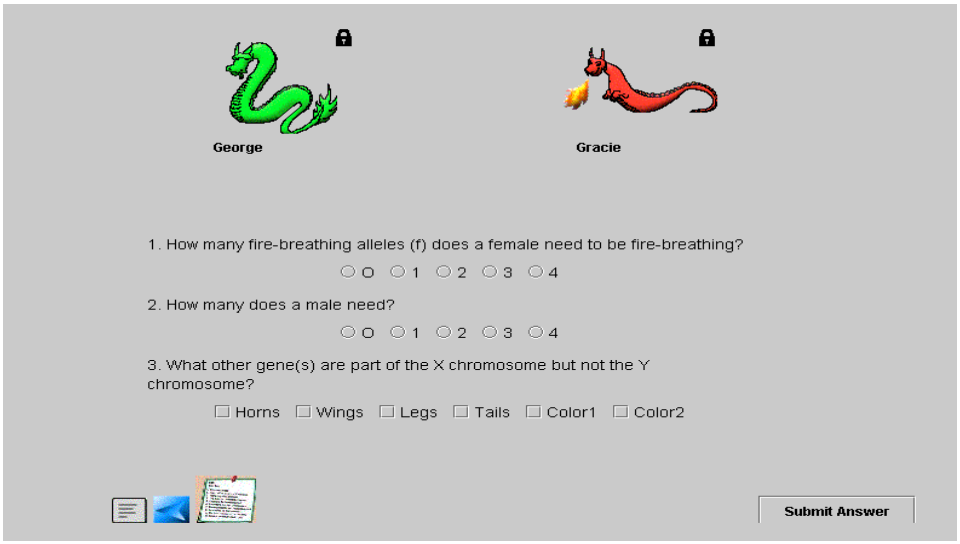
Fire-breathing is recessive to non-fire-breathing and is an X-linked characteristic.

Males:	F- = non-fire-breathing males f- = fire-breathing males
Females:	FF, Ff = non- fire-breathing females ff = fire-breathing females

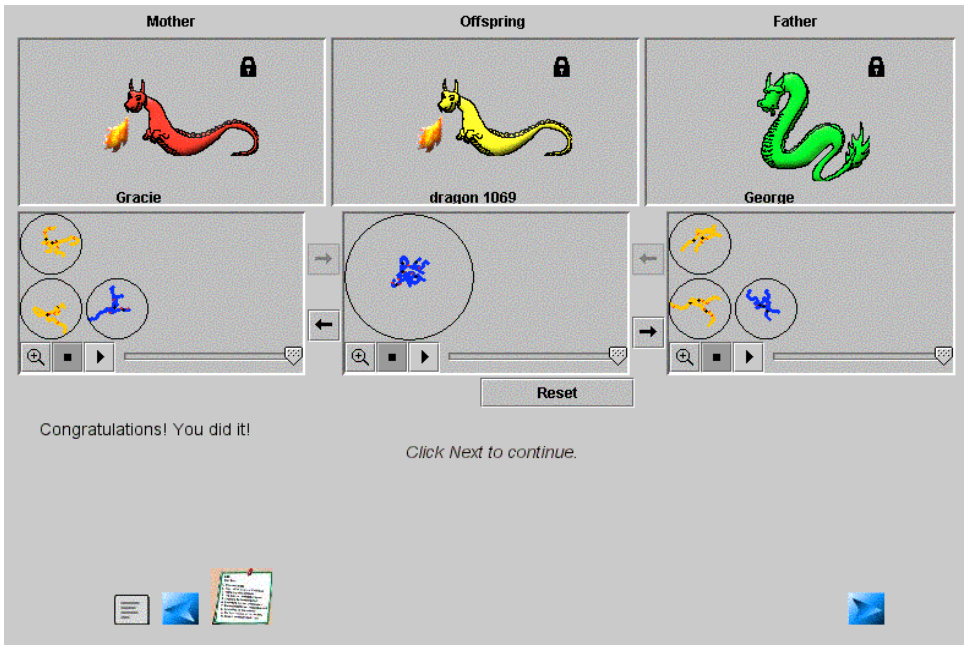
Color is a polygenic, X-linked characteristic.

Males:	Green	A-B-
	Yellow	a-B-
Females:	Red	AABB or AaBB
	Blue	aaBb
	Brown	AABb or AaBb
	Purple	aaBB

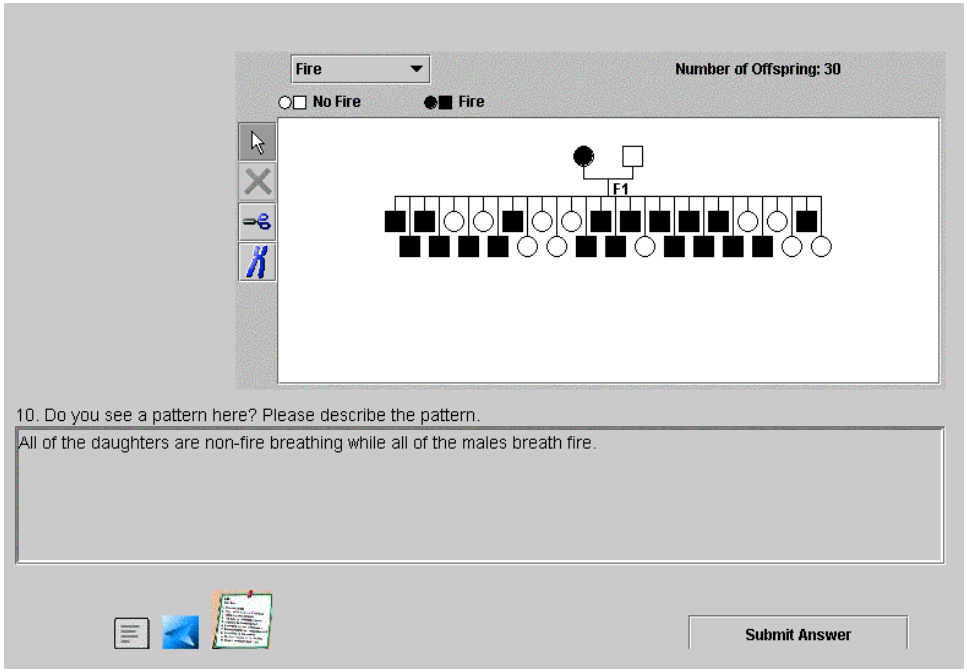
The Dragon Genome Chart is available at the click of a button.



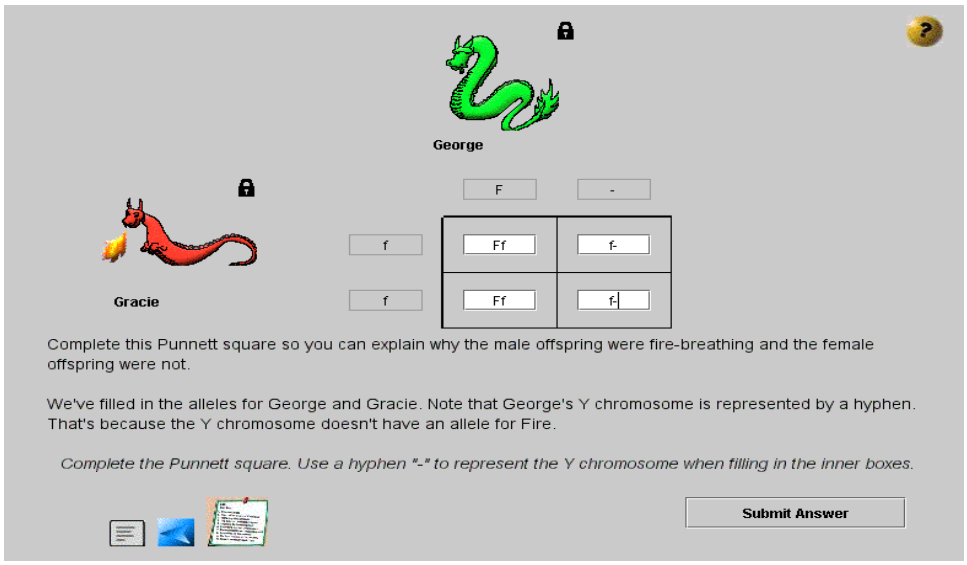
Answer questions about the rule for Fire.



Create a fire breathing male dragon by using the meiosis model. Students must select gametes with f and - using the magnifying glass.



Students breed George and Gracie to get an X-linked pedigree.

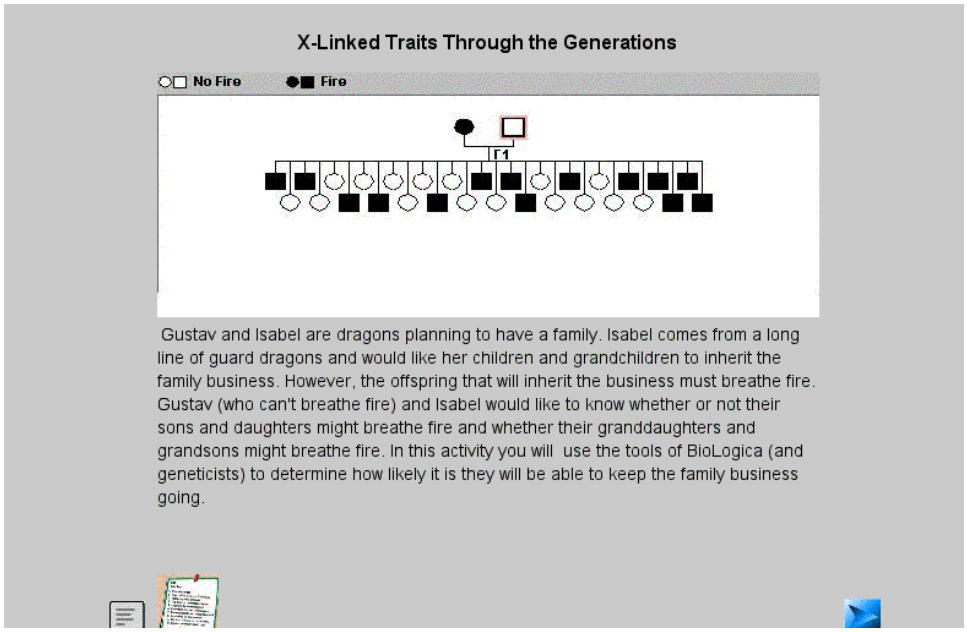


Students complete a Punnett square that explains the pedigree results.

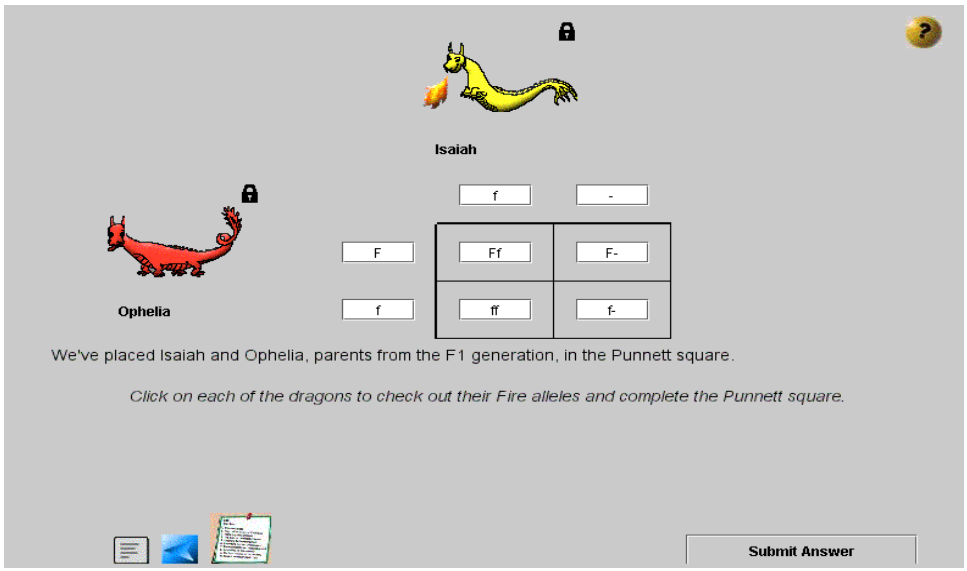
Students then answer a series of questions about what they've done.

4.3 2) X- Linked Traits Through the Generations

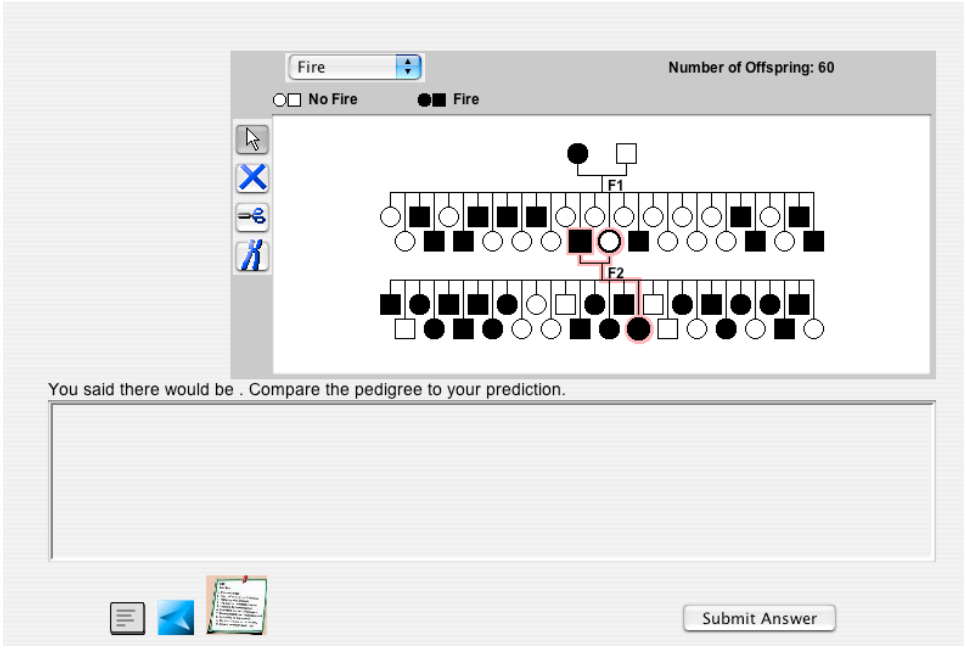
In this section, students determine whether the offspring of a pair of dragons will be able to keep the family business (which requires some fire-breathers) going over several generations. They predict the traits of subsequent generations using rules for Fire, Pedigree Charts and Punnett Squares**.**



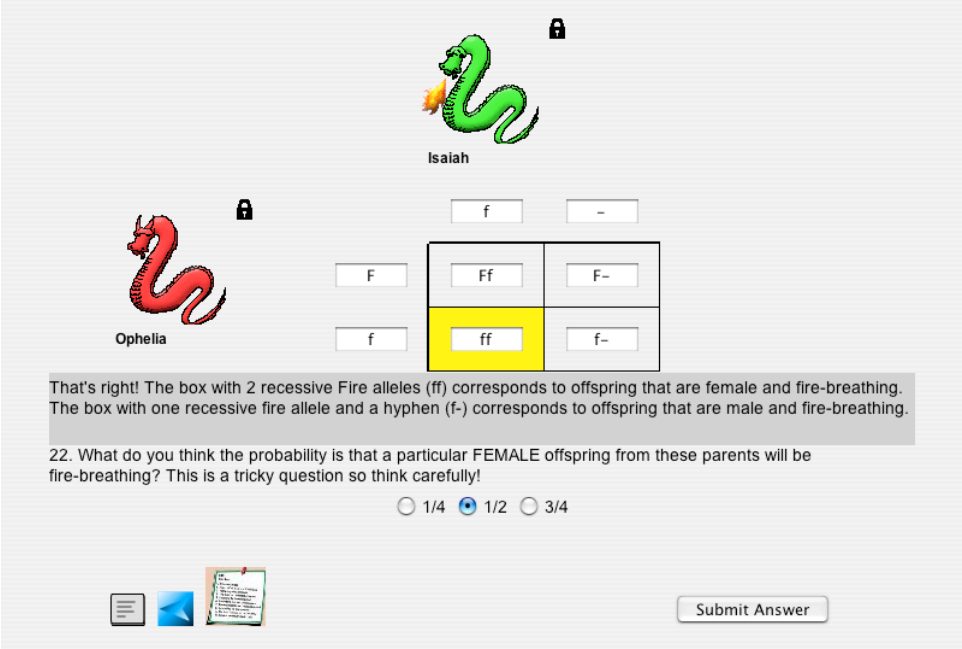
Students predict what the F1 generation will look like before crossing Isabelle and Gustav, shown above.



They then complete a Punnett square to predict the F2 generation.



Then they produce the F2 generation, compare it with their predictions, and explain the results.

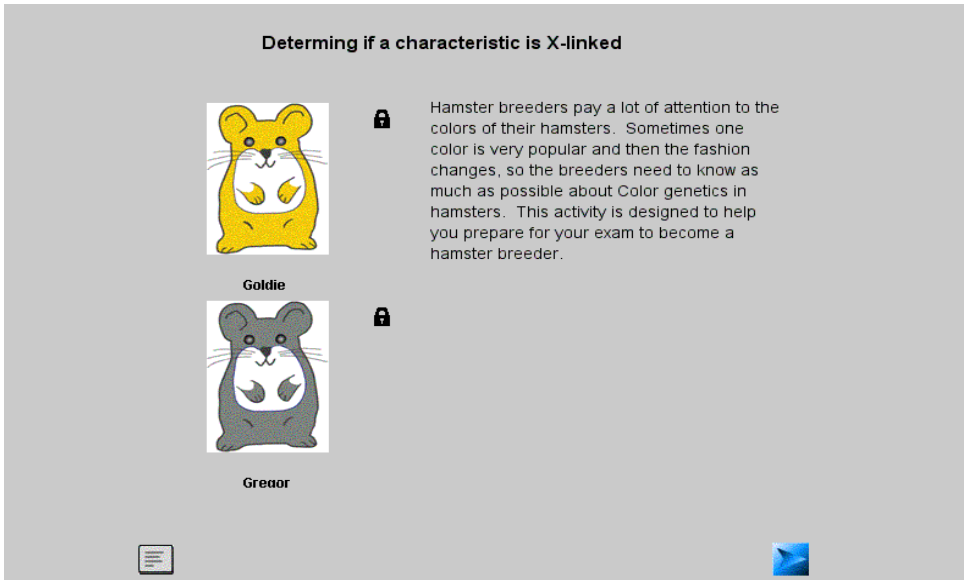


Students work through a series of questions that link Punnett squares and probability and also ask for predictions and explanations.

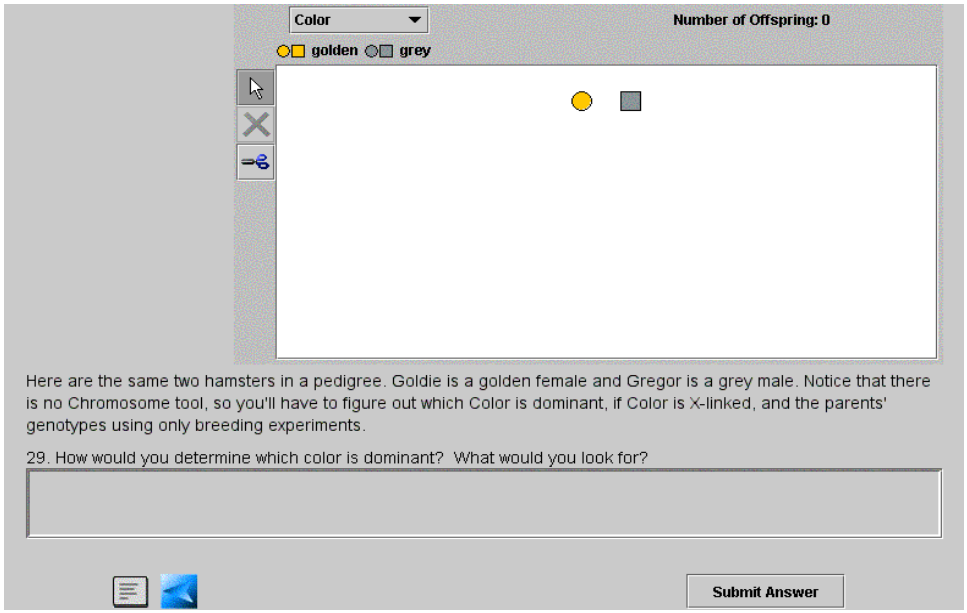
4.4 3) Determining if a characteristic is X-Linked

In this section, students investigate the inheritance of color among hamsters while the reasoning of a geneticist is modeled for them.

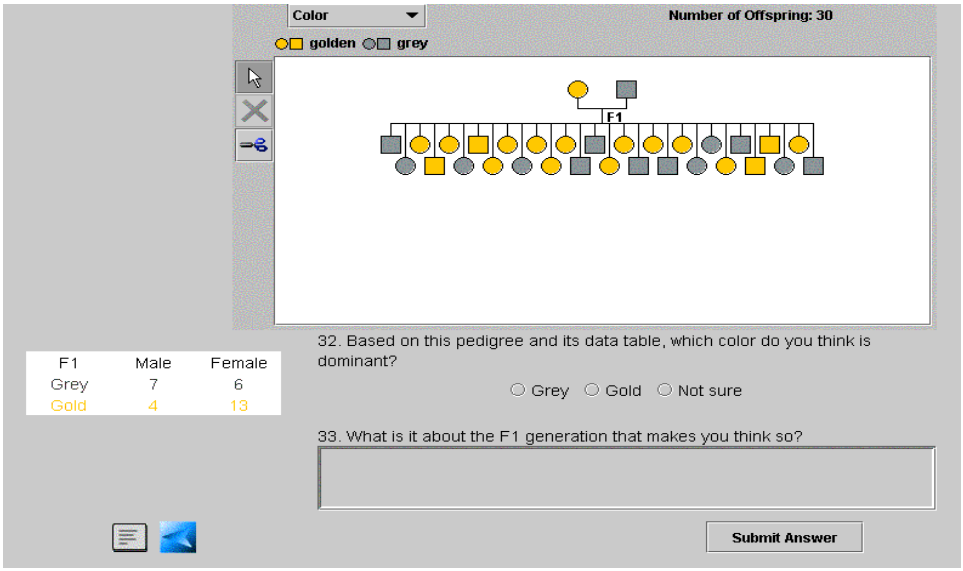
Step 1: Answer a series of higher order questions based on knowledge gained in the preceding 2 sections.
Step 2: Cross (remembering to use the X tool) parents to produce offspring.
Step 3: Create Pedigree charts to determine if traits are dominant or recessive and autosomal or X-linked.
Step 4: Create Punnett Squares to discover the same type of information sought in Step 3.
Step 5: Practice Questions
Step 6: Review and Summary



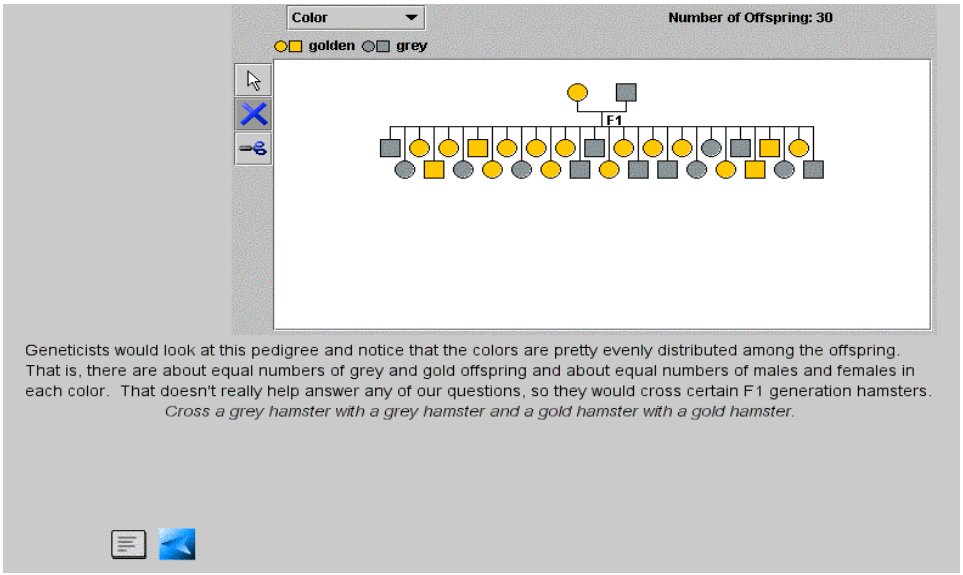
Students act as hamster breeders.



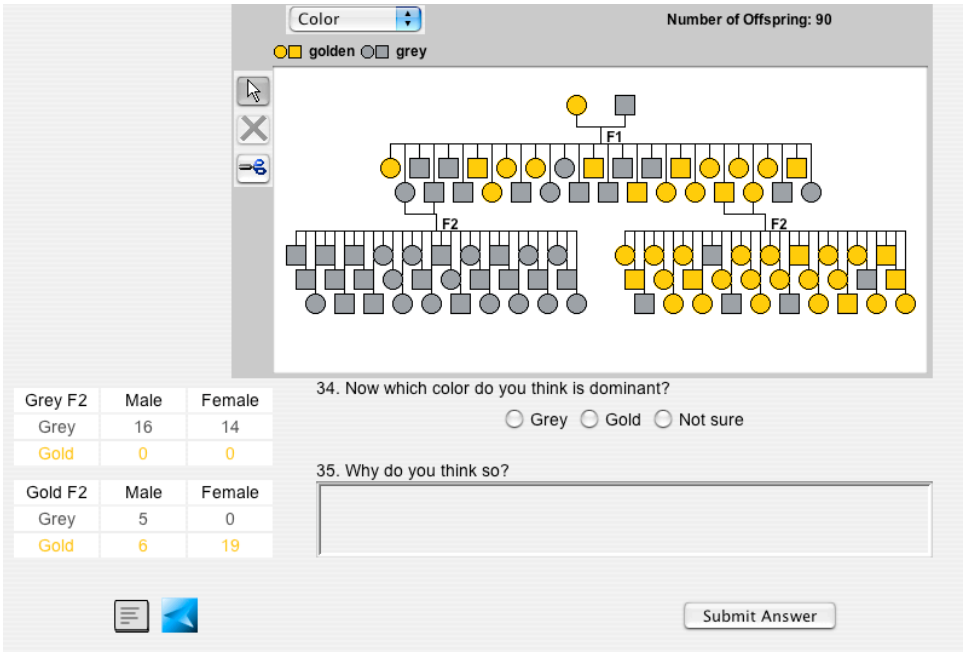
Students are asked to describe how they will determine which color is dominant and whether color is sex-linked in hamsters.



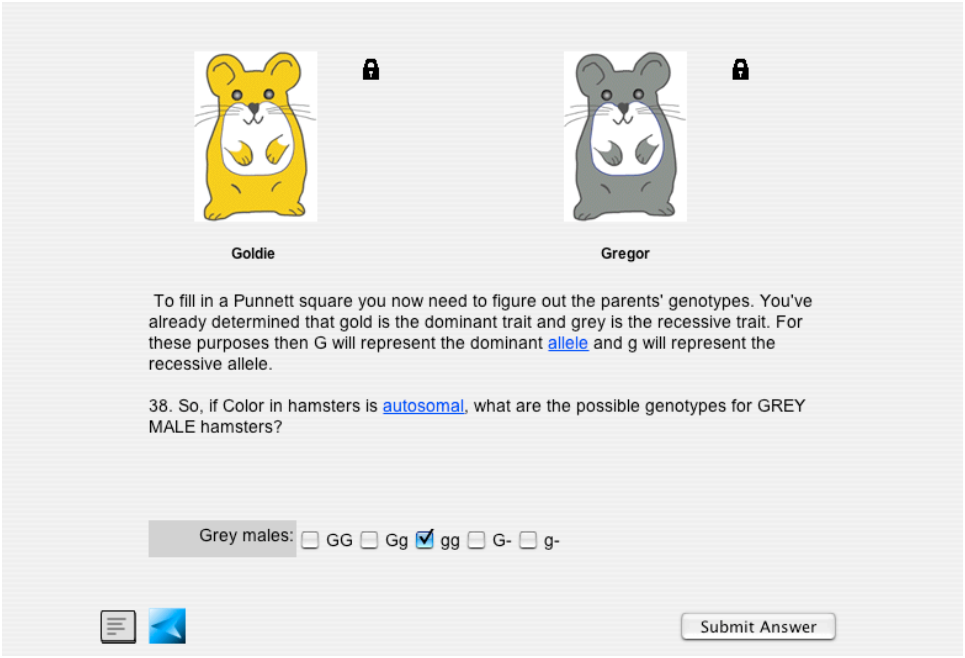
Students are given a data table at left as well as the pedigree and asked to interpret the data and justify their answer.



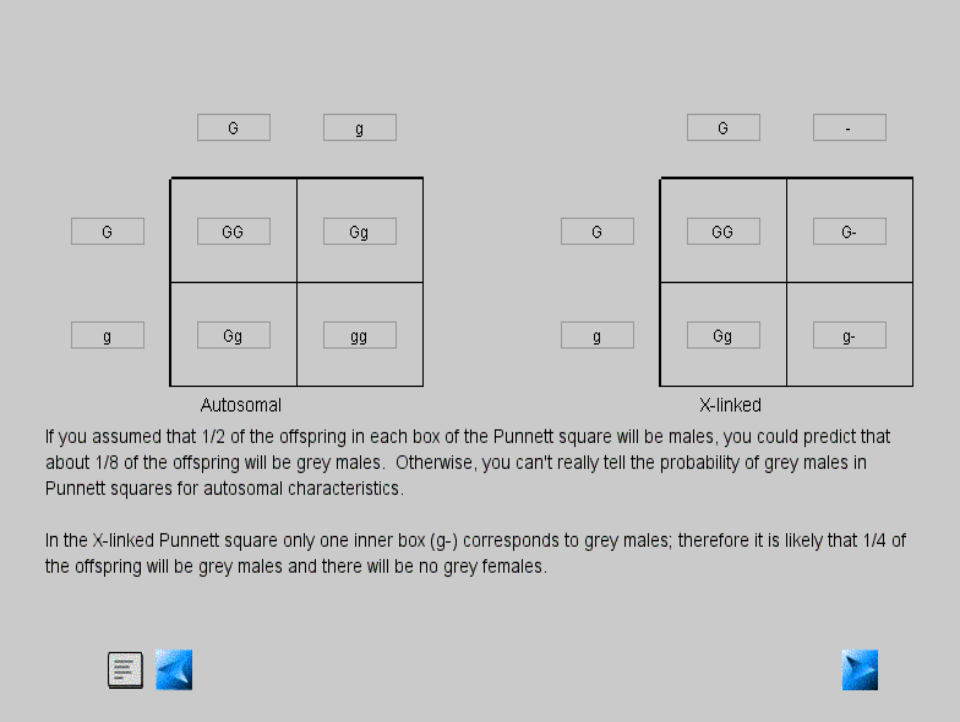
The text explains how a geneticist would think about the data and the problem.



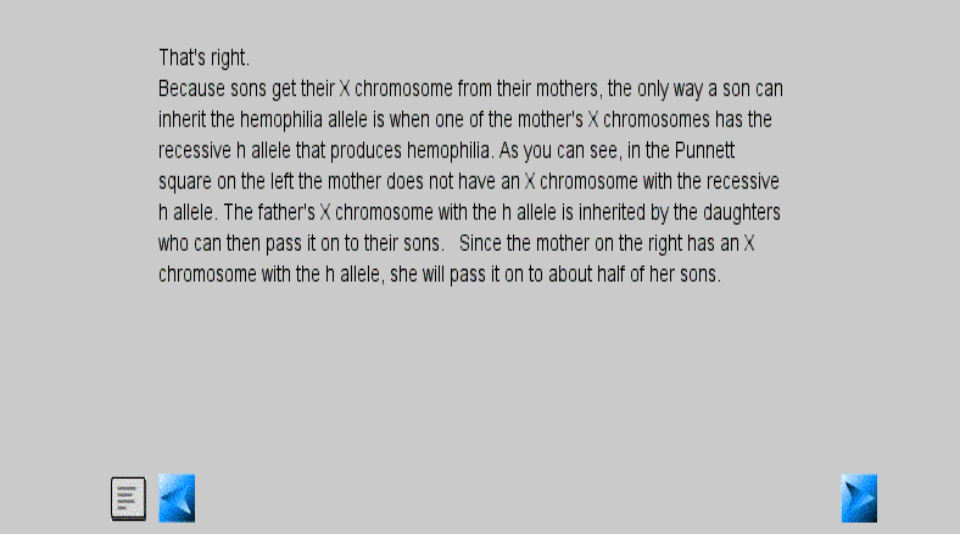
The crosses that produced the F2 generation provide definitive data about dominance. If you cross two parents with the same trait and get some offspring with a different trait, then the parents have the dominant trait and the other trait is recessive.



A series of questions leads students through the reasoning needed to check their answers. It culminates in a comparison between a Punnett Square completed for an autosomal characteristic and a Punnett Square completed for an x-linked characteristic.

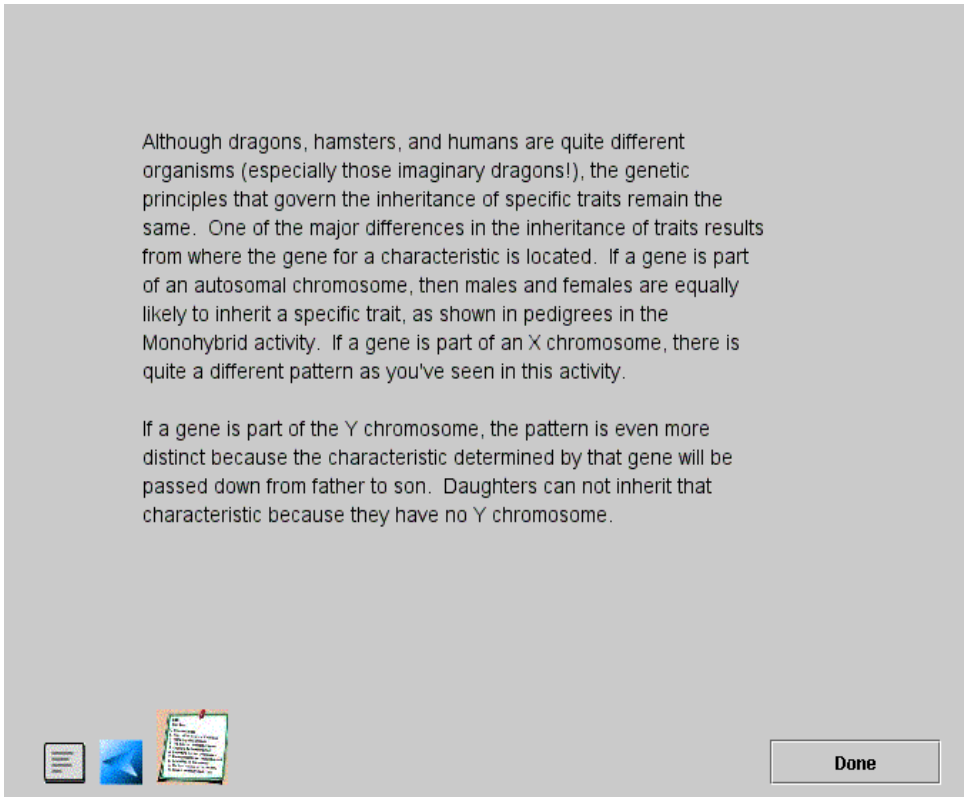


Autosomal and X-Linked Punnett Squares



Explanation of X-linked traits

A series of assessment questions, including questions about human color vision and hemophilia, concludes the section.



When students complete the assessment an explanation of Y linked traits is provided.

5.0 Student Reports

Your students' work with X-Linkage 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 *Mutations*, which focuses on the inheritance patterns for two traits at a time and the differences that occur when the genes for those traits are parts of the same chromosome or parts of different chromosomes.

Mutations II, an optional activity, can also be used after *X-Linkage*. *Mutations II* examines the inheritance patterns of new alleles created by mutations of chromosomes in the germ cells of organisms.