

Genetics – Scales

Teacher's Guide

1.0 Summary

The *Scales* activity follows the *Dihybrid Cross* core activity and is designed to last approximately 45-50 minutes.

2.0 Learning Goals

Driving Question: How do you investigate the inheritance of a new trait?

Scales is a puzzle designed to teach students to reason like geneticists. Students conduct breeding experiments and perform pedigree analyses to determine the mode of inheritance for a new trait.

Learning Goals

- Students will know that factors that determine biological inheritance pass from one generation to the next.
- Students will demonstrate their understanding of the basic principles of independent assortment in solving the puzzles.
- Students will know that the basic principles of Mendelian genetics can be used to calculate the probability of a trait being inherited.
- Students will demonstrate their understanding of the principle of probability by predicting the outcome of several genetic crosses throughout the *Scales* puzzle.
- Students will know that the alleles of different genes segregate independently of one another.
- Students will know that chromosomes assort independently, not individual genes.

Additional Teacher Background

This activity requires students to use the models and reasoning that they have learned in the previous activities such as *Monohybrid*, *Dihybrid Crosses* and *X-Linkage*. These puzzles are more advanced and require abstract reasoning. A student must be able to analyze specific data and form conclusions based on prior knowledge and the given factors of each problem within the puzzle.

The logic goes something like this:

If a cross with Ji-Yan, the scaly dragon, and a dragon without scales produces more than one scaly offspring, then scales must be a genetic trait.

If crossing two dragons without scales produces a dragon with scales, then having scales must be recessive, otherwise having scales is dominant.

Having scales is autosomal if:

- crossing parents without scales produces a daughter with scales or
- crossing a scaly female with a male without scales produces a son without scales.

3.0 Standards Alignment

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

Objective	Standards
Students will learn strategies for investigating a new trait.	Students should demonstrate appropriate procedures, a knowledge base, and a conceptual understanding of scientific investigations.
Students will reason with probabilities to determine inheritance patterns.	Students should learn how to analyze evidence and data.
Student will be able to determine the modes of inheritance for a new trait.	The students will focus on questions that can be answered by using observational data, the knowledge base of science, and processes of reasoning.

4.0 Activity Sections

In the *Scales* activity, students look for evidence that a previously unrecognized trait is genetic in origin. Then they must determine through breeding experiments whether the trait is dominant, recessive, or incompletely dominant; whether it is autosomal or sex-linked; and finally the chromosome of which it is part.

- Step 1: Meet Chi-Yan, a dragon covered in scales.
- Step 2: Cross Chi-Yan with two female dragons, (no scales).
- Step 3: Analyze the pedigree chart and answer the questions.
- Step 4: Make additional crosses as needed to determine if Scales is dominant or recessive.
- Step 5: Follow the same procedure to determine whether the trait is autosomal or sex-linked.
- Step 6. Cross Chi-Yan and a new female dragon in order to determine which chromosome contains the Scales gene.
- Step 7: Complete the Punnett Squares to determine all possible traits of the offspring
- Step 7: Take the Quiz

4.1 The Puzzle Begins

Students are asked how they will determine if having scales is a genetic trait, which it is.

The screenshot shows the 'Scales' activity interface. On the left, there is an illustration of a yellow dragon named 'Chi-Yan'. The main interface area has a 'Scales' dropdown menu at the top. Below it are two radio buttons: 'No Scales' (unselected) and 'Scales' (selected). To the right of these buttons is a 'Number of Offspring: 0' indicator and a question mark icon. The central part of the interface is a large empty box with a small black square in the upper right corner. Below this box is a text input field containing the question: '1. Your goal is to determine if having scales is a genetic condition. Describe what you could do with Chi-Yan's cooperation to figure out if scales is a rash or a novel genetic trait.' At the bottom right of the interface is a 'Submit Answer' button.

Is it genetic?

Scales Number of Offspring: 40

No Scales Scales

Here's Chi-Yan, Xiaofeng and Qing. *Cross each female with Chi-Yan.*

2. Which of the following best describes how useful each cross is to determining if having scales is a genetic trait?

The cross with Xiaofeng is more useful.

The cross with Qing is more useful.

Both crosses are equally useful.

Neither cross is particularly useful.

Submit Answer

Cross the females with Chi-Yan and look at the offspring. Students are asked about their reasoning. Note: You can find the names of the females by using the Arrow tool to click on the circle in the pedigree.

4.2 Determine a Pattern

Students work to establish a pattern of inheritance for the trait of scales.

You're right!

It's true that neither Xiaofeng or her offspring have scales and that Chi-Yan but none of his offspring have scales. But the reason that Jiang said there was no information in the results of this cross is that since none of the offspring have scales there is no pattern to interpret as genetic or not.

But the cross between Chi-Yan and Qing did produce offspring with scales-in fact about 1/2 the offspring have scales. Jiang recognized this pattern as possibly fitting a familiar single-gene inheritance pattern that you have seen as well. The general pattern looks like:

Parent with Phenotype1 X Parent with Phenotype2

↓

1/2 offspring with phenotype1 and 1/2 offspring with phenotype2

Single gene inheritance pattern

You and Jiang now have a hypothesis that Scales is a single-gene characteristic based on your understanding of single-gene inheritance patterns. Since this is the simplest hypothesis that fits the data, you decide to assume that it's "true" and that there is a single Scales gene. If the single-gene hypothesis isn't true, the results of additional crosses you make will not turn out the way the hypothesis predicts.

Given the single-gene hypothesis, the next step is to figure out how the proposed Scales gene is inherited. In other words, you need to figure out

- if having scales is dominant, recessive or incompletely dominant to not having scales and
- if the Scales gene is part of an autosome (autosomal), the X chromosome (X-linked) or the Y chromosome (Y-linked)?

Single Gene Model Directions

As students work their way through the breeding experiments needed to answer these questions, they are asked questions about what they know and why.

Chi-Yan X Qing

scaled inscaled

Cross 1	12	8
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Scales Number of Offspring: 20

No Scales Scales

Here's the pedigree for the cross between Chi-Yan and Qing in which about 1/2 of the offspring have scales.

6. Without doing any more crosses, can you tell **for certain** if having scales is dominant, recessive or incompletely dominant to not having scales?

YES

NO

7. Explain your answer

Qing

Scales

Number of Offspring: 40

No Scales Scales

9. What specific part(s) of the pedigree make you think that having scales is recessive to not having scales? Answer by clicking each offspring that supports this conclusion and explain your answer below.

dragon 8098

Scales

Number of Offspring: 100

No Scales Scales

You're right! The Scales gene is part of an autosome. Given that having scales is recessive AND that female dragons are XX and male dragons are XY, this is indicated by either

- a female offspring with scales who has parents without scales OR
- a male offspring without scales who has a mother with scales and a father without scales.

Scales are a recessive, autosomal trait.

4.3 Where is the gene for scales located?

Students must compare the patterns of offspring with scales to those of the other characteristics. If the Scales pattern matches another characteristic, then the gene for Scales is most likely on the same chromosome.

Here's your pet dragon Chi-Yan and a new female dragon named Yu-Jing that your neighbor Jiang has recently acquired specifically to help with this task. Assuming that crossing over is not taking place during meiosis, use the offspring of a single cross between Chi-Yan and Yu-Jing to decide if the Scales gene is part of Chromosome 1 or Chromosome 2.

When you think you know the answer, click Next.

Use the pull down menu to view the pedigrees of different traits. Using the Arrow tool to select offspring with specific traits helps to make sense of the patterns.

Jiang explains that she noticed two things:

- there are four categories of Scales/Wings offspring occurring in approximately equal frequency
 - scales/wings
 - scales/no wings
 - no scales/wings
 - no scales/no wings
- there are only two categories of Scales/Horns offspring occurring in approximately equal frequency
 - scales/no horns
 - no scales/horns

She also noted that since Chi-Yan has scales, no horns and wings-all recessive traits-his genotype for these three genes must be **ss** for Scales, **hh** for Horns and **ww** for Wings. Thus he produces only **shw** gametes.

Explanation of the evidence that Scales are part of Chromosome 1.

Students then work through some dihybrid reasoning about crossing a different female with Chi-Yan.

You're right! For each gene pair, Chi-Yan can produce only one gamete type (sh for Scales/Horns and sw for Scales/Wings) and Yu-Jing can produce four gamete types (SH, Sh, sH, and sh for Scales/Horns and SW, Sw, sW, sw for Scales/Wings) which would result in four offspring phenotypes for each gene pair as follows:

	sh	offspring phenotypes ↓		sw	offspring phenotypes ↓
SH	SsHh	no scales/ no horns	SW	SsWw	no scales/ no wings
Sh	Sshh	no scales/ no horns	Sw	Ssww	no scales/ wings
sH	ssHh	scales/ horns	sW	ssWw	scales/ no wings
sh	sshh	scales/ no horns	sw	ssww	scales/ wings

Possible phenotypes from crossing Chi-Yan and Yu-Jing

The assessment at the end of the activity involves Juvenile Parkinson's Disease, linked to a recessive allele on a single gene.

5.0 Student Reports

Your students' work with Scales 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.

Offering less guidance, *Plates* is a similar puzzle that involves an incompletely dominant, X-linked trait.