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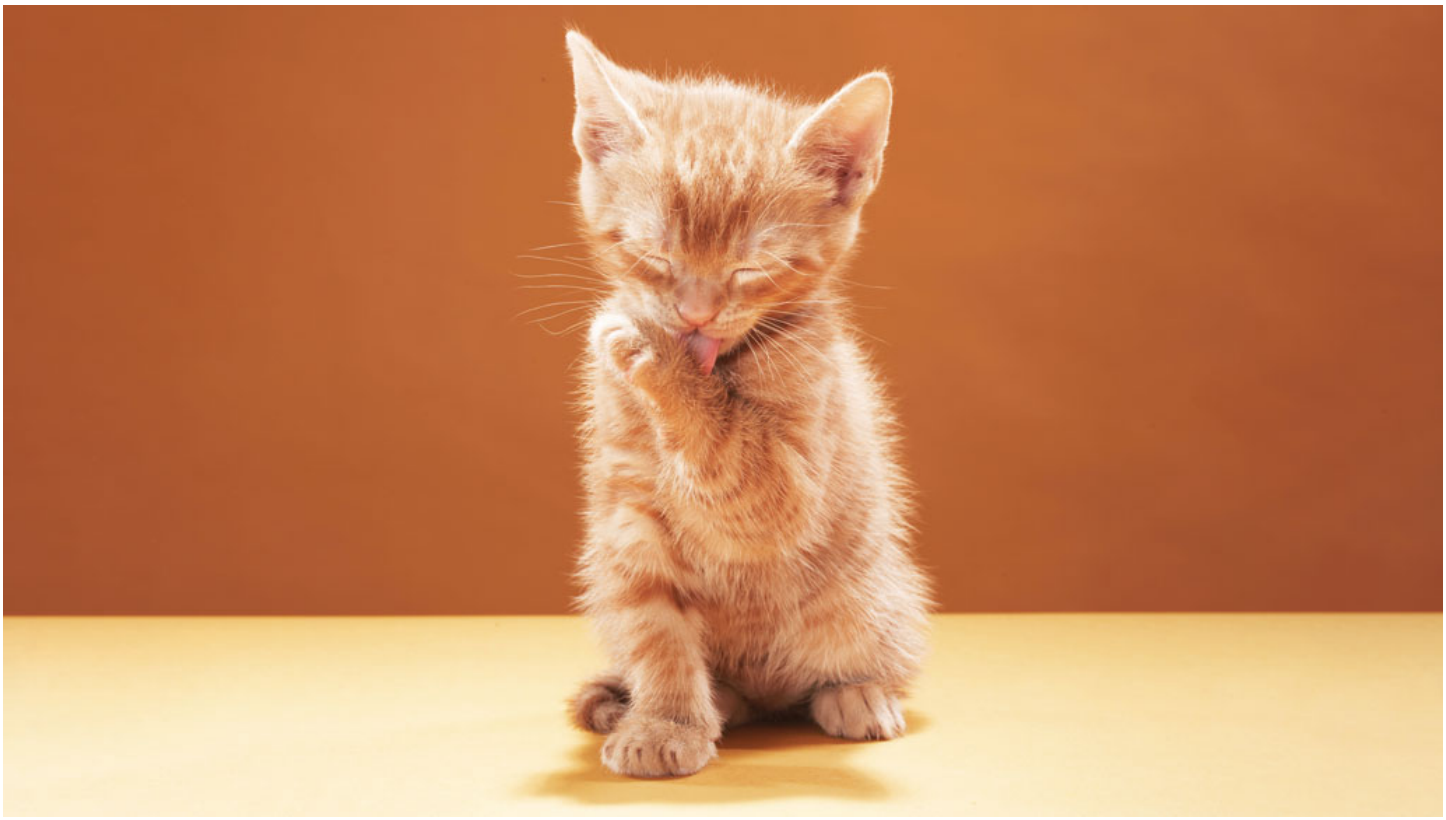

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February 15, 2020

How to Lick Cat Allergies

SOCIETY FOR SCIENCE & THE PUBLIC

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How to Lick Cat Allergies

About this Guide

This Guide, based on the *Science News* article "How to lick cat allergies" asks students to explore how scientists are combating cat allergies, review basic concepts in genetics and analyze Punnett squares.

This Guide includes:

Article-based Comprehension Q&A — These questions, based on the *Science News* article "How to lick cat allergies," Readability: 9.9, ask students to explore some potential solutions to prevent and calm allergic reactions. Related standards include NGSS-DCI: HS-LS1; HS-LS3; HS-LS4; HS-ETS1.

> **Student Comprehension Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Students will identify and categorize various approaches to fending off cat allergies. After discussing the approaches, students will apply similar problem-solving strategies to a new allergen. Related standards include NGSS-DCI: HS-LS1; HS-LS3; HS-ETS1.

> **Student Discussion Worksheet** — These questions are formatted so it's easy to print them out as a worksheet.

Activity: Cats and Punnett Squares

> **Summary:** In this activity, students will review key genetics concepts and construct and analyze a Punnett square for two low-allergen cats. Related standards include NGSS-DCI: HS-LS1; HS-LS3; HS-LS4.
>
> **Approximate class time:** 1 class period to complete the data questions, construct the Punnett square, analyze the results and debrief as a class.

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How to Lick Cat Allergies

Article-based Comprehension, Q&A

Directions for teachers: After your students read "How to lick cat allergies," ask them to answer the following questions.

1. How many people are allergic to cats? How does that compare to the number of people with airborne allergens?

Approximately 10 to 20 percent of people are allergic to cats. By some estimates three times that number, up to 30 percent, have airborne allergies.

2. What protein triggers cat allergies in people? What genes are responsible for making the protein?

Two genes, *Ch1* and *Ch2*, make the Fel d1 protein, the main culprit in cat allergies.

3. Do scientists know the protein's role in cats? What evidence do scientists have that might suggest a possible function of the protein?

Scientists don't know what Fel d1 does in cats. Evidence from unneutered male cats and similarity to other molecules suggests the protein may be a pheromone, a chemical that cats use to communicate through scent.

4. What does finding a version of the protein in lions indicate to scientists about its importance?

Lions and other big cats have versions of Fel d1 as well, suggesting it stuck around through cat evolution and so may be important.

5. Describe one approach currently used to treat people who are allergic to cats. What are some drawbacks of the treatment?

One treatment for cat allergies is desensitization therapy, which trains a person's immune system to be less sensitive to allergens by slowly introducing small amounts of allergens. The treatment can require a lot of time and money, and doesn't provide permanent relief for all symptoms.

6. Describe one approach to treat people who are allergic to cats that is still in testing. What are the advantages and drawbacks of that potential approach?

Some researchers are testing a cat vaccine that uses a virus fragment coated in Fel d1 to trick a cat's immune system into thinking that Fel d1 is an invader. The cat's immune system then makes antibodies that bind to the protein, rendering Fel d1 invisible to human immune systems. The advantages are that humans don't have to get shots to prevent their allergies and the vaccine doesn't seem to harm cats, but the approach doesn't eliminate all Fel d1.

7. Based on the graph titled "Cat food's effects on allergen levels," what is the baseline level of active Fel d1 in cat fur (be sure to include units and define "baseline" levels in your answer)? What does early evidence suggest about a treatment approach that relies on cat food?

The graph shows that the baseline level was about 220 micrograms of active Fel d1 per gram of cat fur. All levels of active Fel d1 in the fur of cats that ate the experimental food over 10 weeks dropped below baseline levels. In some weeks, the level of active Fel d1 was one-third baseline levels. In theory, that should calm symptoms of people with mild to moderate allergies.

8. What does the graph titled "Total nasal symptom score" show (be sure to define the x- and y-axes and their units)? How does the experimental allergy shot compare with the placebo at 29 days after the injection (be sure to explain what a negative percentage indicates)?

The graph shows data from an experiment testing the effectiveness of injections of an Fel d1-binding antibody at reducing nasal symptoms in people with cat allergies versus a placebo shot. The y-axis shows the average percent change in nasal symptom scores from baseline, and the x-axis shows time, measured in days. On day 29, people who received an injection of the antibody saw their nasal symptoms decrease by up to 60 percent. Comparatively, people who received the placebo shot saw about a 30 percent reduction of their nasal symptoms after 29 days. Negative percentages are used to indicate that nasal symptoms have decreased relative to the baseline symptom levels.

9. What does it mean for a cat to be hypoallergenic? Why is this a goal for some researchers?

Cats that are hypoallergenic produce very little to no Fel d1 protein. Breeding such a cat is a goal because some people may not be able to tolerate even small amounts of Fel d1.

10. Why does breeder Tom Lundberg advise people who need low-allergen cats to get potential pets tested and meet them in person?

Even with two low-allergen cats as parents, there's no guarantee that a kitten will be hypoallergenic — not all kittens in a litter will end up with Fel d1 levels. The only way to determine a cat's hypoallergenic status is to test its protein levels, and the only way to be sure how a person with allergies will react to a specific cat is to meet it in person.

11. What tool is Indoor Biotechnologies using to eliminate Fel d1 in cats and how does it work? Do researchers know whether the approach will be harmful to cats? Explain.

Indoor Biotechnologies is using the gene-editing tool CRISPR/Cas9 to delete the genes for making Fel d1 in cat cells. The next step is to delete the genes in cat tissues so that Fel d1 is no longer made. Scientists don't yet know if editing the genes for Fel d1 would be harmful to cats. Some cats that produce very little Fel d1 still appear to be healthy, but the idea needs to be tested.

12. Why might the techniques described for alleviating cat allergies also work for people with other airborne allergies? Give an example.

Since airborne allergies trigger the immune reaction in a similar way, a treatment that is proved to be safe and effective for cat allergies might inspire treatments for other allergies. For example, if a vaccine works in cats, it might also work to fight an allergen in dog dander.

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How to Lick Cat Allergies

Student Comprehension Worksheet

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2. What protein triggers cat allergies in people? What genes are responsible for making the protein?

3. Do scientists know the protein's role in cats? What evidence do scientists have that might suggest a possible function of the protein?

4. What does finding a version of the protein in lions indicate to scientists about its importance?

5. Describe one approach currently used to treat people who are allergic to cats. What are some drawbacks of the treatment?

6. Describe one approach to treat people who are allergic to cats that is still in testing. What are the advantages and drawbacks of that potential approach?

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How to Lick Cat Allergies

Cross-curricular Discussion, Q&A

Directions for teachers:
Use this exercise to help your students improve their problem-solving skills. The article "How to lick cat allergies," explains how science can help fend off cat allergies. With cat allergies as an example, students will brainstorm solutions for other allergies. Students will identify the allergen responsible, how the allergen is spread to humans and what background knowledge would help fight the allergen.

Students should read the article and answer the first set of questions individually. Then have students partner up to compare their answers and apply their thinking to a new allergen. Come together as a class to discuss the solutions that students devised.

Directions for students:

Define the problem, allergen and treatment
Read the article "How to lick cat allergies," and review the chart "Allergy treatments" to answer the following questions.

1. What is the overarching problem that the treatments discussed are trying to solve?

The treatments are trying to prevent or block humans' allergic response to cats.

2. What is the allergen, and how is it produced? How does the allergen reach humans?

Scientists believe the main allergen is the protein Fel d1, which is produced in cats' salivary and sebaceous glands and found in flakes of dead skin. When a cat licks its fur, the protein is spread to its hair, which is then shed and transferred to humans.

3. For each treatment mentioned in the article, answer the following questions:

Does the treatment target the human or cat?

How does the treatment attempt to solve the problem? (For example, does it treat a symptom, stop the production of the allergen, interfere with the allergic response or work through some other mechanism?)

What background information do you think scientists need or needed to develop the treatment?

Antihistamines:

This treatment targets the human and alters one aspect of the body's immune response. Scientists needed to understand the role of histamines in the allergic response and how they are produced in order to create this treatment.

Nasal steroids:

This treatment targets the human. It doesn't block the allergic response itself but treats a symptom of the allergies. Scientists needed to understand what triggers inflammation and how to stop or calm it.

Traditional allergy shots:

This treatment targets the human. It attempts to retrain the human body to be less sensitive to the allergen. Scientists needed to understand what allergen was responsible and how best to administer it, but the mechanism by which the retraining works is still not known.

Lab-made antibodies:

This treatment targets the human by attempting to make the allergen unrecognizable. The antibody masks or alters the structure of the allergen. Scientists need to understand the allergen and its chemical and physical properties to determine a complementary substance, as well as understanding what substances might be safe for the human.

Pet food with antibodies:

This treatment targets the cat by attempting to mask or alter the allergen, thus making it unrecognizable, before it reaches the human. Scientists need to understand the chemical and physical properties of the allergen to determine a complementary substance and to understand what substances are safe for cats.

Vaccine for cats:

This treatment targets the cat. It encourages the cat to produce a complementary substance that masks or alters the structure of the allergen. Scientists need to understand how the allergen can be altered by the cat's immune system, while keeping the cat safe.

Genetic engineering:

This treatment targets the cat. It would stop the production of the allergen in a cat by altering the cat's gene activity. Scientists need to understand what genes are responsible for producing the allergen and what other role these genes have. Scientists also need the tools to modify those genes or their activity.

Group and categorize
Compare your answers with a partner. Discuss which treatments are similar and why. Group them into categories based on their similarities. Once the treatments are grouped, give each group a "category name" that describes the set of approaches. Then answer the questions that follow.

1. Category Name:
Treatments within category:

Category Name:
Treatments within category:

Category Name:
Treatments within category:

2. Which categories require a greater background understanding of human and cat biology? What fields of science are shared across the categories? Which fields are unique to one or more categories?

3. Are some categories of approach more invasive than others? Are some riskier? How does the risk relate to the benefits of the treatment type?

4. Are there any categories of approach that weren't considered or covered in the article?

5. Which treatment would you choose if you had a cat allergy and why?

Apply your thinking to a new allergen
With your partner, choose a different allergy such as pollen, bee stings, particular foods or other animals. Use the questions below to devise possible treatments for the chosen allergy, and select what you think would be the most viable treatment option.

1. What's your chosen allergy? What is the allergen responsible and how is it produced? How does it spread to humans?

2. Describe a possible treatment approach that fits within each category defined above. Can you think of a treatment approach that fits into a different category? If so, explain it.

3. What are the advantages and drawbacks to each treatment?

4. What scientific background information would you need to create each treatment?

5. If you were to further explore and develop one of the treatment, which would you choose? Why? How would you begin to collect the background information needed?

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How to Lick Cat Allergies

Student Discussion Worksheet

Directions:

Define the problem, allergen and treatment
Read the article "How to lick cat allergies," and review the chart "Allergy treatments" to answer the following questions.

1. What is the overarching problem that the treatments discussed are trying to solve?

2. What is the allergen, and how is it produced? How does the allergen reach humans?

3. For each treatment mentioned in the article, answer the following questions:

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What background information do you think scientists need or needed to develop the treatment?

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Nasal steroids:

Traditional allergy shots:

Lab-made antibodies:

Pet food with antibodies:

Vaccine for cats:

Genetic engineering:

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How to Lick Cat Allergies

Activity Guide for Teachers: Cats and Punnett Squares

Purpose: Scientists would like to breed cats that don't trigger allergies in people. By constructing and analyzing a Punnett square for two low-allergen cats, students will review key concepts including patterns and probabilities of inheritance, genotype, phenotype, genes, alleles, chromosomes and mutations. Students will apply critical thinking skills to interpret the likely allergen levels of the resulting cats.

Procedural overview: Students will study data on the genotypes and phenotypes of two Siberian cats and answer associated questions. Then, student groups will construct a Punnett square of a cross between the cats and analyze the results.

Approximate class time: 1 class period to complete the data questions, construct the Punnett square, analyze the results and debrief as a class.

Supplies:
Grid paper for making the Punnett square
Classroom resources on genetic concepts
A projector for introducing the activity (optional)
Cats and Punnett Squares student activity guide

Directions for teachers:
Introduce students to various methods for fending off cat allergies by having them read "How to lick cat allergies." The story discusses the genetics behind the main cat allergen and explains how people are trying to find a reliable way to breed low-allergen cats but have not yet been successful.

Tell students that they will look at some data on two low-allergen Siberian cats. (Note: While this activity uses data from recent genetic research that can be found here https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5753643/, some assumptions have been made and so this scenario should be presented as a hypothetical one.)

To understand the genetic data, it is important that students know the basics of DNA, genes, gene transcription, translation, genotype and phenotype. Background questions No. 1 through 4 below can help facilitate a class discussion that assesses student knowledge of genetic concepts and reviews those concepts as needed. If students need further review, have them consult resources and/or present the information to the class.

Important points are:

- DNA, or deoxyribonucleic acid, typically exists as a double-stranded helix, and each strand is made of a sequence of nucleotides. DNA contains information that gives your cells instructions and so has a major role in determining your traits.

- DNA is packaged in chromosomes that are passed down from parents to offspring. Animals generally have pairs of chromosomes, typically one from each parent.

- Genes are small sections of DNA that have the instructions for making a protein or part of a protein. Proteins are used to digest food, build cells and move your muscles, among other roles.

- In gene transcription, an RNA copy of a DNA strand is made. The RNA is used to make proteins in a process called translation.

- Animals with one chromosome from each parent generally have two versions of each gene. The two versions of a gene are called alleles. The two alleles can be the same or different.

- Mutations are changes in the DNA sequence that makes up a gene. Alleles with mutations have a sequence of nucleotides different from the typical sequence for that gene. Mutations can be inherited or can happen spontaneously, and they can be helpful, neutral or harmful.

- A genotype is all the information carried in the DNA (and by extension genes) of an organism.

- A phenotype is the observable characteristics of an organism.

Next, instruct students to read the section of the activity titled "Analysis of mutation data on Siberian cats," which provides information on mutations identified in two genes, *Ch1* and *Ch2*, in two cats. Break students into small groups and have them analyze the data by answering questions No. 5 through 11. Review the answers as a class.

Review how Punnett squares are used to help predict the genotypes and phenotypes in breeding experiments. Have students work to create a Punnett square for a cross between the two cats (question No. 12). Be sure to explain that the top of the Punnett square lists all the possible combinations of alleles for the two genes in one parent and the left side does the same for the other parent.

By filling out the square, students will determine all the possible genotypes for offspring of the two cats.

If students have previously worked with Punnett squares, challenge them to set up a square for the two genes. If students have not previously worked with Punnett squares, go through the process of determining the possible genotypes for the parents. Then explain how to set up the table and fill in each cell. Check with students as they work to make sure they are on the right track.

When students have completed the Punnett square, review the genotypes and phenotypes and have students answer the remaining questions. Review the answers as a class.

Student directions:

Background questions
Answer the following questions to assess your knowledge of some genetics terms and concepts. Use your notes or classroom resources to look up terms that are new to you.

1. Compare gene transcription and translation.

Transcription is the process by which a gene's DNA sequence is copied to make RNA. Translation is the process by which RNA is used to make a protein.

2. What is an allele? What can make alleles different?

An allele is a form of a gene. Some alleles have mutations that make them different from the typical form found throughout a population.

3. What is a genotype?

A genotype is the genetic information, or DNA, of an organism.

4. What is a phenotype?

A phenotype is the observable characteristics of an organism.

Analysis of mutation data on Siberian cats
Some people have claimed that Siberian cats are naturally low in the common cat allergen Fel d1 and therefore are less likely to cause allergic reactions in people. A recent genetic study investigated common alleles and mutated forms in the *Ch1* and *Ch2* genes, which are known to control production of Fel d1 in Siberian and non-Siberian cats.

The researchers identified the common alleles of the two genes and three mutated forms of the gene that may be of interest. Two of the mutated forms do not make functional Fel d1. This may result in lower amounts of the allergen in a cat with those alleles. The following table describes and gives temporary names for the alleles identified in the study.

Table 1

Gene	Allele	Allele description and distribution	Effect of mutation
Ch1	$Ch1^{+}$	Most common form across all felines	
	$Ch1^{H}$	Mutated form found only in Siberian cats	Error in Fel d1
Ch2	$Ch2^{+}$	Most common form across all felines	
	$Ch2^{S}$	Mutated form found in all Siberian cats and some non-Siberian cats	No error in Fel d1
	$Ch2^{H}$	Mutated form found only in Siberian cats	Error in Fel d1

The researchers then gathered complete data on the genotype and phenotype of two Siberian cats. Note that a previous study of a variety of cats determined that the average salivary concentration of the allergen Fel d1 ranged from 0.4 to 35 μg/mL.

Table 2

Cat	*Ch1* alleles present in the genome	*Ch2* alleles present in the genome	Salivary concentration of Fel d1 (µg/mL)
1	$Ch1^{H}$	$Ch2^{S}$, $Ch2^{H}$	0.48
2	$Ch1^{+}$	$Ch2^{S}$	2.19

Answer the following questions about the data in the study.

5. Based on Table 1, what are the names of the most common alleles of the *Ch1* and *Ch2* genes that are found across all felines?

$Ch1^{+}$ and $Ch2^{+}$

6. What are the names of the three mutated alleles that are found in Siberian cats? Which of these alleles affect the production of the allergen Fel d1?

$Ch1^{H}$, $Ch2^{S}$ and $Ch2^{H}$ are mutated alleles that are found in Siberian cats. $Ch1^{H}$ and $Ch2^{H}$ affect the production of Fel d1.

7. Based on Table 2, which cat has the mutated forms of the alleles that are thought to affect the production of Fel d1? Does the presence of the mutations seem to be related to the level of Fel d1?

Cat 1 has the two mutated forms $Ch1^{H}$ and $Ch2^{H}$ and it has a lower level of Fel d1. The mutations seem to be related to the level.

8. Which column(s) of the table indicate genotype information? Explain your answer.

The columns about the alleles, because the genotype is the genetic information and alleles are genes with different DNA sequences.

9. Which column(s) of the table indicate phenotype information? Explain your answer.

The information about the concentration of the allergen, because the phenotype is an observable characteristic.

10. Many people have claimed that Siberian cats cause fewer allergies. What data in the second table might support this observation?

The values of the allergen level for the two cats is at the low end of the range for all cats, even for cat 2, which does not have any of the two mutations known to affect protein production.

11. One research goal is to identify mutations in the *Ch1* and *Ch2* genes that are common to Siberian cats but not found in non-Siberian cats. Why is this interesting?

Forms of genes that are shared by Siberian cats and not non-Siberian cats may be the ones responsible for the lower allergen levels.

Construct and analyze a Punnett square

Parents contribute to the DNA of their offspring. Generally for animals, one of a pair of chromosomes and its alleles comes from one parent, and the other chromosome and its alleles comes from the other parent. Each pair of alleles is the genotype for a specific trait.

The Punnett square can predict the possible genotypes of offspring from two parents. The top of the Punnett square lists all the possible combinations of alleles that could come from one parent, and the left side lists all the possible combinations from the other parent.

In this activity, you will build a Punnett square for the *Ch1* and *Ch2* genes in the two cats described above. Because two genes are involved, the Punnett square will have four columns for the genotypes of one parent and four rows for the other parent.

Two notes: In this exercise, we are assuming that the two genes are not linked. Also, you may have worked with Punnett squares in which alleles are identified as recessive or dominant. But the research on the alleles of *Ch1* and *Ch2* is still too recent to know inheritance patterns. The good news is you can still create a Punnett square by listing both alleles for each of the two genes in the cells.

12. In your small group, construct a Punnett square for a cross between cats 1 and 2. Show the possible genotypes for cat 1 on the top of the square and the possible genotypes for cat 2 on the left side of the square. Then fill in the squares for the possible genotypes of the cats' offspring.

	$Ch1^{H}Ch2^{S}$	$Ch1^{H}Ch2^{H}$	$Ch1^{H}Ch2^{S}$	$Ch1^{H}Ch2^{H}$
$Ch1^{+}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$
$Ch1^{+}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$
$Ch1^{+}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$
$Ch1^{+}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$

Now analyze the results of your Punnett square.

13. Highlight the genotypes of offspring that contain BOTH of the mutated alleles that affect protein production. (*Answers are bolded in the table below.*)

	$Ch1^{H}Ch2^{S}$	$Ch1^{H}Ch2^{H}$	$Ch1^{H}Ch2^{S}$	$Ch1^{H}Ch2^{H}$
$Ch1^{+}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	**$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$**	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	**$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$**
$Ch1^{+}Ch2^{S}$	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	**$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$**	$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{S}$	**$Ch1^{+}Ch1^{H}Ch2^{S}Ch2^{H}$**
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14. What phenotype would you predict for cats with BOTH mutations?

The cats will probably have lower levels of the allergen.

15. What is the probability that a cat would have both mutations?

There is a six out of sixteen chance, or about 37.5 percent, for a cat with both mutations.

16. The article "How to lick cat allergies" says that only one out of 15 offspring of low-allergen parents is low-allergen. List as many factors as you can think of that could explain why this number is smaller than what your Punnett square describes?

Some possibilities include: The cats in this study might not be representative of the population of low-allergen cats. There might be other genes involved in turning production of Fel d1 on and off. When both alleles of Ch1 are present, $Ch1^{+}$ could compensate for $Ch1^{H}$. When both alleles of Ch2 are present, $Ch2^{S}$ could make more protein than $Ch2^{H}$. The two genes might be linked in a way that affects the pattern of inheritance. Environmental factors might play a role in how much Feld1 is produced. Some other allergen might be produced by cats.

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How to Lick Cat Allergies

Activity Guide for Students: Cats and Punnett Squares

Directions for students:

Background questions
Answer the following questions to assess your knowledge of some genetics terms and concepts. Use your notes or classroom resources to look up terms that are new to you.

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2. What is an allele? What can make alleles different?

3. What is a genotype?

4. What is a phenotype?

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Table 1

Gene	Allele	Allele description and distribution	Effect of mutation
Ch1	$Ch1^{+}$	Most common form across all felines	
	$Ch1^{H}$	Mutated form found only in Siberian cats	Error in Fel d1
Ch2	$Ch2^{+}$	Most common form across all felines	
	$Ch2^{S}$	Mutated form found in all Siberian cats and some non-Siberian cats	No error in Fel d1
	$Ch2^{H}$	Mutated form found only in Siberian cats	Error in Fel d1

The researchers then gathered complete data on the genotype and phenotype of two Siberian cats. Note that a previous study of a variety of cats determined that the average salivary concentration of the allergen Fel d1 ranged from 0.4 to 35 μg/mL.

Table 2

Cat	*Ch1* alleles present in the genome	*Ch2* alleles present in the genome	Salivary concentration of Fel d1 (μg/mL)
1	$Ch1^{H}$	$Ch2^{S}$, $Ch2^{H}$	0.48
2	$Ch1^{+}$	$Ch2^{S}$	2.19

Answer the following questions about the data in the study.

5. Based on Table 1, what are the names of the most common alleles of the *Ch1* and *Ch2* genes that are found across all felines?

6. What are the names of the three mutated alleles that are found in Siberian cats? Which of these alleles affect the production of the allergen Fel d1?

7. Based on Table 2, which cat has the mutated forms of the alleles that are thought to affect the production of Fel d1? Does the presence of the mutations seem to be related to the level of Fel d1?

8. Which column(s) of the table indicate genotype information? Explain your answer.

9. Which column(s) of the table indicate phenotype information? Explain your answer.

10. Many people have claimed that Siberian cats cause fewer allergies. What data in the second table might support this observation?

11. One research goal is to identify mutations in the *Ch1* and *Ch2* genes that are common to Siberian cats but not found in non-Siberian cats. Why is this interesting?

Construct and analyze a Punnett square

Parents contribute to the DNA of their offspring. Generally for animals, one of a pair of chromosomes and its alleles comes from one parent, and the other chromosome and its alleles comes from the other parent. Each pair of alleles is the genotype for a specific trait.

The Punnett square can predict the possible genotypes of offspring from two parents. The top of the Punnett square lists all the possible combinations of alleles that could come from one parent, and the left side lists all the possible combinations from the other parent.

In this activity, you will build a Punnett square for the *Ch1* and *Ch2* genes in the two cats described above. Because two genes are involved, the Punnett square will have four columns for the genotypes of one parent and four rows for the other parent.

Two notes: In this exercise, we are assuming that the two genes are not linked. Also, you may have worked with Punnett squares in which alleles are identified as recessive or dominant. But the research on the alleles of *Ch1* and *Ch2* is still too recent to know inheritance patterns. The good news is you can still create a Punnett square by listing both alleles for each of the two genes in the cells.

12. In your small group, construct a Punnett square for a cross between cats 1 and 2. Show the possible genotypes for cat 1 on the top of the square and the possible genotypes for cat 2 on the left side of the square. Then fill in the squares for the possible genotypes of the cats' offspring.

Now analyze the results of your Punnett square.

13. Highlight the genotypes of offspring that contain BOTH of the mutated alleles that affect protein production.

14. What phenotype would you predict for cats with BOTH mutations?

15. What is the probability that a cat would have both mutations?

16. The article "How to lick cat allergies" says that only one out of 15 offspring of low-allergen parents is low-allergen. List as many factors as you can think of that could explain why this number is smaller than what your Punnett square describes?