GROW NEXT GEN

CHICKENOLOGY

Explore genetics to breed the best brood

HIGH SCHOOL

PILOT CURRICULUM

Chickenology is generously sponsored by

OHIO POULTRY ASSOCIATION

OHIO SOYBEAN COUNCIL

in partnership with educationprojects.org

Investigate cladograms

How might we group organisms to demonstrate evolutionary relationships?
How can we use genetics to build evolutionary relationships?

Standards

- **B.H.1:** Cellular genetics: Genes code for proteins
- **B.E.2:** Speciation: Biological classification expanded to molecular evidence

Introduction

On the surface, many organisms may not appear to have much in common. However, at the genetic level, they may have more in common that you might guess. Genes are made of DNA which is inherited from a parent by its offspring. Some DNA sequences code for mRNA which, in turn, codes for the amino acid sequence of proteins. Genes and proteins that code for basic survival functions tend to be shared by many organisms. Cytochrome c (cyt c) is a protein involved in energy use within the cell. Cyt c is found in all eukaryotes as well as some prokaryotes. As a result, cyt c is an ideal tool to help scientists learn more about the relationships between organisms.

Student prior knowledge

Students should understand that genes in DNA code for proteins that perform cellular functions. Over time, random mutations in the DNA sequence can occur. As a result, the amino acid sequence changes. Scientists can use the changes in the amino acid sequence of cytochrome c to detect evolutionary relationships between organisms. Students should also be familiar with cladograms, branching diagrams that show evolutionary relationships between organisms.

Suggested timeline

1–2 class period(s) (50–100 minutes)

Materials

- Student worksheets: Compare and group, Research and genetic relationships
- Cytochrome c amino acid protein table

Teacher preparation

Print the student worksheet and cytochrome c amino acid protein table

Procedure

1. Brainstorm characteristics for the 10 organisms in each group of cards. What are some of the criteria scientists might use to determine how closely related two organisms are? Discuss with your group and share your ideas with the class.
2. As a group, place the organism cards in order based upon their evolutionary age, from which organism evolved first to the last (left to right). Create a claim with evidence and reasoning (CER) to support your conclusions. Present your CER to the class and compare your claim to that of other class groups.
3. Pass out the cytochrome c amino acid protein table and compare the cyt c sequences between the organisms. Count the number of differences between humans and the other organisms and place that number in the Data table 2. For each organism, circle each amino acid that differs from the human sequence. *Note that a blank cell indicates an amino acid that is missing in some species. In places*

where one species has a blank cell and another has a letter, count that as a difference.

4. Reflect with students how it is possible for all of the organisms to have the same functioning protein, cytochrome c, when there are one or more amino acid sequence differences between organisms.
5. Create a cladogram using the number of amino acid differences between organisms by starting with the greatest number of differences and going to the least number of differences.
6. Make a cladogram using the data in table 2.
    a. Place the two most closely-related species on the two shortest branches. The two most closely-related species have the fewest number of differences in the amino acid sequence.
    b. Place the next two closest related species on the next two shortest branches.
    c. Place the species which is the next closest on the next longest branch. Continue until all the species have been placed.

Suggested wrap-up activity

The students will compare their cytochrome c cladogram to their previous CER construction and determine how similar their evolutionary predictions are to the amino acid sequences.

Differentiation

- Create heterogeneous groups of students (of varying knowledge and ability levels) to complete the CER and cladogram activities together.
- Display the vocabulary at the end of the document ahead of time for the students.

More challenges

- Have the students explore more eukaryotic organism cytochrome c amino acid sequences to add additional information into their cladogram.
- Have students research and report on scientists that have contributed to our understanding of evolution theory over time.
- Compare cladograms: Gather several cladograms and practice reading and interpreting them. If there are differences between them, compare the points of difference. Why are they different and similar? What does this communicate about the evolutionary relationships scientists have formed about each cladogram?
- **Home connection:** Start a conversation about how genetics are used to better understand evolutionary relationships between organisms. Discuss how previous morphological similarities may not demonstrate the same ancestral link as the amino acid, cytochrome c.

Support information

- **Cladogram:** a branching diagram that shows the ancestral relationships among species.
- **Evolution:** the change in the heritable characteristics of biological populations over successive generations.
- **Morphology**: a branch of biology that studies the external and internal structures of living things.
- **Eukaryote**: an organism consisting of a cell or cells in which the genetic material is DNA in the form of chromosomes contained within a distinct nucleus.
- **DNA (deoxyribonucleic acid):** the molecule that carries genetic information for the development and functioning of an organism.
- **Gene:** the basic unit of heredity passed from parent to child. Genes are made up of sequences of DNA and are arranged, one after another, at specific locations on chromosomes in the nucleus of cells.
- **mRNAv (messenger ribonucleic acid):** a single-stranded molecule of RNA that corresponds to the genetic sequence of a gene and is read by a ribosome in the process of synthesizing a protein.
- **Amino acids:** molecules that combine to form proteins.
- **Protein**: a molecule made up of amino acids. Proteins are needed for the body to function properly.

- **Cytochrome c**: a protein found in the mitochondria where it functions to transfer electrons in ATP synthesis.
- According to evolutionary theory, species that recently shared a common ancestor have more similarities in their DNA than ones that last shared a common ancestor long ago. By comparing the order of amino acids that make up the protein cytochrome c and noting the differences in the arrangement, scientists can infer relationships among species. In general, the more amino acids two species share, the more closely related they are in evolutionary time.
- Cladistics is a method of placing species with similar characteristics into groups called **clades.** Clades can be grouped according to branching diagrams (*cladograms*) to show evolutionary relationships. Key features of cladograms are:
  - **Root:** the initial ancestor common to all organisms within the cladogram
  - **Nodes:** a hypothetical or last common ancestor
  - **Outgroup:** the most distantly related species (ancestor) in the cladogram
  - **Ingroups/clades:** a common ancestor and all of its descendants
  - **Derived characters/traits:** evolutionary traits that only appear in some members of an evolutionary group
- Amoeba Sisters Protein Synthesis video: **youtu.be/oefAI2x2CQM**
- Bozeman Science cladogram tutorial: **youtu.be/ouZ9zEkxGWg**

Teaching suggestions
Have the students tape their CER organisms together in order from oldest to youngest, left to right, to share with the class as they discuss their claims.

Career connections
Have you ever wondered what type of scientists may be working in the evolutionary field to improve poultry genetics? Let's take a look!

- **Animal geneticists** analyze the genetic makeup of organisms to discover which genes cause them to behave in certain ways. Geneticists may also study animal health to determine what causes animals to be immune to specific diseases or fail to thrive in certain environments.
- **Evolutionary biologists** study the evolutionary processes that have led to the genetic biodiversity of life on earth.
- **Veterinarians** care for the health of the poultry flock and work to protect public health. They diagnose, treat, and research medical conditions and diseases of pets, livestock, and other animals.

Compare and group

Cladistics is a method of placing species with similar characteristics into groups called clades. Clades can be grouped according to branching diagrams (cladograms) to show evolutionary relationships.

1. Brainstorm morphological characteristics for each of the organisms below.

DATA TABLE 1: EVOLUTIONARY TRAITS OF ORGANISMS

Organism	Traits
Human	
Horse	
Dog	
Rabbit	
Chicken	
Bullfrog	
Rattlesnake	
Screwworm	
Wheat	
Baker's yeast	

2. As a group, compare the organisms and place them in order based upon their evolutionary age: which organism evolved first (oldest) to the last (youngest), from left to right.

   1 2 3 4 5 6 7 8 9 10

3. Create a claim, based on evidence, to answer the focus question: How might we group organisms to show evolutionary relationships? Include evidence in your reasoning to document the logic of your claim.

   Claim:

   Evidence:

   Reasoning:

Cytochrome c amino acid protein table

										10										20										30										40										50								
Amino acid number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Human									G	D	V	E	K	G	K	K	I	F	I	M	K	C	S	Q	C	H	T	V	E	K	G	G	K	H	K	T	G	P	N	L	H	G	L	F	G	R	K	T	G	Q	A	P	G	Y	S	Y	T	A	A
Horse									G	D	V	E	K	G	K	K	I	F	V	Q	K	C	A	Q	C	H	T	V	E	K	G	G	K	H	K	T	G	P	N	L	H	G	L	F	G	R	K	T	G	Q	A	P	G	F	T	Y	T	D	A
Dog									G	D	V	E	K	G	K	K	I	F	V	Q	K	C	A	Q	C	H	T	V	E	K	G	G	K	H	K	T	G	P	N	L	H	G	L	F	G	R	K	T	G	Q	A	P	G	F	S	Y	T	D	A
Rabbit									G	D	V	E	K	G	K	K	I	F	V	Q	K	C	A	Q	C	H	T	V	E	K	G	G	K	H	K	T	G	P	N	L	H	G	L	F	G	R	K	T	G	Q	A	V	G	F	S	Y	T	D	A
Chicken									G	D	I	E	K	G	K	K	I	F	V	Q	K	C	S	Q	C	H	T	V	E	K	G	G	K	H	K	T	G	P	N	L	H	G	L	F	G	R	K	T	G	Q	A	E	G	F	S	Y	T	D	A
Bullfrog									G	D	V	E	K	G	K	K	I	F	V	Q	K	C	A	Q	C	H	T	C	E	K	G	G	K	H	K	V	G	P	N	L	Y	G	L	I	G	R	K	T	G	Q	A	A	G	F	S	Y	T	D	A
Rattlesnake									G	D	V	E	K	G	K	K	I	F	S	M	K	C	G	T	C	H	T	V	E	E	G	G	K	H	K	T	G	P	N	L	H	G	L	F	G	R	K	T	G	Q	A	V	G	Y	S	Y	T	A	A
Screwworm fly					G	V	P	A	G	D	V	E	K	G	K	K	I	F	V	Q	R	C	A	Q	C	H	T	V	E	A	G	G	K	H	K	V	G	P	N	L	H	G	L	F	G	R	K	T	G	Q	A	A	G	F	A	Y	T	N	A
Wheat	A	S	F	S	E	A	P	P	G	N	P	D	A	G	A	K	I	F	K	T	K	C	A	Q	C	H	T	V	D	A	G	A	G	H	K	Q	G	P	N	L	H	G	L	F	G	R	Q	S	G	T	T	A	G	Y	S	Y	S	A	A
Baker's yeast				T	E	F	K	A	G	S	A	K	K	G	A	T	L	F	K	T	R	C	E	L	C	H	T	V	E	K	G	G	P	H	K	V	G	P	N	L	H	G	I	F	G	R	H	S	G	Q	A	Q	G	Y	S	Y	T	D	A

	60										70										80										90										100										110		
Amino acid number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	**1**	**2**
Human	N	K	N	K	G	I	I	W	G	E	D	T	L	M	E	Y	L	E	N	P	K	K	Y	I	P	G	T	K	M	I	F	V	G	I	K	K	K	E	E	R	A	D	L	I	A	Y	L	K	K	A	T	N	E
Horse	N	K	N	K	G	I	T	W	K	E	E	T	L	M	E	Y	L	E	N	P	K	K	Y	I	P	G	T	K	M	I	F	A	G	I	K	K	K	T	E	R	E	D	L	I	A	Y	L	K	K	A	T	N	E
Dog	N	K	N	K	G	I	T	W	G	E	E	T	L	M	E	Y	L	E	N	P	K	K	Y	I	P	G	T	K	M	I	F	A	G	I	K	K	T	G	E	R	A	D	L	I	A	Y	L	K	K	A	T	K	E
Rabbit	N	K	N	K	G	I	T	W	G	E	D	T	L	M	E	Y	L	E	N	P	K	K	Y	I	P	G	T	K	M	I	F	A	G	I	K	K	K	D	E	R	A	D	L	I	A	Y	L	K	K	A	T	N	E
Chicken	N	K	N	K	G	I	T	W	G	E	D	T	L	M	E	Y	L	E	N	P	K	K	Y	I	P	G	T	K	M	I	F	A	G	I	K	K	K	S	E	R	V	D	L	I	A	Y	L	K	D	A	T	S	K
Bullfrog	N	K	N	K	G	I	T	W	G	E	D	T	L	M	E	Y	L	E	N	P	K	K	Y	I	P	G	T	K	M	I	F	A	G	I	K	K	K	G	E	R	Q	D	L	I	A	Y	L	K	S	A	C	S	K
Rattlesnake	N	K	N	K	G	I	T	W	G	D	D	T	L	M	E	Y	L	E	N	P	K	K	Y	I	P	G	T	K	M	V	F	T	G	L	K	K	K	K	E	R	T	D	L	I	A	Y	L	K	E	A	T	A	K
Screwworm fly	N	K	A	K	G	I	T	W	Q	D	D	T	L	F	E	Y	L	E	N	P	K	K	Y	I	P	G	T	K	M	I	F	A	G	L	K	K	P	N	E	R	G	D	L	I	A	Y	L	K	S	A	T	K	
Wheat	N	K	N	K	A	V	E	W	E	E	N	T	L	Y	D	Y	L	L	N	P	K	K	Y	I	P	G	T	K	M	V	F	P	G	L	K	K	P	Q	D	R	A	D	L	I	A	Y	L	K	K	A	T	S	S
Baker's yeast	N	I	K	K	N	V	L	W	D	E	N	N	M	S	E	Y	L	T	N	P	K	K	Y	I	P	G	T	K	M	A	F	G	G	L	K	K	E	K	D	R	N	D	L	I	T	Y	L	K	K	A	C	E	

Symbols in highlighted cells represent amino acids which show no differences on any organism on the list, so they may be ignored.

AMINO ACID SYMBOLS

A: Alanine
C: Cysteine
D: Aspartic acid
E: Glutamic acid
F: Phenylalanine
G: Glycine
H: Histidine
I: Isoleucine
K: Lysine
L: Leucine
M: Methionine
N: Asparagine
P: Proline
Q: Glutamine
R: Argnine
S: Serine
T: Threonine
V: Valine
W: Tryptophan
Y: Tyrosine

Genetic relationships

How can we use genetics to build evolutionary relationships?

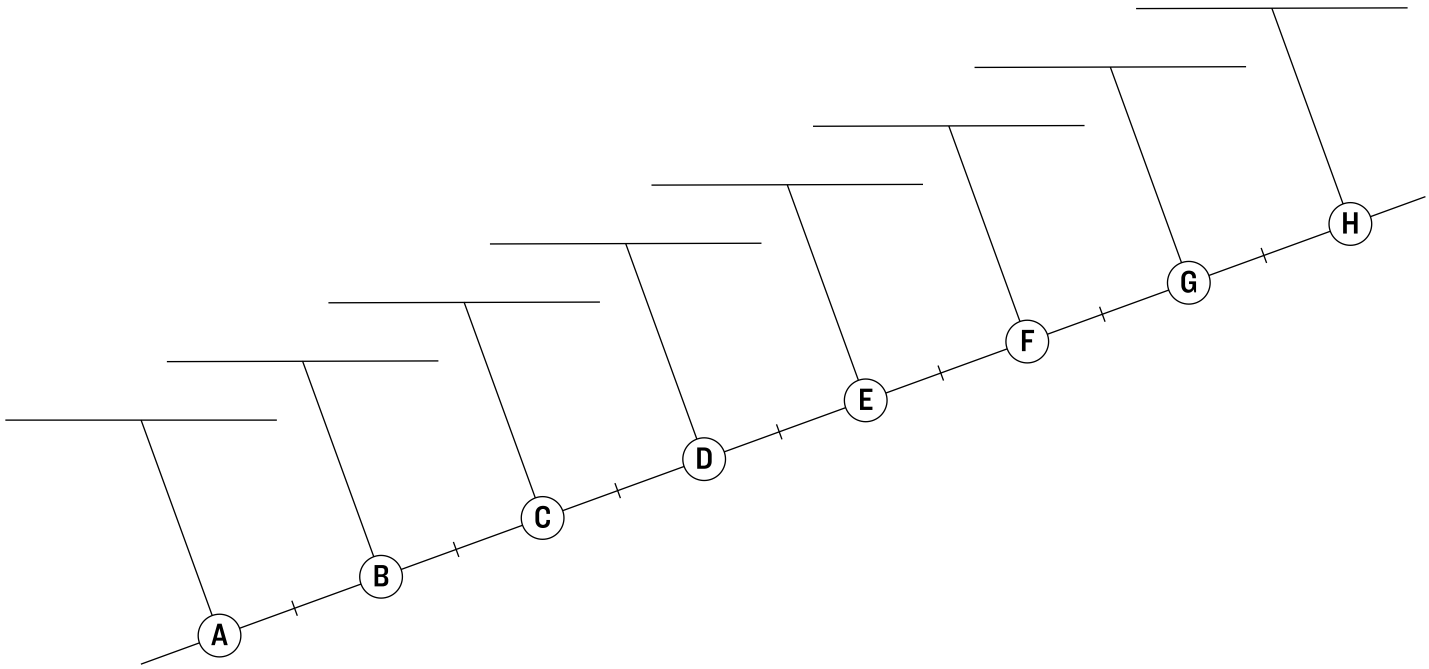
Cytochrome c is a protein with about 100 amino acids. It is present in almost all eukaryotic organisms. It has the same three-dimensional shape in all species, but only 30 of the amino acids are the same in all species. The amino acid sequence of cytochrome c can be used to construct evolutionary relationships between organisms.

1. Determine the number of amino acid differences between humans and all of the other organisms below on the amino acid sequence chart. Use the Cytochrome c amino acid protein table to gather the data to be added to the chart below.

DATA TABLE 2: DIFFERENCES IN AMINO ACID SEQUENCES FOR CYTOCHROME C PROTEIN

	Human	Horse	Dog	Rabbit	Chicken	Bullfrog	Rattlesnake	Screwworm fly	Wheat	Baker's yeast
Human	0									
Horse		0								
Dog			0							
Rabbit				0						
Chicken					0	*10*				
Bullfrog						0				
Rattlesnake							0			
Screwworm fly								0		
Wheat									0	
Baker's yeast										0

2. Cladograms help us by showing evolutionary trends in organisms over time. Create a cladogram based on the cytochrome c amino acid sequence differences in data table 2.



3. Based on the amino acid sequence data that you collected, which organism are humans most closely related to?

4. Which organism is the root of the cladogram (the one that humans are most distantly related to)? How many amino acid sequences differed from a human?

5. What additional data or information can help you confirm your statement above?

6. Compare this cladogram to the original CER sequence you created based on observable traits for each organism. How are they similar and different?

7. How can genetic differences such as these amino acid sequences help us to infer patterns of evolutionary relationships?

Human

Horse

Dog

Rabbit

Horse

- animal
- multicellular
- vertebrate
- mammal
- endothermic
- live birth
- 4 legs
- 2 eyes
- herbivore

Human

- animal
- multicellular
- vertebrate
- mammal
- endothermic
- live birth
- 2 legs; 2 arms
- 2 eyes
- omnivore

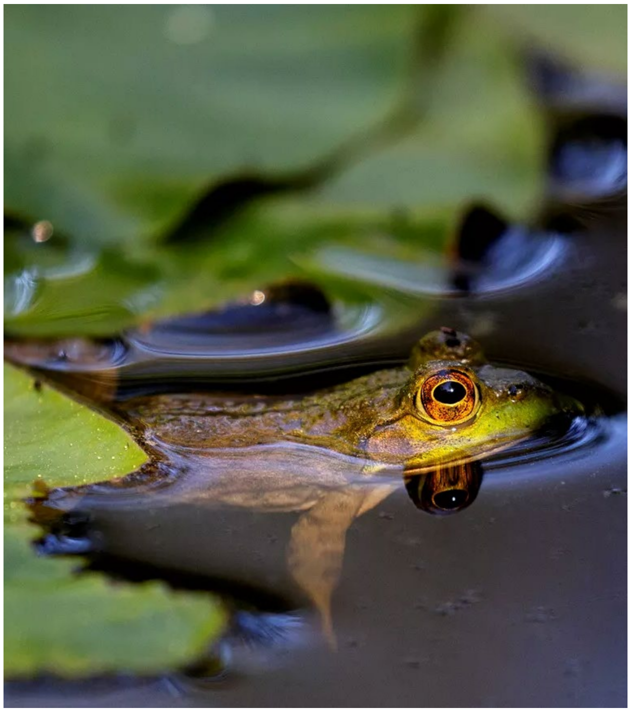
Rabbit

- animal
- multicellular
- vertebrate
- mammal
- endothermic
- live birth
- 4 legs
- 2 eyes
- herbivore

Dog

- animal
- multicellular
- vertebrate
- mammal
- endothermic
- live birth
- 4 legs
- 2 eyes
- omnivore

Chicken



Bullfrog

Rattlesnake

Bullfrog

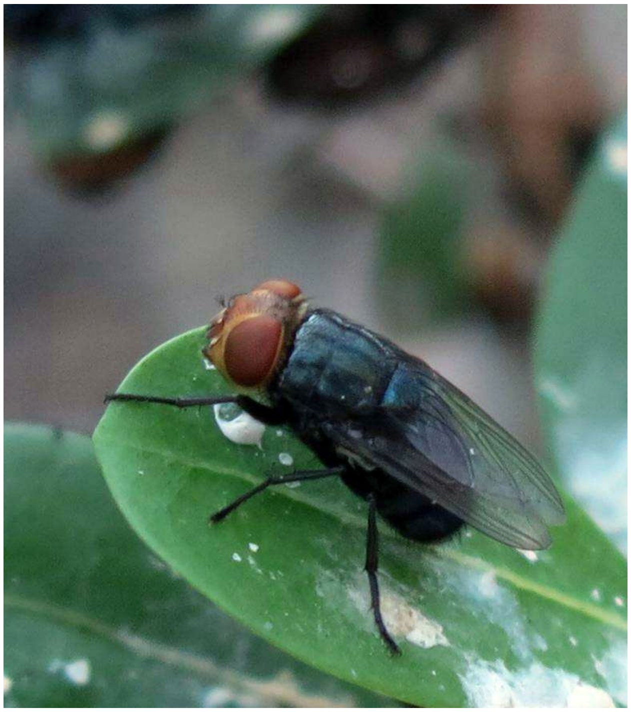
- animal
- multicellular
- vertebrate
- amphibian
- ectothermic
- egg layer; gelatinous covering
- 4 legs
- 2 eyes
- omnivore

Chicken

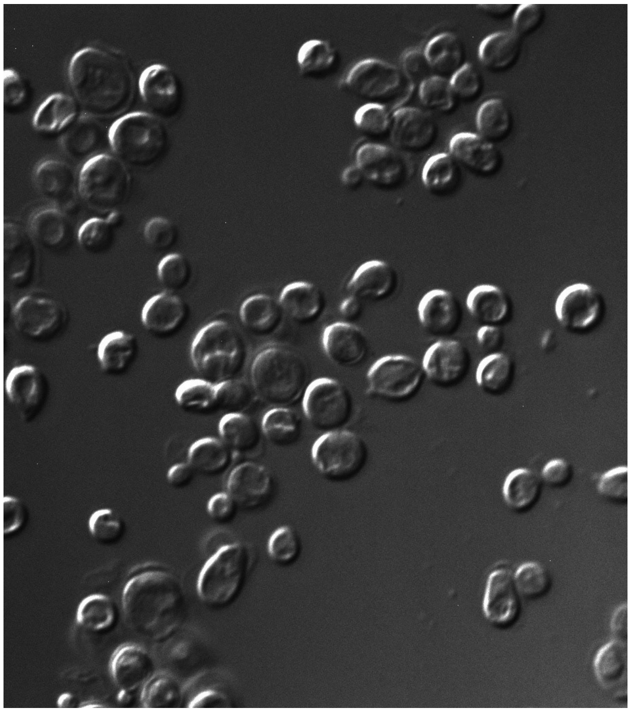
- animal
- multicellular
- vertebrate
- bird
- endothermic
- egg layer; hard shell
- 2 legs; 2 wings
- 2 eyes
- omnivore

Rattlesnake

- animal
- multicellular
- vertebrate
- reptile
- exothermic
- egg layer; soft shell
- 0 legs
- no external ears
- 2 eyes
- carnivore



Screwworm fly



Baker's yeast

Wheat

Baker's yeast

- fungus
- unicellular
- decomposer
- cell wall
- absorb food

Screwworm fly

- animal
- multicellular
- invertebrate
- Insect
- exothermic
- 6 legs
- parasite

Wheat

- plant
- multicellular
- cell wall
- photosynthetic
- grass

Survivor: the chicken edition

How can environmental conditions impact growth rate, behavior, and reproduction?

Standards

- **B.DI.3:** Loss of diversity
- **B.E.1:** Mechanisms

Introduction

Welcome to "Survivor: The Chicken Edition," an exciting and educational journey into the world of biology where you will learn about evolution, natural selection, and biological fitness. This game is designed to help you understand how different traits can influence the survival and reproduction of chickens in various environments. The objective of "Survivor" is to manage a population of chickens in different environments, ensuring their survival through resource management, adaptation to environmental challenges, and successful breeding. You will use strategy and your knowledge of biology to help your chickens thrive. Imagine you are a biologist studying chicken populations in four distinct environments: Forest, Farm, Desert, and Wetland. Each environment presents unique challenges and opportunities for your chickens. As you play, you will draw event cards that simulate real-world scenarios, collect survival points to sustain your chickens, and use trait cards to represent individual chickens with specific traits.

Student prior knowledge

Familiarity with the concepts of inherited traits, natural selection, and environmental services are helpful during this lesson. Students should have an understanding that individual survival is based on meeting the basic requirements for life: food, water, shelter, and oxygen. Organisms must have access to these basic needs in order to reproduce, thereby passing inherited traits on to the next generation.

Suggested timeline

1–2 class periods (50–100 minutes)

Materials

Each student group will require:

- Trait cards
- Event cards
- Student worksheet
- Game pieces
- Game board
- Tokens for survival points optional (bingo dots, counters, dice, ect)

Teacher preparation

- Print off papers for students
- Create a chart paper or white board space for discussion

Procedure

1. As a class, discuss and provide examples of the possible ways species lose diversity. Create a Google Jamboard, etc. to help facilitate discussion. See examples below.
    - Climate change: heat waves, droughts, wildfires
    - Anthropocene effects: urbanization, building dams, creating manmade lakes
    - Invasive species: bird flu, animals, plants
    - Extinction: complete loss of species
2. Divide class into groups of 3–5 students.
3. Play the Survivor: The Chicken Edition game; refer to the student sheet. Each student will select a game piece and draw a trait and an environment card. Students will place their chickens on the game board in the appropriate environment to start the game.
4. Every student begins with 10 survival points.
5. At the beginning of each round, each student will choose one of three options:
    - Move chicken (–2) survival points
    - Breed chicken (–3) survival points
    - Homestead (+1) survival points
6. As a group, one event card is drawn. The event impacts all chickens in the specified environment according to the card's effects. Students must adjust their strategies based on the new conditions introduced by the event. Round one is complete.
7. Continue steps 7–10 for a total of 8 rounds. The player with the most survival points wins. If you run out of survival points then you are extinct and not able to play anymore.
8. At the end of 8 rounds, students will complete the reflection questions on the student worksheet.

Suggested wrap-up activity

As a class, calculate and graph the following data for a class discussion:

- How many chickens lived in which area
- Which chickens survived and which chickens died
- Which loss of diversity method is least/most common

Differentiation

- Change the number of rounds played. Have students work in pairs and manage two chickens they can cross breed to create new chickens. Use a Punnett square to determine which traits the new chicken receives.
- Select specific trait cards or event cards to make the game easier or more challenging.

More challenges

- Change the game to include more rounds. Have students create trait cards and event cards. Add a mutation card or an extinction card to make a specific trait change or to be eliminated from the population.
- At the conclusion of the game, assign student groups to research more specific effects of the loss of diversity items (climate change, anthropocene effects, extinction, and invasive species).
- How are modern poultry farms changing the natural environment to maximize production? What inherited traits are we supporting by utilizing animal science, engineering, and biosecurity features to increase bird health? Create a compare and contrast list of natural environments and commercial poultry environments.
- **Home connection:** How are commercial poultry farms creating habitats to maximize production for human consumption? How do they keep the birds healthy and productive? Discuss how habitats impact bird health and why commercial farms are more productive than the natural environment.

Support information

- **Extinction:** the complete disappearance of a species from Earth.
- **Anthropocene effects:** the time during which humans have had a substantial impact on our planet.
- **Invasive species:** non-native organisms introduced into a new environment that cause harm to the ecosystem or economy.
- **Natural selection:** process in which an organism adapts to its environment through selectively reproducing changes in its genotype.
- **Selective breeding:** also known as artificial selection. A process where humans choose organisms with desired traits to breed together, increasing the frequency of those traits in the population over many generations.
- Set up rules and guidelines of how to play games before you start. Play a practice round or a class round before you send them to play individual rounds. This will allow the students to ask questions about survival points, information to collect, and how to play the game.

Things to note about the game

- If you do not have that trait it does not affect you.
- If you have the trait and points are gained, you gain the total amount. Example: All chickens in the desert lose 1 survival point unless they have long legs, in which case they gain 1 survival point. This player would gain 1 point and retain their initial point for a total of 2 points. (They maintain their initial point, but add an additional point to their score).
- Article on biodiversity: **news.un.org/en/story/2024/01/1145772**
- Crash course video: **youtu.be/5eTCZ9L834s**
- David Attenbourgh: **youtu.be/GlWNuzrqe7U**

Teaching suggestions

- Allow students time to discuss their reasons for selectively breeding chickens.
- Have students research additional reasons behind diversity loss that affect other animals as well as chickens.
- Increase the size of groups playing and collect data on each chicken.

Career connections

Have you ever wondered what type of poultry careers help to make a healthy, safe environment for commercial birds? Let's take a look!

- **Poultry caretakers** help with monitoring flocks for their health and well-being, ensuring they have constant access to fresh food and water as well as a safe living environment. Caretakers walk their barns every day to check their flock and the equipment that helps to keep them safe and fed.
- **Animal scientists** apply principles of the biological, physical, and social sciences to the problems associated with poultry production and management. In other words, they study animal health and behavior in order to help design the perfect environment for commercial birds to live in and produce meat and eggs.
- **Nutritionists** are animal scientists who create diets for different types of poultry by examining their genetics, health conditions, or other factors to best determine their nutritional needs.
- **Veterinarians** care for the health of the poultry flock and work to protect public health. They diagnose, treat, and research medical conditions and diseases of pets, livestock, and other animals.

Survivor: the chicken edition

Worksheet instructions

1. **Initial setup:** Fill out the initial setup section with your starting environment and chicken traits. Each chicken starts with 10 survival points.
2. **Gameplay rounds:** For each round, document the event card drawn, actions taken (moving, breeding chickens, homestead), survival points, and the survival check.
3. **Summary after each round:** Reflect on the challenges, adaptations, and strategies.
4. **End of game summary:** At the end of the game, summarize your final chicken population, the least and most successful traits, and lessons learned about natural selection, selective breeding, environmental impact, and genetic traits.

Game setup

INITIAL SETUP

Starting environment *(circle one):* forest farm desert wetland

INITIAL TRAITS

Trait 1: ______________________________

- Effects:
- Forest:
- Farm:
- Desert:
- Wetland:

Trait 2: ______________________________

- Effects:
- Forest:
- Farm:
- Desert:
- Wetland:

Gameplay rounds

Round		1	2	3	4	5	6
Actions	Homestead						
	Environment *(circle one)*	• Forest • Farm • Desert • Wetland	• Forest • Farm • Desert • Wetland	• Forest • Farm • Desert • Wetland	• Forest • Farm • Desert • Wetland	• Forest • Farm • Desert • Wetland	• Forest • Farm • Desert • Wetland
	Breed						
	Trait 1						
	Trait 2						
	Trait 3						
Event	Effect						
	Loss of diversity						
Tokens	Chicken						
	Forest						
	Farm						
	Desert						
	Wetland						

End of game summary

FINAL CHICKEN POPULATIONS

- Forest:
- Farm:
- Desert:
- Wetland:

LEAST SUCCESSFUL TRAITS

1.

2.

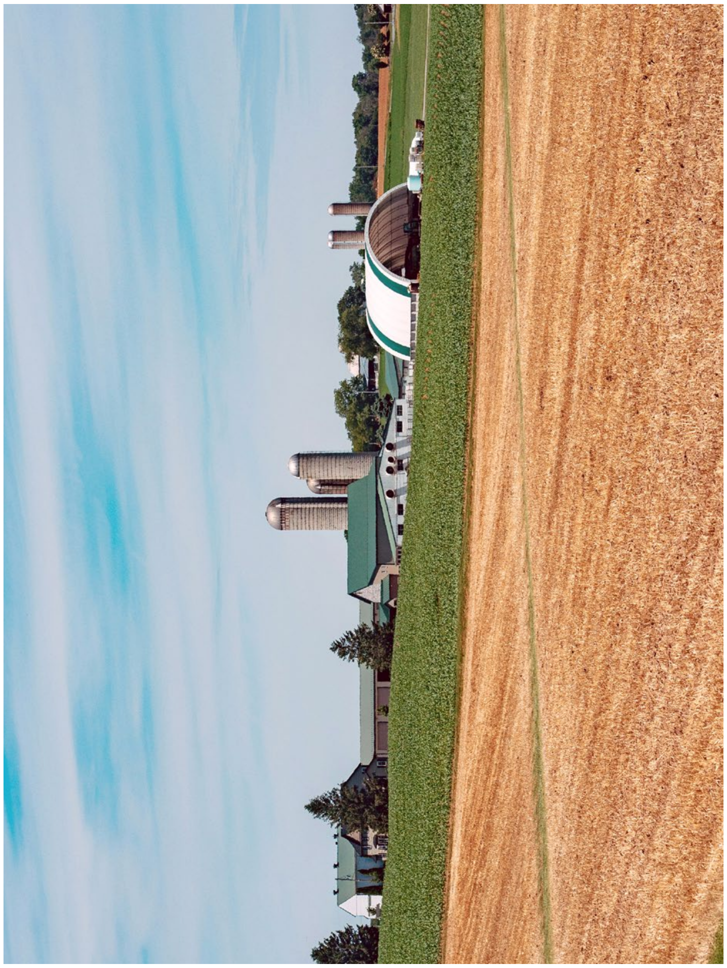
MOST SUCCESSFUL TRAITS

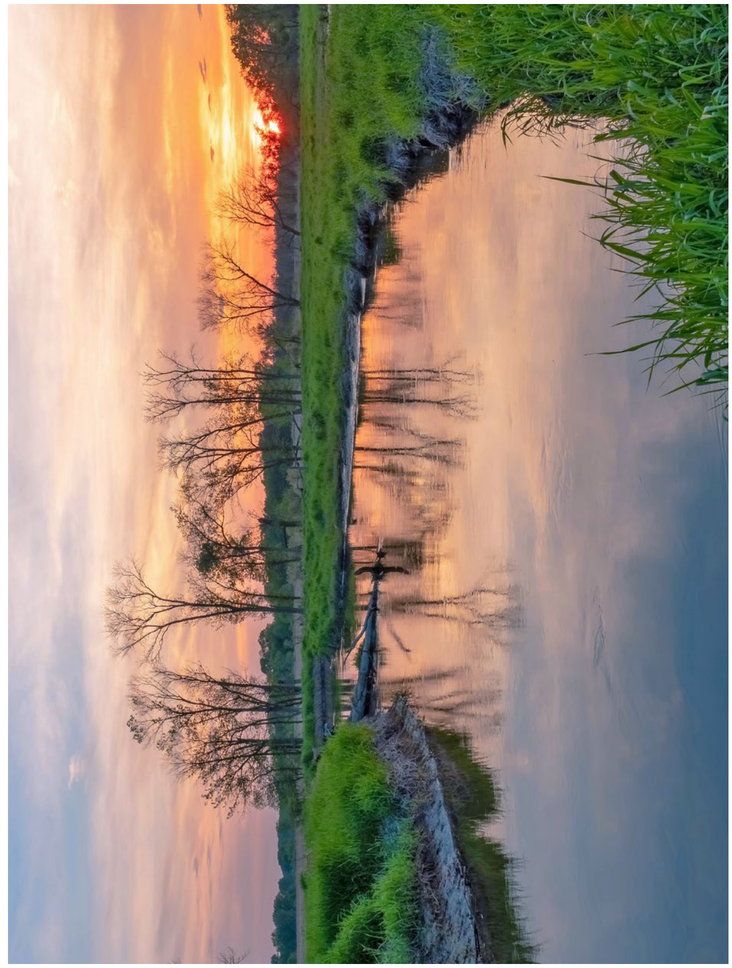
1.

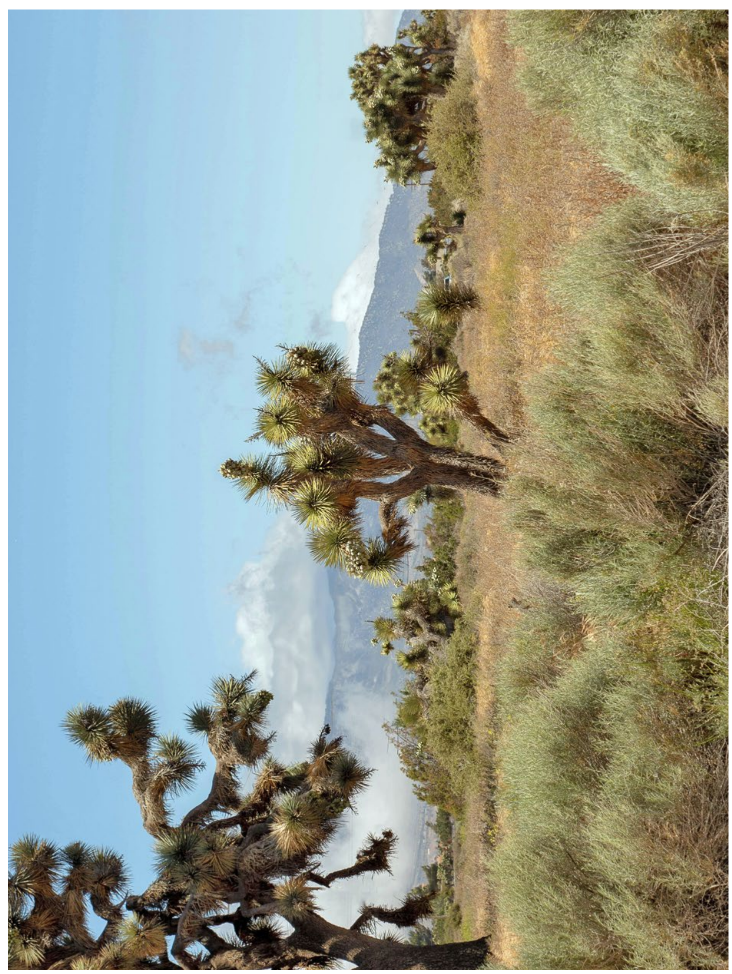
2.

LESSONS LEARNED

- How did selective breeding affect your chicken population?
- What environmental factors had the biggest impact?
- How did genetic traits influence survival and reproduction?
- Which loss of diversity method did your group experience most?







Urbanization

Environment: Forest

Description: Forest area has been cut in half due to housing development, decreasing the availability of food and water in the forest.

Effect: Reduce survival points by (−2) for all chickens in the forest.

Predator attack

Environment: Forest

Description: Predators are more active in the forest this season.

Effect: Chickens with camouflage (brown feathers) gain (+2) survival points. Chickens without camouflage lose (−1) survival point.

Plentiful harvest

Environment: Farm

Description: An unusually bountiful harvest provides ample food for chickens on the farm.

Effect: All chickens on the farm gain (+2) survival points. If a small beak trait is present, gain (+1) additional survival point.

Disease outbreak

Environment: Farm

Description: An avian flu outbreak spreads among farm chickens.

Effect: Chickens with low disease resistance lose (−2) survival points. Chickens with high disease resistance gain (+1) survival point.

Heatwave

Environment: Desert

Description: An intense heat wave strikes the desert.

Effect: Chickens with high heat tolerance gain (+3) survival points. Chickens with low heat tolerance lose (–2) survival points.

Flash flood

Environment: Desert

Description: A sudden flash flood impacts the desert area.

Effect: All chickens in the desert lose (–1) survival point unless they have long legs, in which case they gain (+1) survival point.

Insect swarm

Environment: Any

Description: A swarm of insects provides a temporary food bounty in all areas.

Effect: All chickens with large beaks gain (+3) survival points. Chickens with small beaks gain (+2) survival points. If the beak trait is not present, lose (–1) survival point.

Cold snap

Environment: Wetland

Description: An unexpected cold snap hits the wetland area.

Effect: Chickens with thick feathers gain (+2) survival points. Chickens without thick feathers lose (–1) survival point.

Wildfire

Environment: Forest

Description: A wildfire sweeps through part of the forest.

Effect: All chickens in the affected area lose (−2) survival points. Chickens with high mobility (long legs) gain (+1) survival point.

Resource boom

Environment: Any

Description: An unexpected abundance of resources in one environment.

Effect: The player may choose any one environment. All chickens in that environment gain (+2) survival points.

Migration opportunity

Environment: Any

Description: Favorable conditions for migration.

Effect: Players can move chickens to a different environment without penalty.

Cold winter

Environment: Wetland

Description: An unusually cold winter affects the farm.

Effect: Chickens with thick feathers gain (+2) survival points. Chickens without thick feathers lose (−1) survival point.

Pest infestation

Environment: Farm

Description: Chicken mites attack chickens at night.

Effect: Reduce survival points by (−2) for all chickens on the farm.

New predator introduction

Environment: Wetland

Description: A new predator has been introduced to the wetland area.

Effect: Chickens without camouflage lose (−2) survival points. Chickens with camouflage (brown feathers) gain (+1) survival point.

Windstorm

Environment: Desert

Description: A strong windstorm hits the desert.

Effect: All chickens in the desert lose (−1) survival point. Chickens with strong beaks gain (+1) survival point.

Dam built

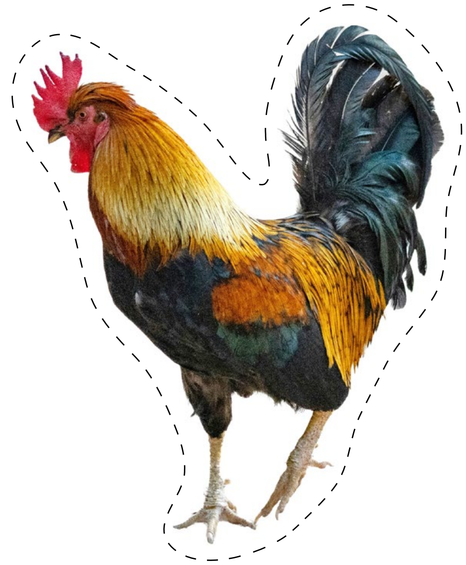
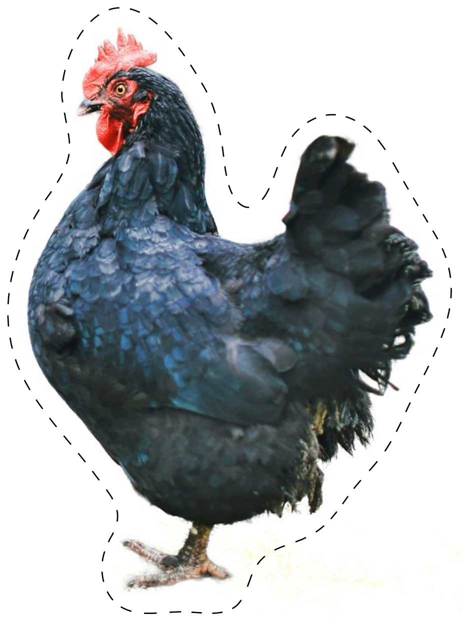
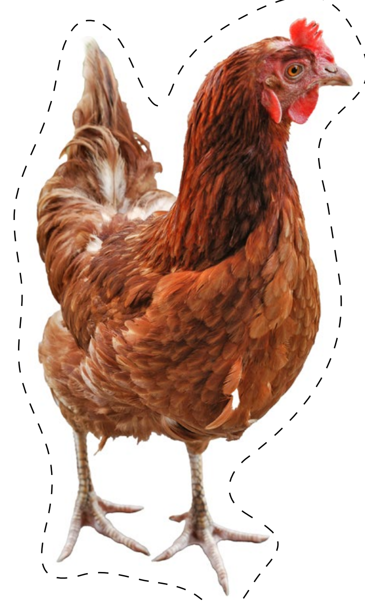
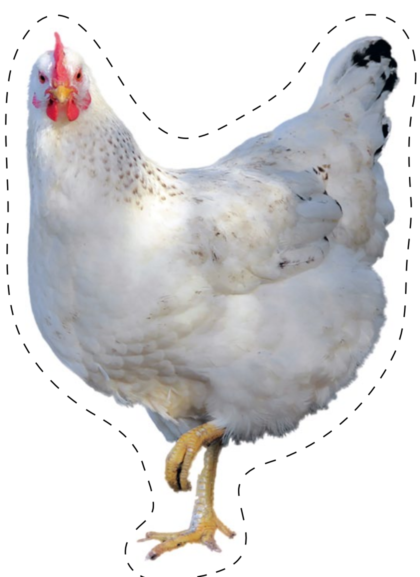
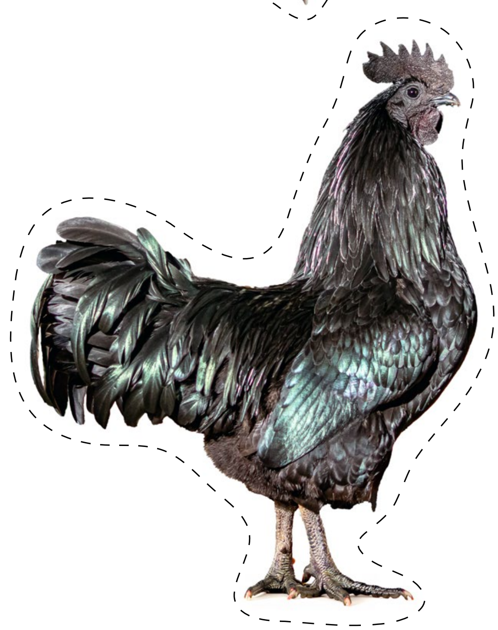
Environment: Wetlands and Farm

Description: Wetlands become flooded and farms experience drought.

Effect: All chickens in the wetlands or farm lose (−1) survival point unless they have long legs, in which case they gain (+1) survival point.





1

Starting environment *(circle one)*:
forest farm desert wetland

Trait: ______________________________

Survival points: ______________________

Effect: _____________________________

2

Starting environment *(circle one)*:
forest farm desert wetland

Trait: ______________________________

Survival points: ______________________

Effect: _____________________________

3

Starting environment *(circle one)*:
forest farm desert wetland

Trait: ______________________________

Survival points: ______________________

Effect: _____________________________

4

Starting environment *(circle one)*:
forest farm desert wetland

Trait: ______________________________

Survival points: ______________________

Effect: _____________________________

1

Starting environment *(circle one)*:
forest farm desert wetland

Trait: ______________________________

Survival points: ______________________

Effect: _____________________________

2

Starting environment *(circle one)*:
forest farm desert wetland

Trait: ______________________________

Survival points: ______________________

Effect: _____________________________

3

Starting environment *(circle one)*:
forest farm desert wetland

Trait: ______________________________

Survival points: ______________________

Effect: _____________________________

4

Starting environment *(circle one)*:
forest farm desert wetland

Trait: ______________________________

Survival points: ______________________

Effect: _____________________________

Trait 1

Feather color

Chickens with brown feathers

Effects

- Forest: +2 survival points (camouflage from predators)
- Farm: Neutral
- Desert: –1 survival point (overheats in the sun)
- Wetland: Neutral

Trait 2

Beak size

Chickens with small beaks

Effects

- Forest: Neutral
- Farm: +2 survival points (efficient for pecking grain)
- Desert: –1 survival point (less effective for finding scarce food)
- Wetland: Neutral

Trait 3

Feather color

Chickens with brown feathers

Effects

- Forest: +2 survival points (camouflage from predators)
- Farm: Neutral
- Desert: –1 survival point (overheats in the sun)
- Wetland: Neutral

Trait 4

Leg length

Chickens with long legs

Effects

- Forest: +1 survival point (better mobility in dense underbrush)
- Farm: Neutral
- Desert: +1 survival point (can cover more ground in search of food)
- Wetland: +2 survival points (better for wading in water)

Trait 5

Feather color

Chickens with white feathers

Effects

- Forest: –2 survival points (easily spotted by predators)
- Farm: Neutral
- Desert: +1 survival point (reflects heat)
- Wetland: –1 survival point (more visible in open areas)

Trait 6

Leg length

Chickens with short legs

Effects

- Forest: –1 survival point (less mobility)
- Farm: +1 survival point (stable and sturdy)
- Desert: Neutral
- Wetland: –2 survival points (difficulty in wading)

Trait 7

Disease resistance

Chickens resistant to common diseases

Effects

- Forest: +2 survival points
- Farm: +2 survival points
- Desert: +1 survival point
- Wetland: +2 survival points

Trait 8

Heat tolerance

Chickens that cannot withstand high temperatures

Effects

- Forest: Neutral
- Farm: Neutral
- Desert: –3 survival points
- Wetland: Neutral

Trait 9

Beak size

Chickens with small beaks

Effects

- Forest: Neutral
- Farm: +2 survival points
  (efficient for pecking grain)
- Desert: –1 survival point
  (less effective for finding scarce food)
- Wetland: Neutral

Trait 10

Leg length

Chickens with long legs

Effects

- Forest: +1 survival point
  (better mobility in dense underbrush)
- Farm: Neutral
- Desert: +1 survival point
  (can cover more ground in search of food)
- Wetland: +2 survival points
  (better for wading in water)

Trait 11

Beak size

Chickens with large beaks

Effects

- Forest: +1 survival point
  (good for cracking hard seeds)
- Farm: Neutral
- Desert: Neutral
- Wetland: +1 survival point (useful for foraging)

Trait 12

Night vision

Chickens that have low night vision

Effects

- Forest: –3 survival points
- Farm: +2 survival points
- Desert: –3 survival points
- Wetland: Neutral

Trait 13

Disease resistance

Chickens are prone to diseases

Effects

- Forest: −2 survival points
- Farm: −2 survival points
- Desert: −1 survival point
- Wetland: −2 survival points

Trait 14

Heat tolerance

Chickens that can withstand high temperatures

Effects

- Forest: Neutral
- Farm: Neutral
- Desert: +3 survival points
- Wetland: Neutral

Trait 15

Night vision

Chickens that have high night vision

Effects

- Forest: +3 survival points
- Farm: −2 survival points
- Desert: +3 survival points
- Wetland: Neutral

Trait 16

Beak size

Chickens with large beaks

Effects

- Forest: +1 survival point
  (good for cracking hard seeds)
- Farm: Neutral
- Desert: Neutral
- Wetland: +1 survival point (useful for foraging)

Trait 17

Feather color

Chickens with white feathers

Effects

- Forest: –2 survival points (easily spotted by predators)
- Farm: Neutral
- Desert: +1 survival point (reflects heat)
- Wetland: –1 survival point (more visible in open areas)

Trait 18

Heat tolerance

Chickens that can withstand high temperatures

Effects

- Forest: Neutral
- Farm: Neutral
- Desert: +3 survival points
- Wetland: Neutral

Trait 19

Beak size

Chickens with small beaks

Effects

- Forest: Neutral
- Farm: +2 survival points (efficient for pecking grain)
- Desert: –1 survival point (less effective for finding scarce food)
- Wetland: Neutral

Trait 20

Leg length

Chickens with short legs

Effects

- Forest: –1 survival point (less mobility)
- Farm: +1 survival point (stable and sturdy)
- Desert: Neutral
- Wetland: –2 survival points (difficulty in wading)

Investigate biosecurity

How do we use biosecurity to keep chickens safe?

Standards

- **Nature of science:** Identify questions and concepts that guide scientific investigations.
- **Nature of science:** Design and conduct scientific investigations using a variety of methods and tools to collect empirical evidence, observing appropriate safety practices.
- **B.DI.3:** Loss of diversity: Humans are a biotic factor in ecosystems and can impact critical variables within these systems.

Introduction

One of the most important ways to prevent disease exposure to your flock is to recognize the early signs of infection and know how to prevent them from spreading. Biosecurity is a set of measures put in place at commercial poultry operations to help minimize the spread of disease.

Student prior knowledge

Problem solving and decoding are important skills to have as a scientist. Students should understand how pathogens spread among populations and how chicken behavior can affect the movement of disease within the flock.

Suggested timeline

1 to 2 class periods (50–100 minutes)

Materials

- Chicken diseases FAQ and worksheet
- Chicken housing FAQ and worksheet
- Poultry biosecurity FAQ and worksheet
- Student clue cards
- Writing utensils

Teacher preparation

- Before class starts, make copies of the chicken housing, poultry biosecurity and chicken diseases FAQs and worksheets and the student clue cards.
- Place students into groups to collaborate for this lesson.

Procedure

1. Introduce the following scenario to students: Avian Influenza Outbreak Due to Biosecurity Lapses.
2. Next, read the background to the students: Cluckingham Palace is a medium-sized chicken farm with several barns housing thousands of chickens. The farm has been operating successfully for years with relatively good biosecurity practices in place. However, due to a recent lapse in biosecurity measures, the farm is experiencing an outbreak of avian influenza. Play the game and figure out who did it!
    a. Students will be given the articles to read one at a time. They will answer the questions after each article and find the CODE word.
    b. Once the students have the code word, have them bring the card to the teacher. The teacher then gives the students the corresponding clue cards. (Chicken–Chicken, Workers–Workers, Barn–Barn).

c. After the students have all three sets of clue cards, they will use the information on the cards to determine which three actions are responsible for allowing the disease to spread through the farm.
d. Students will choose a barn, a worker, and a chicken from each section that they think is the culprit of the outbreak. Students will bring the allegations to the veterinarian (teacher) to determine if they have solved the mystery at Cluckington Palace.

Suggested wrap-up activity

Discuss the purpose of chicken housing and the different types of housing used in poultry farming. Have students research the importance of coop design principles, including ventilation, lighting, nesting boxes, and roosting bars for small and large farms. Discuss the importance of biosecurity protocols and their role in preventing disease spread within poultry flocks.

Differentiation

- Level the text depending on student needs.
- Make a timed challenge or a race to see who finishes first.

More challenges

- Have the students research each of the diseases in more detail and determine which disease is affecting the flock. Determine the most likely source of the disease in the farm.
- **Home connection:** Watch the virtual field trip on biosecurity: https://www.youtube.com/live/mFv8J1MuJnY?si=1lxF3NPooWpig2uW. You could also interview a local poultry farmer about the biosecurity measures they use at their farm.

Support information

- **Biosecurity:** procedures intended to protect humans or animals against disease or harmful biological agents.
- **Culling:** removal of a chicken from the flock.
- **Pullets:** a young hen that is under 1 year of age and has not started laying eggs yet.
- **Pol hens:** a young hen between 18 and 22 weeks.
- Ohio's poultry farms implement strict biosecurity measures to prevent the spread of diseases. These measures include controlled access to farms, sanitation protocols, and monitoring of flock health. Many of Ohio's poultry farms have modern facilities equipped with advanced technology to ensure the health and welfare of the birds. These facilities help to ensure biosecurity measures. Giving students real world connections and problems to solve enhances students' understanding of the content.
- National Poultry Improvement Plan: https://www.ohiopoultry.org/Backyard-Flocks/index.cfm
- Defend the flock: https://www.aphis.usda.gov/livestock-poultry-disease/avian/defend-the-flock
- Poultry biosecurity for 4-H: https://www.youtube.com/watch?v=TnseqPmzJO4

Teaching suggestions

- This activity can be played in a number of ways. You can play it as a class, in pairs, or small groups. You could also assign one group to each of the clue cards and as a class have a debate to determine the three clues.
- Students can do additional research to support their claims.
- Have students determine the source and the spreader of the outbreak to the rest of the barns.
- Teachers can also add additional articles related to each of the diseases represented in the chicken cards.

Career connections

Have you ever wondered what type of poultry careers help to make a healthy, safe environment for commercial birds? Let's take a look!

- **Hatchery workers** manage hen care and equipment to achieve high hatchability while performing tasks such as egg setting, transfer, and care of day-old chicks.
- **Poultry caretakers** help with monitoring flocks for their health and well-being, ensuring they have constant access to fresh food and water as well as a safe living environment. Caretakers walk their barns everyday to check their flock and the equipment that helps to keep them safe and fed.
- **Flock managers** are responsible for assisting in the overall success of the daily pullet barn operations.
- **Maintenance technicians** must be able to read schematics, maintain, troubleshoot, and repair all production equipment, along with support and building services.
- **Poultry service technicians** perform equipment adjustments and repairs, preventive maintenance, and emergency maintenance.
- **Poultry production managers** oversee areas of animal husbandry, flock management, bird scheduling, and movement. They work to determine feeding recommendations.

Answer key

Chicken diseases worksheet

1. What is the primary cause of Pullorum disease?
    a. Avian influenza virus
    c. *Salmonella pullorum* bacterium
    d. Infectious Coryza bacterium
    f. Newcastle disease virus
2. Avian influenza can cause which of the following symptoms in poultry?
    d. Swelling of the face and sinuses
    a. Foamy discharge from the eyes and nostrils
    b. Reduced egg production
    k. All of the above
3. What is a common method of transmission for avian influenza?
    m. Vertical transmission from hen to chick
    t. Contaminated water sources
    i. Direct contact with infected birds
    z. All of the above
4. Infectious coryza is primarily a disease affecting which part of the chicken?
    r. Digestive system
    n. Respiratory system
    b. Reproductive system
    w. Nervous system
5. What is a recommended method for preventing avian influenza outbreaks on a poultry farm?
    f. Feeding antibiotics regularly
    r. Keeping birds in overcrowded conditions
    h. Following strict biosecurity measures
    i. Allowing wild birds access to feed and water
6. Which symptom is *not* associated with infectious coryza?
    o. Swollen eyes
    h. Foul-smelling nasal discharge
    c. Sudden death
    j. Reduced feed intake
7. How is infectious coryza primarily transmitted?
    e. Through direct contact with infected birds
    h. Through aerosol transmission
    p. Through contaminated eggs
    q. Through wild bird droppings

Unscramble the letters of the multiple choice answers to determine which cards you need.

C	H	I	C	K	E	N

Chicken housing worksheet

Important factors for backyard flock housing:

- Providing clean water at all times.
- Ensuring good airflow to prevent respiratory issues.
- Installing locks or latches on coop doors to deter predators.
- Using poultry-safe disinfectants to sanitize the coop.
- Offering one nesting box per 3–4 hens.
- Maintaining a layer of bedding at least 4 inches deep.

Unscramble the highlighted letters to find the clue.

B	A	R	N		C	A	R	D	S

Poultry biosecurity worksheet

1. Who should ask for permission before entering a poultry facility?

V	I	S	I	T	O	R	S

2. Disinfect equipment, vehicles, and footwear before and _____.

A	F	T	E	R

3. Implementing biosecurity zones _______ movement to a minimum.

K	E	E	P	S

4. Eliminate standing ________ sources.

W	A	T	E	R

5. Monitor birds for signs of illness or unusual ________

B	E	H	A	V	I	O	R

6. Wear clean clothing and _______ dedicated to the farm.

F	O	O	T	W	E	A	R

Unscramble the letters in the highlighted boxes to determine which cards you need.

W	O	R	K	E	R

Next steps

Now that you have all the clue cards, choose one barn, worker, and chicken from each section that you think is the culprit of the outbreak. Take your allegations to the veterinarian (teacher) to determine if you have solved the mystery at Cluckington Palace.

ANSWER TO THE CLUES

- Maintenance Technician found the hole that let the outside bird into the farm.
- Barn Two is the source.
- Chickpea has the avian flu.
- If they do the extensions, Lady Cluckington spreads the outbreak to the other barns.

Chicken diseases

Welcome to our guide on common diseases that affect chickens. Understanding these diseases is essential for maintaining the health and welfare of your flock. Here are the details on three significant diseases: Pullorum disease, avian influenza, and infectious coryza.

Pullorum disease

Pullorum disease, caused by the bacterium Salmonella pullorum, primarily affects young chicks but can also affect older birds.

SYMPTOMS

- Weakness and lethargy
- Diarrhea, often pasty white or yellowish in appearance
- Drooping wings
- Decreased feed intake
- Reduced growth rate

TRANSMISSION

- Vertical transmission (from infected hen to chick through the egg)
- Contaminated environment, feed, or water

PREVENTION AND CONTROL

- Test and cull infected birds
- Maintain strict biosecurity measures
- Clean and disinfect poultry housing and equipment

Avian influenza

Avian influenza (AI) is a highly contagious viral disease affecting domestic and wild birds. Some strains can cause severe illness and high mortality rates in poultry.

SYMPTOMS

- Respiratory signs like coughing, sneezing, and nasal discharge
- Swelling of the head, comb, and wattles
- Decreased egg production and quality

TRANSMISSION

- Direct contact with infected birds
- Contaminated equipment, clothing, and footwear
- Exposure to infected wild birds or their droppings

PREVENTION AND CONTROL

- Practice strict biosecurity measures
- Restrict movement of birds and personnel
- Report suspected cases to veterinary authorities

Infectious coryza

Infectious coryza is a bacterial respiratory disease caused by Avibacterium paragallinarum, primarily affecting chickens.

SYMPTOMS

- Swelling of the face and sinuses (swollen eyes)
- Foamy discharge from the eyes and nostrils
- Foul-smelling, bloody nasal discharge
- Reduced feed and water intake
- Drop in egg production and quality

TRANSMISSION

- Direct contact with infected birds or contaminated surfaces
- Aerosol transmission via respiratory secretions
- Carrier birds shedding the bacterium without showing symptoms

PREVENTION AND CONTROL

- Maintain good hygiene and sanitation practices
- Isolate and treat infected birds
- Practice strict quarantine measures for new birds

Remember, early detection and proper management are crucial in preventing disease outbreaks and minimizing their impact on your flock's health and productivity. Regular monitoring, good biosecurity, and prompt veterinary attention are key to maintaining a healthy chicken flock.

For more information or if you suspect any of these diseases in your flock, contact veterinarian Dr. Bawk Vader immediately.

Chicken diseases worksheet

1. What is the primary cause of Pullorum disease?
    a. Avian influenza virus
    c. *Salmonella pullorum* bacterium
    d. Infectious Coryza bacterium
    f. Newcastle disease virus
2. Coryza can cause which of the following symptoms in poultry?
    d. Swelling of the face and sinuses
    a. Foamy discharge from the eyes and nostrils
    b. Reduced egg production
    k. All of the above
3. What is a common method of transmission for avian influenza?
    m. Vertical transmission from hen to chick
    t. Contaminated water sources
    i. Direct contact with infected birds
    z. All of the above
4. Infectious coryza is primarily a disease affecting which part of the chicken?
    r. Digestive system
    n. Respiratory system
    b. Reproductive system
    w. Nervous system
5. What is a recommended method for preventing avian influenza outbreaks on a poultry farm?
    f. Feeding antibiotics regularly
    r. Keeping birds in overcrowded conditions
    h. Following strict biosecurity measures
    i. Allowing wild birds access to feed and water
6. Which symptom is *not* associated with infectious coryza?
    o. Swollen eyes
    h. Foul-smelling nasal discharge
    c. Sudden death
    j. Reduced feed intake
7. How is infectious coryza primarily transmitted?
    e. Through direct contact with infected birds
    h. Through contaminated equipment
    p. Through decreased egg production
    q. Through quarantine measures for new birds

Unscramble the letters of the multiple choice answers to determine which cards you need.

Chicken housing

Welcome to our guide on chicken housing and facilities. Proper housing is essential for the health, safety, and productivity of your chickens. Here's what you need to know:

HOUSING TYPES

- Free-range: Chickens have access to indoor housing and outdoor space.
- Battery cage: Individual cages for each bird, commonly used in commercial egg production.
- Deep litter: Bedding is continuously added to the floor, providing insulation and composting capabilities.
- Pasture-based: Chickens roam freely on pasture during the day and return to a coop at night.

COOP DESIGN

- Size: Allow at least 2–4 square feet of space per bird inside the coop. Provide additional outdoor space if possible.
- Ventilation: Provide adequate ventilation to prevent moisture buildup and respiratory issues.
- Temperature: Provide adequate heating or cooling depending on climate and season.
- Insulation: Ensure coops are insulated and draft-free during colder months to maintain warmth.
- Lighting: Ensure natural or artificial lighting is sufficient for egg production and bird health.
- Nesting boxes: Provide one nesting box per 4–5 hens, with clean bedding for egg-laying.
- Roosting bars: Allow 6–12 inches of roosting space per bird, elevated above the ground.
- Enrichment: Provide dust bathing areas and enrichment items to keep chickens active and entertained.
- Shade: Provide shaded area in the run during hot weather to prevent heat stress.

BEDDING AND LITTER

- Materials: Common options include straw, wood shavings, or recycled paper.
- Depth: Maintain a minimum depth of 4–6 inches, adding more as needed.
- Cleaning: Regularly add fresh bedding and turn the litter to promote decomposition and prevent odor.
- Composting: Used bedding can be composted for fertilizer.

FEED AND WATER

- Feeders: Choose feeders suitable for the number of birds to prevent overcrowding.
- Waterers: Provide clean, fresh water at all times, replacing it regularly to prevent contamination.
- Placement: Keep feeders and waterers raised off the ground to minimize contamination.
- Water management: Prevent standing water and drainage issues in coop and run areas.

SECURITY

- Predator protection: Secure coops and runs with sturdy fencing and hardware cloth to prevent entry by predators.
- Rodent control: Keep feed in rodent-proof containers and seal any entry points for rodents.
- Biosecurity: Implement measures to prevent disease transmission, such as foot baths and controlled access.
- Visitor protocol: Limit visitor access and require biosecurity measures for anyone entering the premises.
- Equipment Control: Prevent sharing of equipment with other poultry farms to avoid disease transmission.

Remember: Well-designed and maintained housing and facilities are essential for the health and welfare of your chickens. Regular monitoring, cleaning, and maintenance will help ensure a productive and healthy flock.

For more information or specific questions about chicken housing, feel free to contact us.
Cluck Norris of Nugget Construction

Chicken housing worksheet

Important factors for backyard flock housing:

- Providing clean water at all times.
- Ensuring good airflow to prevent respiratory issues.
- Installing locks or latches on coop doors to deter predators.
- Using poultry-safe disinfectants to sanitize the coop.
- Offering one nesting box per 3–4 hens.
- Maintaining a layer of bedding at least 4 inches deep.

Unscramble the highlighted letters to find the clue.

Poultry biosecurity

Welcome to our poultry farm! To ensure the health and safety of our birds and the prevention of disease spread, it's essential to follow proper biosecurity measures. Please read and adhere to the following guidelines:

RESTRICTED ACCESS

- Only authorized personnel should have access to the poultry facilities.
- Visitors must obtain permission and follow biosecurity protocols before entering the farm.

CLOTHING AND FOOTWEAR

- Wear clean clothing and footwear dedicated to the farm.
- Use disposable shoe covers and disinfect boots before entering poultry areas.

HAND HYGIENE

- Wash hands thoroughly with soap and water before and after handling birds or eggs.
- Use hand sanitizers provided at designated locations.

EQUIPMENT AND VEHICLES

- Equipment and vehicles entering the farm should be clean and disinfected.
- Disinfect equipment, vehicles, and footwear before and after use.

BIRD HEALTH MONITORING

- Monitor birds for signs of illness, such as decreased feed intake or unusual behavior.
- Report any signs of illness to farm management immediately.

PEST CONTROL

- Implement measures to control pests such as rodents and wild birds.
- Secure feed storage areas and eliminate standing water sources.

BIOSECURITY ZONES

- Implement biosecurity zones to control movement within the farm.
- Keep poultry houses and production areas separate from other farm activities.

CLEANLINESS AND SANITATION

- Keep poultry facilities clean and well-maintained.
- Regularly clean and disinfect equipment, feeders, and waterers.

By following these biosecurity measures, you are helping to protect the health and welfare of our poultry and ensure the sustainability of our farm. Thank you for your cooperation!

For any questions or concerns, please contact farm management.
Henrietta Eggbert, Cluckington Palace

Poultry biosecurity worksheet

1. Who should ask for permission before entering a poultry facility?

2. Disinfect equipment, vehicles, and footwear before and _____.

3. Implementing biosecurity zones _______ movement to a minimum.

4. Eliminate standing ________ sources.

5. Monitor birds for signs of illness or unusual ________

6. Wear clean clothing and _______ dedicated to the farm.

Unscramble the letters in the highlighted boxes to determine which cards you need.

WORKER

Flock Manager

Cluckingham Palace has four separate barns. The flock manager did not change clothes before entering the third barn and forgot to wear foot covers.

WORKER

Poultry Service Technician

Today was a busy day for the poultry service technician; he visited 10 farms. Due to his stressful day he forgot to wash his car before entering Cluckingham Palace. One of the previous farms reported having sick birds the next day. He entered Barn Four first.

WORKER

Poultry Production Manager

The Poultry Production Manager was running late for an appointment and did not wait for the door locking system to be fully activated before entering Barn One. This could allow an outside bird to gain access to the barn.

WORKER

Maintenance Technician

While working on the air condition vents at Cluckingham Palace, a hole was discovered in one of the screens of Barn Two. This could allow outside birds to gain access to the barn.

CHICKEN

Henny Penny

Henny lives in Barn One. She has been experiencing some nasal discharge, swollen sinuses, and a swollen face. She has been eating less food as well.

CHICKEN

Chickpea

Chickpea lives in Barn Two. She is experiencing a swollen face and diarrhea, along with a loss of appetite and decreased egg production.

CHICKEN

Amelia Egghart

Amelia lives in Barn Three. She has been experiencing white diarrhea which is causing some dehydration.

CHICKEN

Lady Cluckington

Lady Cluckington now lives in Barn Four. She was recently moved by the Poultry Service Technician from Barn Two because of conflicts with other flock members and depression.

FACILITY

Barn One

Pol hens
Age of chickens: 22 weeks to 24 weeks

FACILITY

Barn Two

Laying hens
Age of chickens: approx 1 year to 5 years

FACILITY

Barn Three

Pullets
Age of chickens: 15 to 22 weeks

FACILITY

Barn Four

Laying hens
Age of chickens: approx. 1 year to 5 years

Investigate biodiversity

How do inherited traits impact survival? How can we use Simpson's Index of Diversity to quantify the change of diversity within an ecosystem?

Standards

- **B.H.3: Genetic mechanisms and inheritance**
- **B.E.1: Mechanisms:** Natural Selection
- **B.DI.1: Biodiversity:** Species Diversity

Introduction

What characteristics help organisms to survive and reproduce over time? The theory of natural selection demonstrates how genetic variation within a species provides different traits that help certain members of a population survive and reproduce, passing on these traits to the next generation. Simpson's Index of Diversity is a tool used to measure the level of biodiversity present in each ecosystem. It measures both the species richness and the species evenness in a community.

Student prior knowledge

Students should be familiar with the process of natural selection and the concept of "survival of the fittest". It is important that they understand what heritable traits are (variation within species) and how they are passed down from one generation to the next. This knowledge will help them to understand how competition within an ecosystem can lead to evolutionary change within that ecosystem over time.

Students should also have a basic understanding of algebra in order to utilize Simpson's Index of Diversity to determine the level of diversity within an ecosystem.

Suggested Timeline

1–2 class periods (50–100 minutes)

Materials

- *Natural selection and change* student sheet
- 1 plastic cup per student (stomach)
- 1 large plastic cup per student (community cup)
- Beak options (1 set per group of 4–5 students)
    - 1 plastic spoon
    - 1 paper clip
    - 1 set of chopsticks
    - 1 forceps
    - 1 pipe cleaner
    - Alternative: any classroom item can be used for a beak
- Food items per student group. These items can either be counted or weighed. They should be dry beans:
    - 100 split peas or 150 g split peas
    - 100 lentils or 150 g lentils
    - 100 navy beans or 150 g navy beans
    - 100 pinto beans or 150 g pinto beans
    - 100 black-eyed beans or 150 g black-eyed beans
- *Suggested: 1 large pizza box per group*

Teacher preparation

Prepare student group materials: 4 empty cups, 1 spoon, 1 forceps, 1 paperclip, 2 chopsticks, 1 pipe cleaner, 1 cup containing the assortment of beans above in the materials section. The pizza box, if used, will help keep beans in one area.

Procedure

PART 1: SURVIVAL OF THE FITTEST SIMULATION

1. Introduce the topic of natural selection by survival of the fittest. Ask the students what they think "survival of the fittest" means.
    - How can one organism do better than (outcompete) another organism in its environment?
    - If an organism is able to perform better, what does that mean for that organism?
    - How will it pass this advantageous trait on to the next generation?
    - How does the survival of the fittest theory impact the biodiversity of an ecosystem?
2. Ask students what an organism's basic needs are. Ask them to discuss this with a partner and fill in the Survival of the Fittest student sheet.
3. Pass out the food, beaks, and cups (and pizza box, if using) to each student group.
    - Let the students explore the beak types and food for a few minutes. Each student will use the same beak throughout the entire simulation.
    - Ask them to write a claim of their beak's ability to consume food based on their observations. Will they survive (be able to consume enough food) in order to reproduce and pass on their heritable trait?
4. Play the Survival of the Fittest simulation. Each round is 60 seconds (1 minute) long.
    - **Round 1**: Have the students record the quantity or weight of different beans that they will try to consume in the following rounds on their data chart. Dump 1 cup of beans on the student group table (or dump into the empty pizza box to help keep beans on the table). Have each student practice using their beak to 'eat' the food for one minute. When they are finished, have them record the amount of beans on their chart and place their stomach contents into the community cup. *Note: Students must pick up each piece of food individually and place it in the cup without scooping it into the cup. One hand must hold the cup; the other hand must hold the beak.*
    - **Round 2**: Have each student group stand in a circle with their beaks and stomachs ready. Do not add any additional beans to this round. Have each student try to "eat" as much of the remaining beans as they can in 60 seconds. Record the group data on the student sheet. *Remember, their goal is to survive and make it to the next round.*
    - **Round 3:** The top 3 students from each group compete in this round. Do not add any additional beans to the table. Have the students stand in a circle with their beaks and stomachs ready. Have each student try to "eat" as much as they can in 60 seconds. Record data on the student sheet.
5. Have students submit class data to determine which beak type (trait) performs best. Which beak type is most successful? (Alternatively, students can also examine food data. Food sources are plants, which reproduce. Which food type is most successful and able to survive to reproduce into the next generation?)

PART 2: SIMPSON'S INDEX OF DIVERSITY

6. Next, have the students use their data as a class to calculate the difference in biodiversity between the beginning populations of beans and beaks (before round 1) compared to the final biodiversity of the same species (after round 3).

Suggested wrap-up activity

Have students discuss the importance of competition within species. Ultimately, if competition drives how traits are selected for within a species, and there is high competition for food resources, how might this impact evolution? What happens to the ecosystem's biodiversity over time? Or conversely, what happens to a species when competition ceases to exist?

Differentiation

- Differentiate according to students' fine motor skills. It might be necessary to use only large feed items and/or spoons as beaks if this differentiation piece is necessary for the students.
- Provide only 1 food type and 1 beak type to a group of students to determine alternative heritable traits such as agility, eyesight, behavior, etc.
- Provide students with predetermined data for analysis instead of participating in the modeling lab.

More challenges

- Have the students watch the following video and describe how natural selection has led to new finch species on the Galápagos Islands. **youtu.be/sG4Y8sVYfFY** How has the biodiversity of this island changed with natural selection?
- Explain how the black pepper moth coloration changes from year to year depending upon predation. Peppered moth simulation: **echalk.co.uk/Science/Biology/PepperedMoth/PepperedMoth.htm**
- **Home connection:** How are modern poultry farms changing the necessity for variation among poultry for production needs? How are consumer choices (white meat preferences, food costs, etc.) related to trait selection in poultry for commercial production?

Support information

- **Biodiversity:** the number of different species within an ecosystem.
- **Species richness:** the number of species within an area.
- **Species evenness:** the measure of relative abundance of each species within an area.

THE THEORY OF EVOLUTION BY NATURAL SELECTION

- **Variation:** Members of any given species are seldom exactly the same, either inside or outside. Organisms can vary in size, coloration, ability to fight off diseases, and countless other traits.
- **Inheritance:** When organisms reproduce, they pass on their DNA–the set of instructions encoded in living cells for building bodies–to their offspring. Since many traits are encoded in DNA, offspring often inherit the variations of their parents.
- **Selection**: Environments cannot support unlimited populations. Because resources are limited, more organisms are born than can survive. Some individuals will be more successful at finding food, mating, or avoiding predators and will have a better chance to thrive, reproduce, and pass on their DNA. Small variations can influence whether or not an individual lives and reproduces.
- **Time**: In generation after generation, advantageous traits help some individuals survive and reproduce. These traits are passed on to greater and greater numbers of offspring. After just a few generations or after thousands, such traits become common in the population.
- **Adaptation:** The result is a population that is better suited—better adapted—to some aspect of the environment than it was before. The Survival of the Fittest simulation is one way to explain biological fitness, the ability of an organism to reproduce and pass on its DNA to the next generation. Therefore, "survival of the fittest" means that the fittest organism in a population is the organism that is able to breed and reproduce most successfully.

SIMPSON'S INDEX OF DIVERSITY

A tool used to measure the level of diversity within an ecosystem or community. It measures both the species richness and the species evenness in a community. A community dominated by one or two species is considered to be less diverse than one in which several species have a similar abundance. The Simpson's Index of Diversity value (D) ranges between 0 and 1. In Simpson's Index of Diversity, "1" represents infinite diversity and "0", no diversity.

Bozeman science: Ecosystem diversity: `youtu.be/QKIMS0hVJdc`

$$D = 1 - \frac{\Sigma\, n(n-1)}{N(N-1)}$$

Simpson's Index of Diversity

n = the total number of organisms of a particular species

N = the total number of organisms of all species

Teaching suggestions

This can be a messy lesson to do with students! It may be a good idea to create an area for your students to feed in such as a new pizza box or something similar that is the same size for all student groups. This will provide a measurable area for the ecosystem as well as provide camouflage for food items to hide in.

Career connections

Have you ever wondered what type of poultry careers help to make a healthy, safe environment for commercial birds? Let's take a look!

- **Poultry caretakers** help with monitoring flocks for their health and well-being, ensuring they have constant access to fresh food and water as well as a safe living environment. Caretakers walk their barns every day to check their flock and the equipment that helps to keep them safe and fed.
- **Animal scientists** apply principles of the biological, physical, and social sciences to the problems associated with poultry production and management. In other words, they study animal health and behavior in order to help design the perfect environment for commercial birds to live in and produce meat and eggs.
- **Hatchery workers** manage hen care and equipment to achieve high hatchability while performing tasks such as egg setting, transfer, and care of day-old chicks.

Natural selection and change

In your group, discuss the following questions:
1. What does an organism need to survive and reproduce? How do inherited traits impact survival?
2. Predict which beak type and food source will be the most successful (survive to the next generation).

Part 1: Survival of the fittest simulation
1. Each group will need to collect the following items:
    - 1 plastic cup (stomach) and 1 beak type (mouth) per person
    - 1 cup of food
    - 1 student worksheet
2. You will use your beak to pick up the available food and drop it into your stomach in rounds of 60 seconds each. The amount of food that you eat will then be counted to determine the most successful trait (inherited trait) of your population. You will use the same beak for the entire simulation. *It is important that you pick up the food with your beak and drop it into your stomach (no scooping into your stomach allowed).*
    - **Round 1:** Count or weigh each food type in your group cup and record in data table 1. Each group is given one minute to practice feeding with their beak by picking one item up at a time and dropping them into their stomach. * You may not roll it into your stomach! Record your data in table 1 when your round is up and empty your stomach contents into the community cup so that those beans may be removed from the ecosystem.
    - **Round 2:** Members of the group compete with one another at the same time as each student tries to eat as much food as possible in 60 seconds. Remember each item must be picked up individually! Record your data in table 1 when your round is up and empty your stomach contents in the community cup so that those beans may be removed from the ecosystem.
    - **Round 3:** Only the top 3 members of your group have survived to the third round! The remaining 3 group members compete with one another to eat as much food as possible in 60 seconds. Record your data in table 1 when your round is up and empty your stomach contents in the community cup so that those beans may be removed from the ecosystem.
3. Share your group data from rounds 1, 2, and 3 with the class to calculate the Simpson's Index of Diversity changes within your ecosystem.

Part 2: Simpson's Index of Diversity
Simpson's Index of Diversity is a tool used to measure the level of biodiversity present in each sample. It measures both the species richness (number of species per sample) and the species evenness (relative abundance of each individual species per sample) in a community. A community dominated by one or two species is considered to be less diverse than one in which several species have a similar abundance. The Simpson's Index of Diversity value (D) ranges between 0 and 1. In Simpson's Index of Diversity, "1" represents infinite diversity and "0", no diversity.

$$D = 1 - \frac{\Sigma\, n(n-1)}{N(N-1)}$$

Simpson's Index of Diversity
n = the total number of organisms of a particular species
N = the total number of organisms of all species

DATA TABLE 1: INITIAL BIODIVERSITY

Species	Number (n)	n(n−1)	Observations
Pipe cleaner			
Forceps			
Chopsticks			
Plastic spoon			
Paperclip			
Lentils			
Split peas			
Navy beans			
Pinto beans			
Black-eyed peas			
Total	**N =**	**Σ n(n−1) =**	

4. Calculate the biodiversity of the class ecosystem in two different time events, before round 1 begins and at the end of round 3, using data tables 2 and 3 below.

DATA TABLE 2: SURVIVAL OF THE FITTEST SIMULATION

Species	Initial population	Round 1	Round 2	Round 3	Total population
Pipe cleaner					
Forceps					
Chopsticks					
Plastic spoon					
Paperclip					
Lentils					
Split peas					
Navy beans					
Pinto beans					
Black-eyed peas					

DATA TABLE 3: FINAL BIODIVERSITY

Species	Number (n)	n(n–1)	Observations
Pipe cleaner			
Forceps			
Chopsticks			
Plastic spoon			
Paperclip			
Lentils			
Split peas			
Navy beans			
Pinto beans			
Black-eyed peas			
Total	**N =**	**Σ n(n–1) =**	

5. How did the species evenness and species richness change in your sample from data table 2 to data table 3?

Investigate Hardy–Weinberg and the evolution of turkeys

How can natural selection change allele frequencies and drive color evolution in turkeys?

Standards

- **B.H.3: Genetic mechanisms and inheritance**
- **B.E.1: Mechanisms:** Natural selection
- **B.E.2: Speciation:** Variation of organisms within species due to population genetics and gene frequency

Introduction

Evolution in a population is defined as a change in the frequency of its alleles. The Hardy–Weinberg principle is a tool that can be used to estimate the allele frequencies among a population from generation to generation. The population is considered to be in equilibrium as long as the following five conditions are met:

1. The population is large.
2. Members of the population show no preference in mating.
3. There are no mutations.
4. Members are not moving into or out of the population.
5. There is no natural selection.

If these conditions are met, the population's allele frequencies will stay the same from generation to generation and we will know no evolution took place within the population.

In this lab we will look at a population of turkeys that has met the five Hardy–Weinberg principle conditions and is currently in equilibrium. We will then look at a population of turkeys where the changing habitat conditions have produced turkeys with lighter coat patterns. How will natural selection affect the gene frequency and evolution within the population?

In turkeys, black feather patterns are dominant over bronze feather patterns.
In the Hardy–Weinberg principle the following variables represent alleles.

Phenotype	Genotype	HW variable
Homozygous black	BB	p^2
Heterozygous black	Bb	$2pq$
Homozygous bronze	bb	q^2

Student prior knowledge

In order to successfully complete this activity, students should know the basic concepts of genetics: Mendel's laws, patterns of dominance, and recessive allele inheritance. Students should be able to describe how traits are passed from generation to generation. A general understanding of the concept of evolution and how evolution occurs among a population is fundamental to understanding this activity.

Suggested timeline

1–2 class periods (50–100 minutes)

Materials

- *Feathers of change* student sheet
- Turkey allele cards
- Scratch paper for calculations
- Calculator

Teacher preparation

This activity is a teacher-guided activity involving the whole class. Prior to class the teacher will need to print the turkey allele cards and *Feathers of change* student document.

- For part 1, each student will need:
    - One capital "B" card
    - One lowercase "b" card
- For part 2:
    - 50% of the students will need two lowercase "b" cards
    - 50% of the students will need one capital "B" card and one lowercase "b" card

At the beginning of each part of the activity, pass out cards to each student.

Procedure

1. Divide the students into groups and prepare to run the first Hardy–Weinberg simulation.
    - In this simulation each class member will represent a heterozygous black turkey.
    - Ask the students to make a prediction for the allele frequency of the turkey population.
    - Each student trades one allele card at a time with other students continuously for two minutes.
    - Record students' data in data table 1.
    - Use this data to determine the allele frequency as a percentage in data table 2.
    - Use the data in table 1 and the Hardy–Weinberg equation to determine the frequency as a decimal in Data table 3.
2. Pose the following questions to the class:
    - In the first simulation, did your predictions agree with the allele frequencies calculated in data table 2?
    - If your class results in data table 2 did not agree, what are some of the possible reasons why?
3. Prepare to run the second Hardy–Weinberg simulation.
    - In this simulation each class member will have either a heterozygous (Bb) black genotype or a homozygous bronze genotype (bb).
    - Ask the students to make a prediction for the allele frequency of the turkey population.
    - Each student should trade one allele card at a time with other students continuously for 2 minutes.
    - Record their data in data table 4.
    - Use this data to determine the allele frequency as a percentage in Data table 5.
    - Use the data in table 4 and the Hardy–Weinberg equation to determine the frequency as a decimal in Data table 6.
4. Pose the following questions to the class:
    - In the second simulation, did your predictions agree with the allele frequencies calculated in Data table 5?
    - If your class results in data table 5 did not agree, what are some of the possible reasons why?
    - Which condition of the Hardy–Weinberg principle influenced the greatest difference between your data table 2 and data table 5?
    - If changing habitats continue to select for bronze turkeys, which variable in the Hardy–Weinberg principle would decrease the most? Which one would increase the most? Why?
    - How does natural selection drive evolution?

Suggested wrap-up activity

1. The class will revisit Hardy–Weinberg's 5 conditions for a population to remain in equilibrium and discuss the results from the first and second simulations.
   - Did natural selection occur? What scientific proof do you have to support this?
   - What are some factors that could cause the population's allele frequencies to shift? Be specific! What are plausible reasons that the color patterns of turkey feathers change?
2. Is this an evolutionary shift that could lead to a new species? Why or why not?
   - Define the term **species**. How would we know that a new species has evolved from another species?

Differentiation

- Students can count populations of other types (i.e. insects, birds or trees) and see if they can apply these principles to other populations. (They will need to use various sampling techniques then generalize to a larger scale.)
- This activity can be led by the teacher for those students struggling with the concept or done individually at the student's own pace for those students that are comfortable with the concepts after the simulation portion.
- Students may need extra support with the Hardy–Weinberg calculations. They could watch remedial videos and use practice questions for more practice. `youtu.be/oG7ob-Mt08c`

More challenges

- Research mechanisms of evolution. Have student groups present their findings to the class or create a project that can be shared with other groups in a gallery walk. Discuss examples of each mechanism in taxonomy and predict future extinctions and/or speciation events due to current environmental challenges.
- **Home connection:** Start a conversation about the changing habitats in your local area. How have they changed over time? Why did these changes take place? Have you noticed any changes in wild flora or fauna populations?

Support information

- **Genotype:** the combination of alleles for a particular gene for an organism.
- **Allele:** variants of a gene.
- **Dominant allele:** one or two alleles may be present for this phenotype to be expressed; masks the recessive allele.
- **Recessive allele:** two alleles must be present for this phenotype to be expressed in an organism.
- **Allele frequencies:** the percentage of each available allele of a gene in a gene pool for a population.
- **Phenotype:** the observable traits of an organism's genotype.
- **Evolution:** the change in allele frequencies in a population over time.
- **Hardy–Weinberg principle:** tool that can be used to estimate the allele frequencies among a population from generation to generation.
- The expression of inherited traits of an organism are influenced by the environment in which the organism lives. Environmental factors such as diet, temperature, humidity, oxygen levels, light cycles, and the presence of mutagens all impact gene expression.
- Solving Hardy–Weinberg problems by Bozeman Science: `youtu.be/xPkOAnK20kw`

Teaching suggestions

- Turkey Allele cards: Print these cards on cardstock and laminate them to hold up for multiple classes. Numbering the cards makes it easier to sort them after each activity.
- Continue to add to your class gene pool from period to period to simulate the natural world. Keep class data sets from year to year to provide your students with annual data that they can track to determine if the changing environment is impacting the turkey population.

Career connections

Have you ever wondered what type of poultry careers help to make a healthy, safe environment for commercial birds? Let's take a look!

- **Geneticists** are biologists who study genetics, the science of genes, heredity and variations of organisms.
- **Veterinarians** care for the health of the poultry flocks and work to protect public health. They diagnose, treat, and research medical conditions and diseases of pets, livestock, and other animals.
- **Breeders** select and breed poultry for the desired characteristics such as meat and/or egg production in commercial poultry settings.
- **Animal scientists** apply principles of the biological, physical, and social sciences to the problems associated with poultry production and management. In other words, they study animal health and behavior in order to help design the perfect environment for commercial birds to live in and produce meat and eggs.

Feathers of change

Evolution in a population is defined as a change in the frequency of its alleles. The Hardy–Weinberg principle is a tool that can be used to estimate the allele frequencies among a population from generation to generation. The population is considered to be in equilibrium as long as the following five conditions are met:

1. The population is large.
2. Members of the population show no preference in mating.
3. There are no mutations.
4. Members are not moving into or out of the population.
5. There is no natural selection.

If these conditions are met, the population's allele frequencies will stay the same from generation to generation and we will know no evolution took place within the population.

In this lab we will look at a population of turkeys that has met the five Hardy–Weinberg principle conditions and is currently in equilibrium. We will then look at a population of turkeys where the changing habitat conditions have produced turkeys with lighter coat patterns. How will natural selection affect the gene frequency and evolution within the population?

In turkeys, black feather patterns are dominant over bronze feather patterns.
In the Hardy–Weinberg principle the following variables represent alleles.

Phenotype	Genotype	HW variable
Homozygous black	BB	p^2
Heterozygous black	Bb	$2pq$
Homozygous bronze	bb	q^2

Procedure

PART 1: CALCULATING THE GENE FREQUENCIES OF THE EQUILIBRIUM FIELD

We will run a simulation representing the equilibrium of a turkey population. Each student should trade one allele card at a time with other students continuously for 2 minutes. In this simulation each class member will represent a heterozygous black turkey.

Hypothesis: What is your prediction for allele frequency of the population at the end of this round? Add as a percent next to each allele.

p or B	
q or b	

After this activity, record the class totals in data table 1.

Data table 1

Genotype	Number of students	Number of alleles	Total of each
BB			
Bb			
bb			
Total number of students		Total number of alleles	

Determine the allelic frequencies by totaling the number of “B”s and the total of “b”s divided by the total number of alleles in the class.

Data table 2

HW symbol	Allele	Allele frequency (as percentage)
p	B	
q	b	

Analyze the class data using the variables and the equation ($p^2 + 2pq + q^2 = 1$) to determine if the equation will predict the allelic frequency for your classroom population.

Data table 3

Hardy–Weinberg calculation	Allele frequency (as decimal)
p^2	
$2pq$	
q^2	

PART 2: CALCULATING THE GENE FREQUENCIES FOR THE POPULATION WHERE BRONZE FEATHERED TURKEYS WERE SELECTED

In this simulation each class member will have either a homozygous bronze genotype or heterozygous genotype. All of the homozygous black genotypes have been removed from the population since we no longer want to have black turkeys.

Hypothesis: What is your prediction for the genotypic ratios in the population since all turkeys are homozygous recessive or heterozygous?

p or B	
q or b	

After the activity, record the class totals in the following table:

Data table 4

Genotype	Number of students	Number of alleles	Total of each
BB			
Bb			
bb			
Total number of students		Total number of alleles	

Determine the allelic frequencies by totaling the number of “B”s and the total of “b”s divided by the total number of alleles in the class in data table 5.

Data table 5

HW symbol	Allele	Allele frequency (as percentage)
p	B	
q	b	

Analyze the class data using the variables and the equation ($p^2 + 2pq + q^2 = 1$) to determine if the equation will predict the allelic frequency for your classroom population.

Data table 6

Hardy–Weinberg calculation	Allele frequency (as decimal)
p^2	
$2pq$	
q^2	

Reflection

1. In the first simulation, did your predictions agree with the allele frequencies calculated in data table 2?
2. If your class results in data table 2 did not agree, what are some of the possible reasons why?
3. In the second simulation, did your predictions agree with the allele frequencies calculated in data table 5?
4. If your class results in data table 5 did not agree, what are some of the possible reasons why?
5. Which condition(s) of the Hardy–Weinberg principle influenced the difference between the frequency of your alleles in your data tables 2 and 5?
6. If changing habitats continue to select for bronze turkeys, which variable in the Hardy–Weinberg principle would decrease the most? Which one would increase the most? Why?

B (black feathers)

B (black feathers)

B (black feathers)

B (black feathers)

b (bronze feathers)

b (bronze feathers)

b (bronze feathers)

b (bronze feathers)

Investigate protein synthesis

How are proteins coded for by DNA?

Standards

- **B.H.1:** Cellular genetics
- **B.H.2:** Structure and function of DNA in cells

Introduction

Scientists can obtain new combinations of desirable traits in animals through genetics. Let's take a look at how deoxyribonucleic acid (DNA) regulates the flow of information within a chicken's cells in the process known as protein synthesis. DNA, the molecule of life, is one of the most recognizable nucleic acids, a double-stranded helix. The process by which DNA codes for proteins involves enzymes and additional single-stranded nucleic acids, specifically messenger ribonucleic acid (mRNA) and transfer ribonucleic acid (tRNA). All students need to know the steps in protein synthesis in order to understand the mechanics of genetics and how traits are expressed. This activity helps to assess student understanding and/or review the concept. The steps in protein synthesis–transcription from DNA to mRNA and translation from mRNA to tRNA–can be demonstrated by modeling. In this activity, each triplet code of DNA represents a word in a sentence rather than a code for an amino acid. Introns and exons are omitted. The words can be found by transcribing the DNA into mRNA, then translating into tRNA.

Student prior knowledge

Students should understand that each nucleotide consists of a phosphate group, a sugar molecule (deoxyribose) and one of four nitrogenous bases: adenine (A), thymine (T), cytosine (C), or guanine (G). Students should know that A pairs with T, and C with G, through hydrogen bonds, forming complementary base pairs.

Suggested timeline

1 class period (50 minutes)

Materials

- DNA strand cards and tRNA cards with words on the back
- Transcription/translation data sheet
- Large sheet of paper
- Markers

Teacher preparation

1. Set out DNA strands at a central location in the room.
2. Set out tRNA cards around the perimeter of the room, grouped by first letters of the anticodons (As together, Cs together, etc).
3. Assign sentences to student groups. (If all students will practice all roles, each group of four should have four sentences assigned.)

Procedure

1. Choose one person to be the transcriber. Find the DNA strands assigned located at the table in the center of the room.
2. On the data sheet provided, transcribe the mRNA codons from the DNA strand (without moving the DNA).
3. At the group table, choose a different person to translate the mRNA codons to tRNA anticodons. Write these anticodons on your data sheet.
4. Choose two people to go find the tRNA anticodons around the room. Turn over the anticodons to find the words of the sentence and write that sentence in large print/script on the transcription/translation data sheet.

Hint: The first triplet code is a "start" code, which represents in eukaryotes the amino acid methionine. For this activity, it is the same triplet code for all and is denoted by the word "START." Each punctuation symbol is represented by different "stop" anticodons.

ANSWER KEY

1. TAC AAA CCC TGA CCG AGG TGA CCC ATG ATT
   Soybeans are a leading crop in the United States.
2. TAC AAA CCC TTG GAT ATT
   Soybeans are nitrogen-fixing legumes.
3. TAC AAA CCC TGT TGA GAA ATT
   Soybeans are high in protein.
4. TAC TCC CTT TGA CCC TCG AGG AAA CCA ATT
   Ohio ranks in the top ten soybean production.
5. TAC TCC ATA AGC TGA AGA CCA ATT
   Ohio is number 2 in egg production.
6. TAC CGC TTT GCG CCG TGC ATT
   Chicken can live 5–10 years.
7. TAC CGC CCC AAC ATT
   Chickens are omnivores.
8. TAC CGC CCC TAT CCT ATT
   Chickens are warm-blooded animals.
9. TAC CGC TTT AGT GAC ATC ATT
   Chickens have excellent night vision.
10. TAC CGC CCA TTA TGG TAA ATT
   Chickens originated from red junglefowl.
11. TAC CGC TTT CAT CGT AGA CGG ATT
   Chickens can lay 280–320 eggs annually.
12. TAC CGC CAT GAG AGA GTT CTC ATT
   Chickens lay one egg every 24–36 hours.
13. TAC AGA TTT CGA TGA GAA ATT
   Eggs have 6 grams of protein.
14. TAC CGC CCA AGA TTA GCA CAA ATT
   Chickens produce eggs at 18 weeks.
15. TAC ACG TTC CAG ACT CCC GGG TGA CCC AGA ATT
   Eggshell color doesn't affect the nutrition of the egg.

Suggested wrap-up activity/discussion questions

- How are chromosomes, DNA, genes, and proteins related?
- What area of the cell does the table holding DNA represent in this modeling activity?
- Why can't the DNA strand be brought back to your group?
- What area of the cell does your table represent?
- What do the words represent? The completed sentences?
- What do you think the consequences might be if an error occurred in the cell as it goes through the process of protein synthesis?

Differentiation

- Make cards longer sequences with fewer matches.
- Add colors to the strands to make it easier to match.
- Divide groups into sections so they know that someone in their group will match the card.

More challenges

- Research each DNA sentence statement to find evidence to support or refute this statement.
- Have students make their own sentences and strips, then repeat the activity.
- **Home connection**: Have students share the content of the DNA sentences statements at home to highlight Ohio agriculture during family conversation. Students can add in the additional information from their statement research to enrich the conversation. Ask the students to share with the class one statement that surprised people the most during their conversations.

Support information

- **Messenger RNA (mRNA):** carries genetic information from the DNA to the ribosome for protein synthesis.
- **Ribosomal RNA (rRNA):** forms part of the ribosome's structure and catalyzes protein synthesis.
- **Transfer RNA (tRNA):** carries amino acids to the ribosome during protein synthesis.
- **Translation:** begins with the start codon AUG. Find the corresponding AUG on the mRNA strand. Clip three nucleotides at a time (codon) into the ribosome, corresponding to each triplet on the mRNA. Match each codon with its corresponding amino acid according to the genetic code chart. Add the corresponding amino acid card to the growing polypeptide chain to make the DNA sentences.
- **Elongation:** move the ribosome along the mRNA strand, reading each codon. Add the appropriate amino acids to the growing polypeptide chain. These are the words to your sentence.
- **Termination:** when a stop codon (UAA, UAG, or UGA) is reached, translation stops. Complete the polypeptide chain. This is the end of your sentence.
- NOVA scienceNOW: Deadly Letters
  pbs.org/wgbh/nova/teachers/activities/0401_02_nsn.html
- Translation: DNA to mRNA to Protein
  nature.com/scitable/topicpage/translation-dna-to-mrna-to-protein-393/
- Protein Synthesis (Updated) Amoeba Sisters
  youtu.be/oefAI2x2CQM
- DNA, Hot Pockets, & The Longest Word Ever: Crash Course Biology #11
  youtu.be/itsb2SqR-R0
- Protein synthesis race
  biomanbio.com/HTML5GamesandLabs/LifeChemgames/protsynthracehtml5page.html

Career connections

Have you ever wondered what type of poultry careers help to make a healthy, safe environment for commercial birds? Let's take a look!

- **Breeders** observe the health of the flock and record data on laying efficiency and behavior to select the traits to be combined for future generations.
- **Veterinarians** care for the health of the poultry flock and work to protect public health. They diagnose, treat, and research medical conditions and diseases of pets, livestock, and other animals.
- **Geneticists** are biologists who study genetics, the science of genes, heredity, and variation of organisms.

INVESTIGATE PROTEIN SYNTHESIS

Transcription/translation group data sheet

Sentence number: ______________ **Transcriber name:** ______________________________

mRNA codons

Translator name: ______________________________

tRNA codons

Sentence

INVESTIGATE PROTEIN SYNTHESIS

Transcription/translation group data sheet

Sentence number: ______________ **Transcriber name:** ______________________________

mRNA codons

Translator name: ______________________________

tRNA codons

Sentence

1 TAC AAA CCC TGA CCG AGG TGA CCC ATG ATT

2 TAC AAA CCC TTG GAT ATT

3 TAC AAA CCC TGT TGA GAA ATT

4 TAC TCC CTT TGA CCC TCG AGG AAA CCA ATT

5 TAC TCC ATA AGC TGA AGA CCA ATT

6 TAC CGC TTT GCG CCG TGC ATT

7 TAC CGC CCC AAC ATT

8 TAC CGC CCC TAT CCT ATT

9 TAC CGC TTT AGT GAC ATC ATT

10 TAC CGC CCA TTA TGG TAA ATT

11 TAC CGC TTT CAT CGT AGA CGG ATT

12 TAC CGC CAT GAG AGA GTT CTC ATT

13 TAC AGA TTT CGA TGA GAA ATT

14 TAC CGC CCA AGA TTA GCA CAA ATT

15 TAC ACG TTC CAG ACT CCC GGG TGA CCC AGA ATT

UAC

UUG

UCG

CGC

UAU

UGG

GAG

UUC

nitrogen-fixing

start

chicken/s

top

red

warm-blooded

color

one

AUU	GAU
AGG	UUU
CCU	UAA
GUU	CAG

legumes

.
(period)

can/have

ten

junglefowl

animals

doesn’t

every

AAA	UGU
CCA	GCG
AGU	CAU
CUC	ACU

high	soybean/s
live	production/produces/ originated
lay	excellent
affect	24–26 hours

CCC	GAA
AUA	CCG
GAC	CGU
GCA	GGG

protein	are/the
5–10	number
280–320	night
nutrition	18

UGA

UCC

AGC

UGC

AUC

CGG

CAA

Ohio

a/of/in

years

2

annually

vision

weeks

AUG

CUU

AGA

AAC

UUA

CGA

ACG

ranks

United States

omnivores

egg/s

6 grams

from/at

eggshell

Investigate how a chicken grows

How does a chicken grow and develop?

Standards

B.C.1: Cell structure and function

Introduction

How do cells grow and divide? In this lesson, students will learn that somatic cells grow and divide during the cell cycle, which includes mitosis and cytokinesis. This process is important for body cells in order for an organism to grow and repair itself through its lifetime. A cell spends most of its life in interphase, not dividing but performing normal body functions for organisms. The cell spends a small portion of its time in mitosis and cytokinesis dividing.

Student prior knowledge

In this lesson students will learn that somatic cells grow and divide during the cell cycle and process called mitosis. Students will observe cell growth and division laboratory investigation. The goal of mitosis is to produce a new cell that is identical to the parent cell. Mitosis occurs in somatic (body) cells for growth and repair. Somatic cells have a complete set of DNA, and they are capable of reproducing by themselves as often as needed. Knowledge of how to operate a foldscope is also helpful for this lesson.

Suggested timeline

1–2 class periods (50–100 minutes)

Materials

- Foldscopes
- Onion root tip slides
- Cell cycle inventory sheet (student copies)
- Mitosis song with images print out (or projected)
- Asexual cards
- Asexual note-taking chart

Teacher preparation

- Prepare a class set of foldscopes for student use along with onion root tip slides.
- Print off student worksheets and asexual cards
- Project song and images

Procedure

1. Ask the students how chickens reproduce (asexual or sexual?).
2. Investigate by what method chickens grow, develop, and heal from injuries they incur.
3. Pass out student mitosis song sheets and sing the song as a class while viewing the mitosis cell division chart.
4. Give each student or group of students onion root tip slides, foldscopes, and the cell cycle inventory sheet.
5. Have students identify the phase mitosis on the slides.
6. Each group should examine slides, searching for samples of dividing onion root tip slides.

7. Using foldscopes, students will locate any cells they believe to be in interphase, mitosis, or cytokinesis on the onion root tip slides.
8. Using the cell cycle inventory sheet, students record their data and answer the lab questions following data collection.
9. As a class, define asexual reproduction and its benefits.
10. Break students into groups and assign asexual reproduction types.
11. Groups of students will research different asexual reproduction types:
    - Binary fission (e.g., bacteria)
    - Budding (e.g., yeast, hydra)
    - Fragmentation (e.g., starfish, planaria)
    - Regeneration (e.g., spotted gecko)
    - Vegetative propagation (e.g., plants like potatoes and strawberries)
    - Parthenogenesis (e.g., aphid nymphs)
    - Spore formation (e.g., fungi, algae)
    - Other (come up with own form or organism)
12. Each group researches their assigned form and prepares a brief presentation.
    - Items to include in presentation: process steps, diagram, pros, cons, organism examples, and at least 2 interesting facts
13. Groups create a visual aid (poster, chart, or digital presentation) to accompany their explanation.
14. During the presentation, students will fill in the asexual chart with the characteristics of each form of asexual reproduction.

Suggested wrap-up activity

- Discuss the difference between asexual and sexual reproduction.
- Sing the mitosis song.
- Give the students some form of assessment (written, oral, drawing, etc.).

Differentiation

- Provide learning stations to have students learn more about each stages.
- Watch a video clip of mitosis process.
- Provide different levels of complexity in the content.
- Offer reading materials at varying reading levels. Use simpler texts or summaries for students who need more support, and provide more complex, in-depth articles for advanced learners.
- Allow students to demonstrate their understanding in different ways. Options could include writing a report, creating a PowerPoint presentation, making a video, drawing a comic strip, or designing a 3D model.
- Group students by mixed abilities for peer tutoring or by similar abilities for focused instruction.

More challenges

- Advanced research project: investigate how genetic variation occurs in organisms that reproduce asexually.
- Cross-curricular connection: explore the ethical implications and potential applications of cloning in agriculture and medicine.
- **Home connection:** Explore the following questions with relatives or friends: What if a chicken could reproduce asexually? How would this make a farmer's life easier? What complications could occur with chickens reproducing asexually? If you could engineer a chicken to reproduce sexually or asexually for your poultry business, which would you choose? Explain your answer.

Support information

- **Asexual reproduction**: a mode of reproduction in which a new offspring is produced by a single parent.
- **Sexual reproduction:** a type of reproduction that involves a complex life cycle in which a gamete with a single set of chromosomes combines with another gamete to produce a zygote that develops into an organism composed of cells with two sets of chromosomes.
- **Budding**: a form of asexual reproduction in which a new organism grows out of the body of the parent organism.
- **Fragmentation**: a form of asexual reproduction in which an organism breaks into pieces, each of which can grow into a new organism.
- **Regeneration:** a form of asexual reproduction in which an organism regrows a part of its body that has been lost or damaged.
- **Binary fission**: a form of asexual reproduction in which a single organism divides into two identical daughter cells.
- **Vegetative propagation**: a form of asexual reproduction in plants in which new plants grow from parts of the parent plant.
- **Parthenogenesis:** a natural form of asexual reproduction in which growth and development of an embryo occur directly from an egg, without need for fertilization.
- **Spores**: a form of asexual reproduction where organisms produce spores that develop into new individuals.
- Biological fitness is the ability for a species to reproduce, pass on heritable traits, and survive to the next generation. This lesson explores the variations in which organisms reproduce asexually. Asexual reproduction is expedient and does not require a mate. Asexual creates clones of the parent, unless there is a mutation. If organisms are well suited to their environment then that species' offspring will continue to survive.
- Amoeba Sisters' short mitosis poem **https://youtu.be/snKrKC9wYvw**
- Amoeba Sisters'"The Amazing Cell" video **youtu.be/f-ldPgEfAHI**
- Crash Course Biology mitosis video **youtu.be/L0k-enzoeOM**

Teaching suggestions

- Establish behavioral guidelines for presentations and group work.
- Establish safety procedures for using glass slides and foldscopes.

Career connections

Have you ever wondered what type of poultry careers help to make a healthy, safe environment for commercial birds? Let's take a look!

- **Geneticists** are biologists who study genetics, the science of genes, heredity, and variation of organisms.
- **Animal Scientists** apply principles of the biological, physical, and social sciences to the problems associated with poultry production and management. In other words, they study animal health and behavior in order to help design the perfect environment for commercial birds to live in and produce meat and eggs.
- **Veterinarians** care for the health of the poultry flock and work to protect public health. They diagnose, treat, and research medical conditions and diseases of pets, livestock, and other animals.
- **Entomologists** are scientists that specialize in studying insects and their importance to food production in our world.

Asexual note-taking

While students are presenting asexual types, fill in the chart for each organism below.

BINARY FISSION

<table>
<tr><td colspan="3">Define</td><td rowspan="2">Drawing</td></tr>
<tr><td>Pros</td><td>Cons</td><td>Example organisms</td></tr>
</table>

BUDDING

<table>
<tr><td colspan="3">Define</td><td rowspan="2">Drawing</td></tr>
<tr><td>Pros</td><td>Cons</td><td>Example organisms</td></tr>
</table>

FRAGMENTATION

Define			Drawing
Pros	Cons	Example organisms	

REGENERATION

Define			Drawing
Pros	Cons	Example organisms	

VEGETATIVE PROPAGATION

Define			Drawing
Pros	Cons	Example organisms	

PARTHENOGENESIS

<table>
<tr><td colspan="3">Define</td><td rowspan="2">Drawing</td></tr>
<tr><td>Pros</td><td>Cons</td><td>Example organisms</td></tr>
</table>

SPORE FORMATION

<table>
<tr><td colspan="3">Define</td><td rowspan="2">Drawing</td></tr>
<tr><td>Pros</td><td>Cons</td><td>Example organisms</td></tr>
</table>

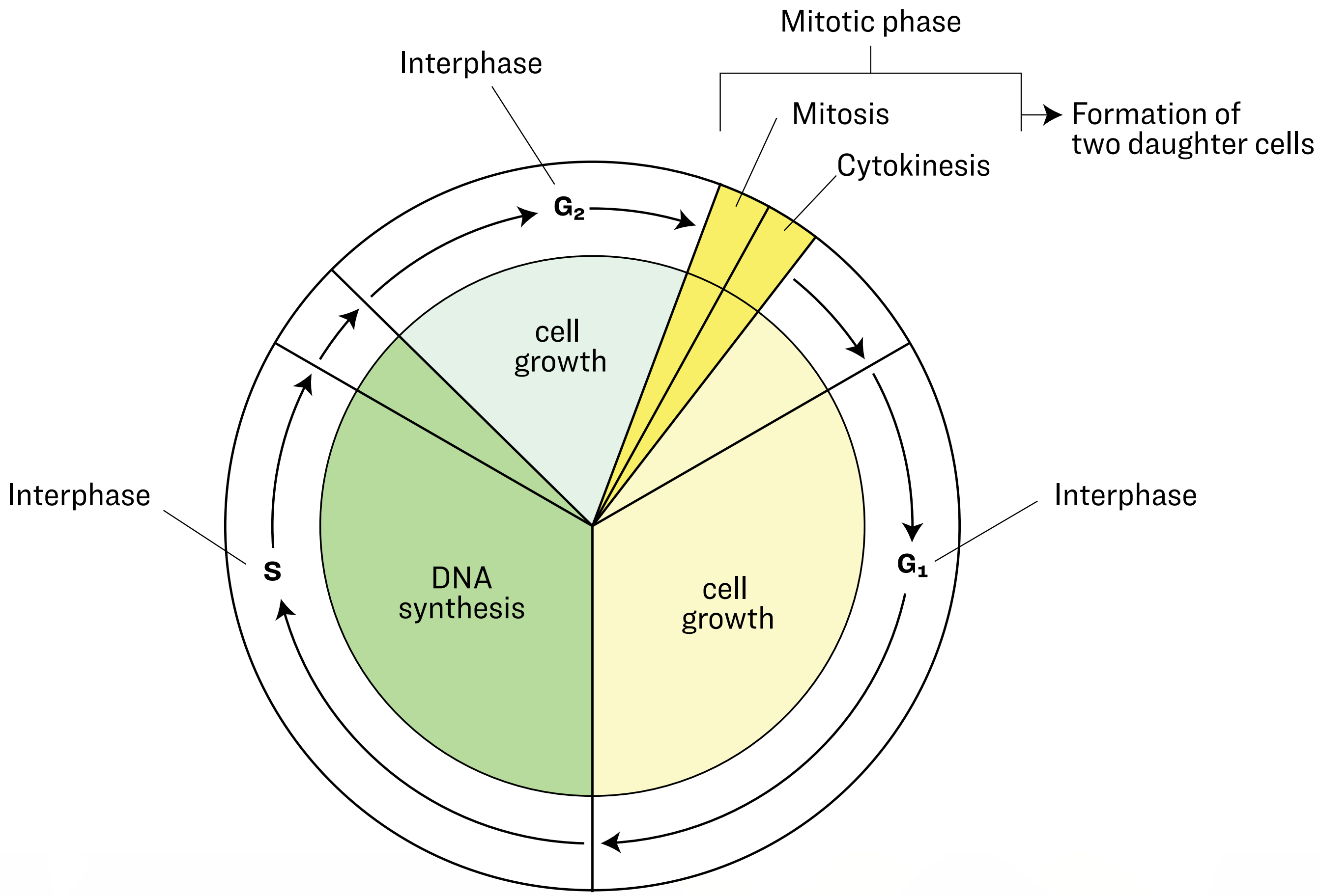
OTHER

<table>
<tr><td colspan="3">Define</td><td rowspan="2">Drawing</td></tr>
<tr><td>Pros</td><td>Cons</td><td>Example organisms</td></tr>
</table>

Cell cycle inventory

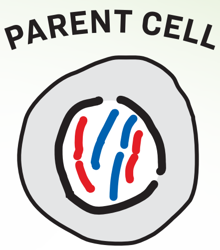
All multicellular organisms undergo mitosis in order to grow and repair themselves. Using your microscope, examine the slide containing onion root cells. Identify any onion root cells that you see in these stages: interphase, mitosis, cytokinesis.

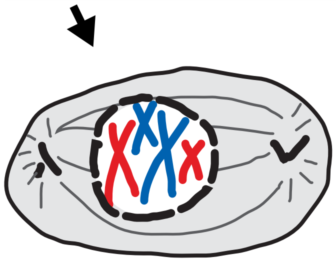
1. Draw an image of a cell you see in each phase under “image of cell in this phase”.
2. Write what you see occurring in each image you draw under “description of cells in this phase”.
3. Record the number of cells you see in each phase on your cell cycle inventory sheet. Then answer the laboratory question in the space provided below.



	Interphase	Mitosis	Cytokinesis
Image of cell in this phase			
Description of cell in this phase			
Number of onion cells in this phase			

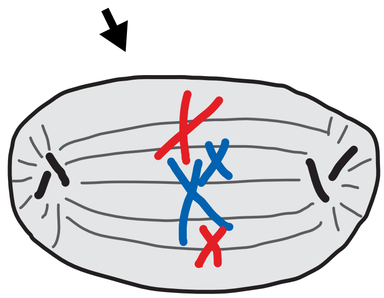
Mitosis





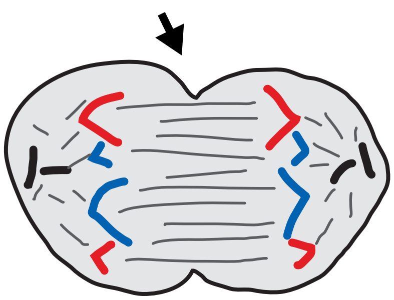
Prophase

Chromatin condenses into chromosomes.
Nuclear envelope disappears.



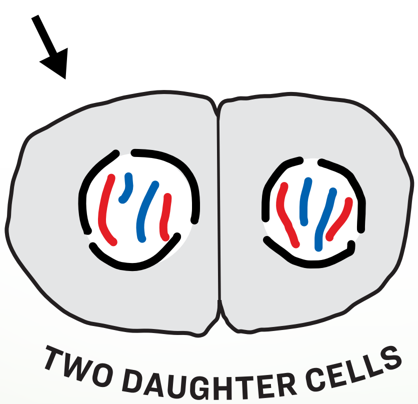
Metaphase

Chromosomes align at
the equatorial plate.



Anaphase

Sister chromatids separate.
Centrometers divide.



Telophase

Chromatin expands.
Cytoplasm divides.

Mitosis song

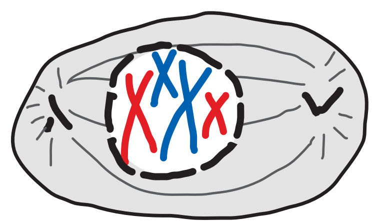
Sung to the tune of the "Addams Family" theme

Mitosis, oh mitosis, let's sing it loud and clear,
As cells divide and multiply, the stages do appear.
Da da da dum (snap snap)
Da da da dum (snap snap)
Da da da dum, da da da dum, da da da dum (snap snap)

Interphase, prophase, metaphase, anaphase,
Telophase, cytokinesis, mitosis we embrace!
Da da da dum (snap snap)
Da da da dum (snap snap)
Da da da dum, da da da dum, da da da dum (snap snap)

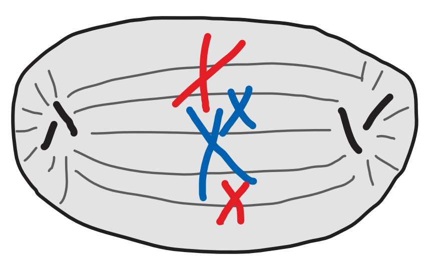
Interphase, the cell's preparing, DNA is duplicated,
Chromosomes are copied, energy's allocated.
Da da da dum (snap snap)
Da da da dum (snap snap)
Da da da dum, da da da dum, da da da dum (snap snap)

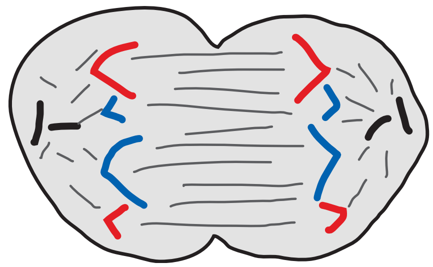
Prophase comes with condensation,
chromosomes now visible,
Nuclear membrane dissolves,
the cell's becoming divisible.



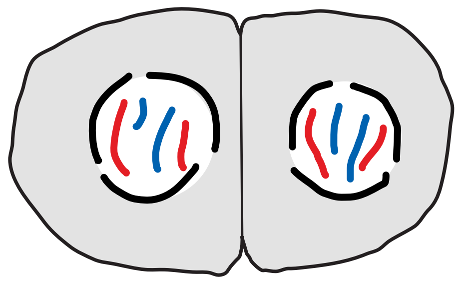
Da da da dum (snap snap)
Da da da dum (snap snap)
Da da da dum, da da da dum, da da da dum (snap snap)

Metaphase, they line up neatly,
in the cell's equator zone,
Spindle fibers hold them steady,
in a line they're shown.
Da da da dum (snap snap)
Da da da dum (snap snap)
Da da da dum, da da da dum,
da da da dum (snap snap)





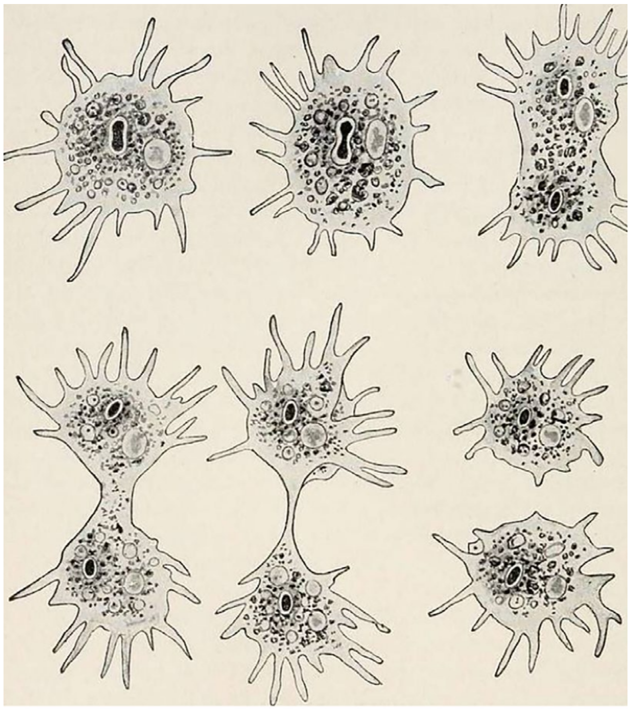
Anaphase, they start to separate,
pulled to opposite poles,
Chromatids moving toward each side,
as the tension takes its toll.
Da da da dum (snap snap)
Da da da dum (snap snap)
Da da da dum, da da da dum,
da da da dum (snap snap)



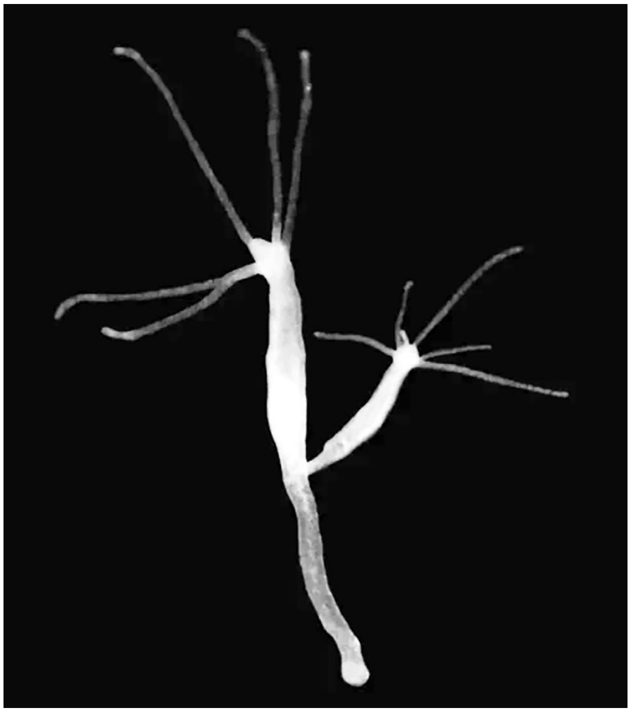
Telophase sees the chromosomes,
at poles they do reside,
New nuclei form around them,
in this final stride.
Da da da dum (snap snap)
Da da da dum (snap snap)
Da da da dum, da da da dum,
da da da dum (snap snap)

Cytokinesis, the last to come, as the cell begins to part,
Two new cells emerge triumphant, mitosis, let's restart!
Da da da dum (snap snap)
Da da da dum (snap snap)
Da da da dum, da da da dum, da da da dum (snap snap)

Interphase, prophase, metaphase, anaphase,
Telophase, cytokinesis, mitosis we embrace! (snap snap)



Binary fission



Budding

Fragmentation

Regeneration

Budding

Budding is a form of asexual reproduction in which a new organism grows out of the body of the parent organism.

Examples: yeast, hydra

Binary fission

Binary fission is a form of asexual reproduction in which a single organism divides into two identical daughter cells.

Examples: bacteria (e.g., *E. coli),* amoeba

Regeneration

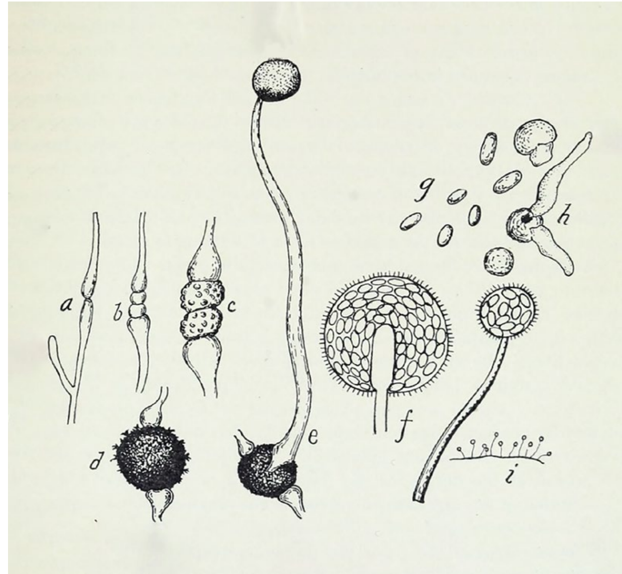
Regeneration is a form of asexual reproduction in which an organism regrows a part of its body that has been lost or damaged.
Example: Lizard regrows a missing tail.

Fragmentation

Fragmentation is a form of asexual reproduction in which an organism breaks into pieces, each of which can grow into a new organism.

Examples: starfish, planaria

Vegetative propagation



Spore formation

Parthenogenesis

Spore formation

Spore formation is a form of asexual reproduction in which organisms produce spores that develop into new individuals.

Examples: fungi, algae

Vegetative propagation

Vegetative propagation is a form of asexual reproduction in plants in which new plants grow from parts of the parent plant.

Examples: potatoes, strawberries

Parthenogenesis

Parthenogenesis is a natural form of asexual reproduction in which growth and development of an embryo occur directly from an egg, without need for fertilization.

Examples: aphids, bees

Investigate how chickens pass on traits

How do chickens pass down their traits from one generation to the next?

Standards

- **B.C.1:** Cell structure and function
- **B.H.3:** Genetic mechanisms and inheritance

Introduction

Did you know that there is more than one way that traits can be passed on between parents and their offspring? In this lesson students will explore sexual reproduction as they consider how heritable information is passed on to the next generation. Through song and dance, students will learn about meiosis and the creation of sex cells.

Student prior knowledge

The goal of meiosis is to produce haploid gametes that have half the DNA of the parent cell. Meiosis occurs in gamete cells to produce haploid cells for sexual reproduction. Students should have prior knowledge of cell anatomy, where the nucleus is located, and that chromosomes exist inside the nucleus. Students should understand that DNA contains information for heritable traits that are passed from one generation of organisms to the next and the forms of cell division (mitosis and meiosis).

Suggested timeline

One class period (50 minutes)

Materials

- Play-Doh or modeling clay (different colors)
- Tape or something to make circles
- Song/music
- Copies of Meiosis in motion review sheet

Teacher preparation

- Make small pieces of clay to represent the chromosomes.
- Make circles or an area large enough to move students.
- Make copies of the student worksheet.

Procedure

Complete the meiosis modeling steps in the song (speak or sing the lyrics). The Meiosis song review is in the student worksheet: Meiosis in motion review.

1. Have students get a piece of Play-Doh and stand in a circle shape on the floor.
2. Have the students pair with a partner.
3. Prophase I
    - Students (chromosome pairs) move into the first cell boundary.
    - Have students “synapse” by linking arms, representing homologous chromosomes pairing up.
    - Explain “crossing over” by having them mix Play-Doh pieces together.

4. Metaphase I
    - Chromosome pairs line up in the middle of the cell (the equator).
    - Use tape to mark the metaphase plate and have students stand along it.
    - Independent assortment happens to make sure to mix genes with tetrad.
5. Anaphase I
    - Students unlink arms from the group but stay in new pairs and move to opposite sides of the cell boundary.
    - Explain the separation of homologous chromosomes.
6. Telophase I and Cytokinesis
    - Have a student “cut” the circle in two.
    - Students now separate into two groups, each within their own cell boundary.
    - Explain the formation of two new cells, each with half the original number of chromosomes.
7. Prophase II
    - Each group (new cells) starts in their own cell boundary.
    - Students prepare for the next division without pairing up (since they are now single chromosomes).
8. Metaphase II
    - Students line up in the middle of each cell again.
9. Anaphase II
    - Students drop arms with partner.
    - Students separate again, moving to opposite sides of each cell boundary, representing the sister chromatids being pulled apart.
10. Telophase II and Cytokinesis:
    - Have someone “cut” the circle in two again.
    - Each cell boundary now has students divided, representing the final four haploid cells.
    - Discuss the result: four genetically unique cells.

Suggested wrap-up activity

- Have students compare the similarities and differences in mitosis and meiosis. Students need to explain how each makes a different cell.
- Conduct lab activities using microscopes to observe onion root tip cells (for mitosis) and prepared slides of lily anthers or other suitable specimens (for meiosis).

Differentiation

- Have students wear signs or tags to show phases.
- Print out the lyrics and have students complete it in smaller groups.
- Make labels and signs to match the terms with the lyrics.
- Make cards instead of dancing—have them use cards with the drawing of the phases on it to symbolize the movement.

More challenges

- Students may draw phases as you are dancing or after you are done.
- Have students make their own dances or poems to show the phases. Develop crossword puzzles, word searches, or quizzes to reinforce terminology and concepts related to cell division. Use virtual labs and simulations if resources are limited. Many online platforms offer interactive simulations that allow students to explore cell division in a controlled virtual environment.
- Discuss real-world applications and case studies where understanding mitosis and meiosis is crucial, such as cancer research, genetic disorders, and reproductive technology. Highlight how errors in these processes can lead to medical conditions, reinforcing the importance of accurate cell division.

- **Home connection:** Research common genetic traits in chickens such as feather color, comb shape, and egg color. Create a chart that shows how these traits are inherited and the role of dominant and recessive alleles. If possible, visit a local farm or hatchery to observe different breeds of chickens and their traits.

Support information

- **Independent assortment:** refers to the random distribution of maternal and paternal chromosomes into gametes during meiosis.
- **Synapsis:** the pairing of two chromosomes that occurs during meiosis.
- **Crossover:** the exchange of genetic material between non-sister chromatids of homologous chromosomes during meiosis.
- **Tertard:** homologous pair of chromosomes that are crossed over.
- Something that students often miss or that takes time to sink in is the fact that in the first round of anaphase they are still with a "partner" or the replicated chromosome. Anaphase two is when the chromosome actually splits into a single chromatid. Independent assortment is random and is a mix of both egg and sperm genes.
- Understanding these concepts provides students with a solid foundation in genetics and cell biology: how genetic information is passed on, how genetic diversity arises, and the fundamental processes of cell division. Somatic cells have a complete set of DNA, and they are capable of reproducing by themselves as often as needed. This is important for body cells in order for an organism to grow and repair itself through its lifetime. A cell spends most of its life in interphase, not dividing but performing normal body functioning for the organisms. The cell spends a small portion of its time in mitosis dividing.
  Meiosis: Where the Sex Starts - Crash Course Biology #13: **youtu.be/qCLmR9-YY7o**
  Mitosis vs. Meiosis:
  ck12.org/biology/mitosis-vs.-meiosis/lesson/mitosis-vs.-meiosis-ms-ls/

Teaching suggestions

Establish behavioral guidelines before playing the meiosis square dance.

Career connections

Have you ever wondered what type of poultry careers help to make a healthy, safe environment for commercial birds? Let's take a look!

- **Geneticists** are biologists who study genetics, the science of genes, heredity, and variation of organisms.
- **Animal Scientists** apply principles of the biological, physical, and social sciences to the problems associated with poultry production and management. In other words, they study animal health and behavior in order to help design the perfect environment for commercial birds to live in and produce meat and eggs.
- **Veterinarians** care for the health of the poultry flock and work to protect public health. They diagnose, treat, and research medical conditions and diseases of pets, livestock, and other animals.

Meiosis in motion review

Sing the Meiosis square dance with the class while your teacher directs your movement with your partners as you perform meiosis with your group.

Prophase I is where we start
Link your arms to make your mark
Homologous pairs is what we are
Synapsis make our genes move far

Make a match with a new pair
A tetrad square is in the air
Swing your partners round and round
Trading genes, crossover has been found

Metaphase I has now begun
Promenade to the center for some fun
Independent assortment makes its mark
No one knows which way to part

Drop your arms; now you're free
Two new partners I do see
Move to the pole
Anaphase I is the goal

Telophase I is next to come
Cytokinesis increases the sum
Haploid cells you have become
2 new daughter cells—but we're not done!

Prophase II you're on your own
Spindles appear in your zone

Promenade to the center for some fun
Single file because you're number one
Metaphase II is now complete
It is time to stomp your feet (stomp, stomp, stomp)

Have no fear
Anaphase II is near
Split in half so it may appear
This is the final frontier

Telophase II comes out of the blue
Cytokines splits us in two
Genetically unique
4 haploid cells with great technique

Review questions

Answer the following review questions and produce a drawing of the cell cycle stage being described to the right of each answer.

1. If a diploid cell starts meiosis with 16 chromosomes, how many chromosomes are present during Prophase I? What significant event occurs with these chromosomes during Prophase I?

2. In a cell with 8 chromosomes, how are the chromosomes arranged during Metaphase I? How does this arrangement differ from mitosis?

3. In a cell with 10 chromosomes, how many chromosomes move to each pole during Anaphase I? What is the significance of this separation for genetic diversity?

4. If a cell with 22 chromosomes undergoes Telophase I and Cytokinesis, how many chromosomes does each resulting cell have? Are the resulting cells diploid or haploid? Explain why.

5. In the cells resulting from Telophase I with 6 chromosomes each, what is the state of the chromosomes during Prophase II? Do homologous chromosomes pair up again in Prophase II? Explain.

6. How are the chromosomes arranged during Metaphase II in a cell that started Meiosis II with 36 chromosomes? How does this arrangement ensure proper division in the next phase?

7. In a cell with 28 chromosomes at the start of Metaphase II, how many chromatids are pulled to each pole during Anaphase II? What is the result of this separation?

8. If a cell with 48 chromosomes undergoes Anaphase II and each chromatid moves to a different pole, how many chromosomes are in each of the four resulting cells after Telophase II and Cytokinesis? How do these chromosome numbers compare to the original cell before meiosis began?

Meiosis in motion answer key

1. There are still 16 chromosomes present during Prophase I, but they are in pairs, making 8 pairs of homologous chromosomes. Homologous chromosomes pair up and crossing over occurs.

2. The 8 chromosomes (4 pairs of homologous chromosomes) line up in pairs at the cell's equator. In mitosis, individual chromosomes line up, not pairs.

3. Each pole will receive 5 chromosomes, representing one chromosome from each homologous pair (single chromatid). This separation ensures that each new cell will have a mix of maternal and paternal chromosomes, increasing genetic diversity (independent assortment).

4. Each resulting cell will have 11 chromosomes. The resulting cells are haploid because they contain half the original number of chromosomes.

5. The chromosomes in each of the resulting cells from Telophase I remain as 6 individual chromosomes. Homologous chromosomes do not pair up again; this occurs only in Prophase I.

6. The 36 chromosomes line up single-file along the equator of the cell. This ensures that each chromatid will be properly separated into the new cells.

7. 14 chromatids are pulled to each pole, since there are 28 chromatids in total (2 per chromosome). Each chromatid becomes an independent chromosome.

8. Each of the four resulting cells will have 24 chromosomes. These cells have half the chromosome number of the original cell, ensuring they are haploid and ready for fertilization in sexual reproduction.

Investigate poultry genetics

How can we predict the expression of traits in poultry?

Standards

- **B.H.1:** Cellular genetics
- **B.H.3:** Genetic mechanisms and inheritance

Introduction

Why do turkeys and chickens look so different from one another? Why do different breeds of poultry have different plumage colors and feather patterns and produce different colored eggs? Humans have been selecting traits in poultry for hundreds of years through the process of artificial selection and hybridization. In this lesson students will learn about poultry genetics and predict why certain traits exist in selected poultry. They will investigate examples of multiple allele, incomplete dominance, and sex-linked traits as they compare poultry traits in order to explain why some traits are not used within commercial poultry farms.

Student prior knowledge

Students should be familiar with the following expressions of the inheritance of traits: dominant/recessive, incomplete dominance, multiple alleles, and sex-linked traits. Students should be comfortable with completing Punnett squares before attempting the investigation in this lab.

Suggested timeline

1–2 class periods (50–100 minutes)

Materials

- Student artificial selection worksheet
- Student incomplete dominance worksheet
- Student sex-linked worksheet

Teacher Preparation

Print off student worksheets

Procedure

1. Ask the students to brainstorm what chickens and turkeys look like, being as descriptive as possible. They can brainstorm alone or in a group using sticky notes or whiteboards. Put these descriptions in a place for the class to see.
2. Reflect on the student descriptions of chickens. For example, if a student wrote that chickens come in many plumage color patterns, discuss how this happens as a result of genetic inheritance. If a chicken is black, what could its parents look like? Consider these ideas as a class.
3. Pass out the student worksheets and review the terminology at the top of each page (multiple alleles, incomplete dominance, and sex-linked traits).
4. Working in groups, have students investigate the multiple alleles in Investigation 1.
5. Review the multiple allele worksheet as a class and discuss how poultry combs have different purposes in various climates. Next, discuss how these combs are expressed and why possible producers make selection choices based on housing and production needs.

6. Working in groups, have students investigate incomplete dominance in Investigation 2.
7. Review part 2 as a class and discuss how smooth and curling feathers impact poultry populations.
8. Smooth feathers are a genetic trait, meaning that this trait was selected for at some point in chicken ancestry. What purpose could curled or smooth feathers serve in the natural and human environments?
9. Working in groups, have students investigate sex-linked traits in Investigation 3.
10. Review part 3 as a class and discuss why feather patterns can help a producer determine the gender of chicks and how this is important in commercial decision making.

Suggested wrap-up activity

Genetics are complicated! Many traits are controlled by more than one gene (comb type, feather patterns, etc.). Is it possible to breed for specific traits by observing phenotypic traits in parents? Why are commercial poultry so different from wild poultry? How has the commercial poultry industry changed chickens and turkeys through selective breeding and hybridization? Have students research the characteristics of wild and commercial birds and debate which characteristics they feel are most important to food production as we move into the future.

Differentiation

Create differentiated groups for laboratory time. Ensure each group contains students of varying ability levels as a support in answering lab questions. Parts 1–3 sequentially increase in complexity.

More challenges

- Explore egg color in chickens. Egg color is a multiple allele trait like skin color is in humans. Darker eggs have more dominant alleles on each gene location than lighter-colored eggs. Have students research chicken breeds like Marans that have very dark brown eggs and determine the genotypes that make this phenotype possible.
- Explore plumage colors and patterns. Single color feathers are known as primary color patterns in chickens, whereas multiple colors on a single feather are known as secondary color patterns. Pick a breed of chicken and explain which color pattern it contains by exploring its feather colors. Is it possible for a chicken to display both primary and secondary color patterns at the same time?
- **Home connection:** What types of chickens or turkeys interest you most? Why? Share the differences in poultry heritable traits at home. What traits would you choose? Colored or white eggs? How many eggs per week? Feather pattern colors?

Support information

- **DNA (deoxyribonucleic acid):** the material containing the genetic instructions used in the development and function of an organism. DNA is arranged in the double helix–shaped strands.
- **Gene:** a segment of DNA that carries a blueprint for the function of a cell and ultimately a particular characteristic of an organism.
- **Chromosome:** a structure containing a complete strand of DNA. Chromosomes function in the transmission of hereditary material from one generation to the next. Chromosomes typically come in pairs, with one set donated from the mother and one from the father. Chickens have 39 pairs.
- **Genotype:** the genetic makeup of an organism, represented by 2 alleles.
- **Heterozygous:** having two different alleles of a particular gene or genes.
- **Homozygous:** having two identical alleles of a particular gene or genes.
- **Phenotype:** the observable physical or biochemical characteristics of an organism resulting from its genotype. Examples of aspects of a chicken's phenotype include body shape, feather color, eye color, comb type, and so on.

- **Punnett square:** a square diagram that is used to predict the genotypes and phenotypes of a selectively-bred cross.
- **Multiple alleles trait:** a genetic trait that is controlled by more than 2 alleles.
- **Codominance:** when both alleles for a gene are expressed equally.
- **Incomplete dominance:** when both alleles for a gene are incompletely expressed or blend their characteristics to make a new phenotypic expression.
- **Sex-linked traits:** when the genes are located on the sex chromosomes of an organism.
- Comb type in chickens is controlled by two or more different genes on two different chromosomes. One is the rose comb gene (R) and the other is the pea comb gene (P). A presence of the gene is represented by the dominant allele (R); an absence of the gene is represented by the recessive allele (r). Both the rose comb gene and the pea comb gene can express themselves in the heterozygous state (Rr). That is, only one copy of the rose comb gene or the pea comb gene is sufficient for that type of comb to occur. Therefore, both genes can be thought of as dominant genes.
- When at least one copy of the rose comb gene is present and the pea comb gene is absent, the result is a rose comb. In other words, a chicken with a rose comb has one of two possible gene combinations: RRpp or Rrpp.
- When at least one copy of the pea comb gene is present and the rose comb gene is absent, the result is a pea comb. A chicken with a pea comb has one of two possible gene combinations: rrPP or rrPp.
- When at least one copy of each gene is present, the result is a walnut comb. A chicken with a walnut comb has one of four possible gene combinations: RRPP, RrPP, RRPp, or RrPp.
- When both genes are absent, the result is a single comb. A chicken with a single comb has the only possible gene combination: rrpp.
- When the duplex comb gene is present, the comb will be divided and demonstrated as either the v-shape (D^v) or the buttercup (D^b) comb. If the duplex comb gene is absent the comb will be represented as the single (d) comb.
- The frazzle gene (FF) is lethal to poultry and not found in nature as the chicks die soon after birth. However, it is incompletely dominant to the smooth (ff) feather pattern and can result in a frizzle (Ff) feather pattern.
- Poultry do not display external genitalia, making it very difficult to accurately determine gender until later maturation. Sex-linked feathering traits such as barring can help producers to know what gender chicks are. Male poultry have 2 ZZ chromosomes, whereas female poultry only have one Z chromosome and one W chromosome and are the determining gender for sex determination.

Teaching suggestions

- Prior knowledge of basic genetic information is important for this lesson. Students should have prior knowledge of the information in this lesson and general working knowledge of Punnett squares. See support information above.
- Have students work in groups of 3 or 4 as they work through parts 1, 2, and 3. It is important that they see that chickens have many breed varieties, each exhibiting specific characteristics that are important to consumers. What characteristics are important to your students?

Career connections

Have you ever wondered what type of poultry careers help to make a healthy, safe environment for commercial birds? Let's take a look!

- **Animal scientists** apply principles of the biological, physical, and social sciences to the problems associated with poultry production and management. In other words, they study animal health and behavior in order to help design the perfect environment for commercial birds to live in and produce meat and eggs.
- **Geneticists** are biologists who study genetics, the science of genes, heredity, and variation of organisms.
- **Breeders** observe the health of the flock and record data on laying efficiency and behavior to select the traits to be combined for future generations.

Investigation 1: Multiple alleles

Chickens are not able to sweat so they control their body temperature with the help of their wattles and comb. In warm seasons, the wattles and comb will help reduce the temperature of the bird by diffusing some of the heat back into the air. In cooler seasons, a smaller wattles and comb help to conserve body heat and prevent loss of heat back into the air compared to a large wattles and comb.

How can farmers around the world help their poultry regulate their temperature? Artificial selection in poultry is a process by which humans choose traits that they wish to develop within the flock. These traits are genetic, determined by genes located in the bird's DNA. These traits are passed on from parents to offspring as alleles during sexual reproduction. Chicken combs are multiple allele traits that may be expressed as dominant/recessive traits. This means that chicken combs are determined by more than one gene. It all depends on the combination of alleles that each chicken has in its genotype.

Part 1

Let's start by looking at 4 distinct multiple allele comb types that are expressed as a combination of two dominant/recessive gene combinations:

Rose

RRpp or Rrpp

Pea

rrPP or rrPp

Walnut

R_P_
(must have 1 dominant allele of each gene)

Single

rrpp

What could we produce if we selectively bred a chicken that is heterozygous (Rrpp) for rose comb and another chicken that is heterozygous (rrPp) for pea comb?

1. How many comb types of each type would we expect to see? Complete the Punnett square and write the correct percentage by each comb type below.

DATA TABLE 1
Rrpp × rrPp

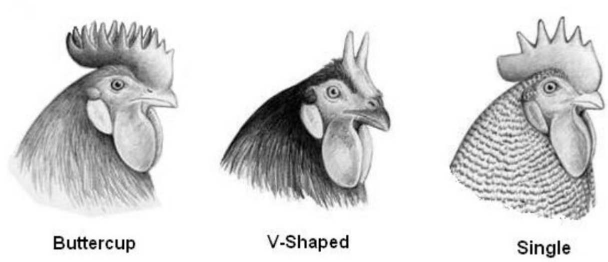
	Rp	**Rp**	**rp**	**rp**
rP				
rp				
rP				
rp				

__________ __________ __________ __________

2. How could a farmer breed more chickens that are suited for a hot climate? What genotype(s) would allow the farmer to produce chickens that could keep their temperature as cool as possible? Please show your Punnett square and explain your answer below.

Part 2

The duplex comb gene determines whether or not a chicken will have a divided or single comb. Take a look at the comb images to the right to see examples of the duplex gene compared to the single comb. In data table 2, please review the multiple allele pattern of inheritance for the duplex gene.



DATA TABLE 2

Phenotype	Allele	Pattern of inheritance
Duplex: V shape	D^v	Dominant to buttercup and single comb
Duplex: buttercup	D^b	Dominant to single comb
Single	d	Recessive

3. What type of comb is expressed with the following genotypes?

DATA TABLE 3

Genotype	Phenotype
D^vD^v	
D^vD^b	
D^vd	
D^bD^b	
D^bd	
dd	

4. Is it possible to breed a V-shaped comb chicken to a buttercup comb chicken and still receive a single comb chicken? Please show your Punnett square and explain your answer below.

5. Why would the duplex gene (double comb) be beneficial to some farmers? Which comb would be the most beneficial in a hot climate?

Investigation 2: Incomplete dominance

Feathering in chickens, the ability for the feathers to lay down or curl outward, is an incompletely dominant gene. Feathers that lay down help a chicken to stay warm and maintain their body temperature in cold weather. This is known as smooth feathering (ff). Feathers that curl outward allow the chicken's body heat to escape into the environment and is known as frizzle feathering (Ff). If a chicken possesses two of these curling alleles, it will not be able to maintain its body temperature and will die shortly after hatching. This combination is known as frazzled feathering (FF).

The curling trait has become popular with chicken enthusiasts and makes the chicken look unusual, to say the least! Take a look at the Smooth chicken versus the Frizzle chicken below and discuss how this trait is both helpful and harmful to birds.

Smooth feathers (ff)

Frizzled feathers (Ff)

1. Identify the phenotype for each genotype listed, then complete the Punnett squares and answer the following questions.

Genotype	Phenotype
FF	
Ff	
ff	

A frizzle rooster is crossed with a hen that is frazzled.

How many offspring are...

- Smooth: ___________
- Frizzled: ___________
- Frazzled: ___________

2. Two frizzle chickens are crossed.

How many offspring are...

- Smooth: ___________
- Frizzled: ___________
- Frazzled: ___________

3. A Frizzle rooster is crossed with a hen that has normal feathers.

How many offspring are...

- Smooth: ___________
- Frizzled: ___________
- Frazzled: ___________

4. A Frazzled rooster is crossed with a hen that has normal feathers.

How many offspring are...

- Smooth: ___________
- Frizzled: ___________
- Frazzled: ___________

5. Poultry breeders need to be careful when breeding chickens for this trait. Look at your data in the Punnett squares above and explain what would be the best method to breed frizzle chickens for consumers.

6. Explain why commercial breeders would not want this trait amongst their flock.

7. This trait is very rare in wild poultry even though it is dominant to smooth feathers. Why don't you see more frizzled bird species in the wild?

Investigation 3: Sex-linked

Organisms have two sets of chromosomes: autosomes and sex chromosomes. The autosomes are all of the chromosomes that are not sex chromosomes. The sex chromosomes carry the genetic information that determines the sex of the offspring. In humans, the sex chromosomes are referred to as X and Y. A human with the sex chromosomes of XX is female and one with the sex chromosomes of XY is male. However, in poultry, the sex chromosomes are referred to as Z and W. A turkey or chicken with the sex chromosomes of ZW is female and the sex chromosomes of ZZ is male. The Z chromosome in poultry is larger and has more genes, similar to the X chromosome in humans. See the sex chromosomes of mammals and birds illustrated below.

Figure 1: gender determination

Organism	Male	Female	Determine the sex of offspring
Mammals	XY	XX	male
Birds	ZZ	ZW	female

In poultry, it is very difficult to determine the sex of newly-hatched chicks. Poultry do not have any external way to prove gender identification. However, some breeds of chickens are referred to as "autosexing" because when they hatch, their sex can be determined based on a "barred" feather pattern due to its location on the Z chromosome.

The barring gene is an absence of coloration in the feather, causing white stripes (bars) on the feathers. As chicks, the down feathers of a barred chicken will be light in color, whereas chicks without the barred gene will be solid.

Males can have zero, one, or two barred genes (Z^BZ^B, Z^BZ^b, Z^bZ^b); two copies intensifies the barring pattern. Females can either have one or no barred genes (Z^BW or Z^bW).

1. Identify the coloration of the chickens as either solid or barred in the chart below.

Male poultry	Solid or barred?	Female poultry	Solid or barred?
Z^BZ^B		Z^BW	
Z^BZ^b		Z^bW	
Z^bZ^b			

2. What will be the outcome of a cross between a barred male (Z^BZ^B) and solid female (Z^bW)? Complete the Punnett square:

   a. How many chicks will have barred feathers?

	Z^B	Z^B
Z^b		
W		

3. Could you tell the difference between the male and females of these offspring when they hatch?

4. What will be the outcome of a cross between a solid male (Z^bZ^b) and barred female(Z^BW)? Complete the Punnett square:

	Z^b	Z^b
Z^B		
W		

   a. How many chicks will have solid feathers?

   b. What is their sex?

   c. How many chicks will have barred feathers?

   d. What is their sex?

   e. Could you tell the difference between the male and females of these offspring when they hatch?

5. How can breeders use these sex-linked traits to help them identify the gender of newly-hatched chicks? Why would this be helpful to commercial breeders?

Investigate poultry challenges

How can poultry farmers keep up with consumer demand in the food industry?
What challenges have we faced in growing food throughout human history?
How might farmers use genetics to solve these on-farm challenges?

Standards

B.H.5: Modern genetics

Introduction

Poultry farmers face a multifaceted set of challenges that require a combination of good management practices, technological adoption, effective disease control, and adaptability to market and environmental changes. These challenges can impact productivity, profitability, and the overall sustainability of poultry farming operations. Addressing these challenges requires continuous learning, investment, and strategic planning to ensure sustainable and profitable poultry farming operations. By 2050, it is estimated that there will be over 10 billion people on the planet. We do not have additional land on which to grow or produce more food. Modern chicken breeding practices utilize a combination of traditional techniques and cutting-edge technologies to enhance productivity, health, and adaptability. Selective breeding and hybridization remain foundational, but should genetic selection, gene editing, and other advanced methods be used to meet the growing demand for poultry production? These practices could address challenges related to disease, feed efficiency, and environmental sustainability.

Student prior knowledge

- Students should have completed an introductory lesson on inheritance and basic Mendialian genetics. Students need to understand that an organism's inheritance pertains to alleles being passed from parent to offspring during sexual reproduction.
- Students should have a basic understanding of spontaneous changes in an organism's DNA that may or may not pass from parent to offspring due to Mendelian genetics and basic genetic law assumptions.
- Human technology has an impact on an organism's genotype and phenotype.
- Selective breeding involves choosing parent chickens with desirable traits to produce offspring that inherit those traits. This practice has been foundational in developing specialized breeds for meat (broilers) and egg production (layers). Hybridization involves crossing different breeds or lines of chickens to produce hybrids that exhibit hybrid vigor (heterosis). This practice is common in commercial operations to achieve superior performance.

Suggested Timeline

1–3 class periods (50–150 minutes)

Materials

- Poultry challenge cards
- Chicken breed cards
- Student KWL chart
- Computers for research

Teacher preparation
Print out handouts or upload digital copies.

Procedure

DAY 1

1. Pose the question: What challenges or problems have we faced in growing food throughout human history? Give some examples: not enough rain, too much rain, harvesting crops by hand took a long time, using horses to pull plows was hard work. Give students two minutes to brainstorm on their own, then group brainstorm for three minutes with their table. Give each group a chance to share what they believe is the biggest challenge on their list.
2. Ask: What are the current challenges in agriculture or food production? (i.e. food may have lower nutrient content; soil may not be able to grow enough food) Have them again brainstorm on their own for two minutes, then group brainstorm for another three minutes. Collect their challenges on a document, parking lot, or Jamboard to revisit.
3. Briefly discuss different ways that scientists have selectively bred chickens. Use the chicken cards to discuss how students would selectively breed chickens for problems they discussed if possible.
4. Have students take out the KWL chart before assigning each type of genetic technology. Students will take note of what they know, what they want to know (questions), what they learn, and ethical issues after researching.
5. The teacher will assign various technologies for altering the genetics of plants/animals to student groups.
6. Students will use research materials to gather information on each type of genetic technology: selective breeding/artificial selection, hybrids, induced mutation/mutagenesis, genetic engineering (use of rDNA), and genome editing (TALENs, ZFNs, CRISPR).

DAY 2

7. Print off or assign poultry challenges to each group.
8. Upon entering the classroom, students will divide into groups to discuss their research from the previous day with others, so one student who investigated each technology is represented in each group (i.e., one person from each– selective breeding/artificial selection, hybrids, induced mutation/mutagenesis, genetic engineering (use of rDNA), and genome editing (TALENs, ZFNs, CRISPR– will meet together to share information).
9. After sharing information, students (remaining in the same groups) will receive a "poultry challenge card" with a problem that a farmer would like to solve using biotechnology. Provide students with the chicken breed cards to help them determine traits and genetics they might want to use to solve the challenge card.
10. Encourage student creativity in addressing the problems! Using research information from day 1, students will determine the best genetic technology method to produce the desired results in order to help the farmer.
11. Students will continue online research to produce a CER (Claim–Evidence–Reasoning) in order to answer their challenge question.

DAY 3

12. Students may need additional time for evidence and CER production. If so, provide time; however, limit this time to bell work.
13. Students will create a poster (using a white board, poster board, or online program) to display their information in a persuasive format.
14. Upon completion, students will communicate their evidence to peers through class presentation or an online format such as FlipGrid.

Suggested wrap-up activity

- Have the students create a flipgrid about one poultry chicken challenge to share with another student group.
- Hold a debate about the ethical issues different forms of genetic technology could create.

Differentiation

- Heterogeneous student grouping works best for this activity.
- Provide specific content articles at the appropriate reading level for heterogeneous student groups.
- The jigsaw practice can be eliminated and student groups complete all research together as one group.

More challenges

- Expand the research into other organisms and other global or local problems.
- Interview a local farmer and provide them with a solution to a problem their farm is facing.
- **Home Connection:** If you are interested in cross breeding or selectively breeding at home, consider using the chicken cards to create your own breeds based on the desired traits you want, such as feather color, egg production, etc.

Support information

- **Mutagenesis:** introduces random genetic changes using external agents.
- **CRISPR:** precise and targeted genome editing with minimal off-target effects.
- **Genetics:** the study of genes and inheritance in living organisms.
- **Heredity:** the passing on of physical or mental characteristics genetically from one generation to another.
- **Inheritance:** the way genetic information is passed from a parent to a child.
- **Cross breeding:** animal breeding with crosses within a single species (but of a different breed).
- **Genetic modification:** any change to an organism's DNA through any method from selective breeding to genome editing.
- **Selective breeding/artificial selection:** the process of choosing an organism with a particular genotype to cross with another of the same species in order to produce offspring with a specific trait(s).
- **Hybridization:** the practice of crossing two pure varieties of an organism to create a more hardy offspring. Many different hybrids have been created in many different organisms.
- **Induced mutation/mutagenesis:** the use of radiation or chemicals to create a change in the DNA of an organism.
- **Genetic engineering:** a method of changing the DNA of an organism by inserting a piece of DNA from another organism using recombinant DNA technology—this is how a GMO might be created; also referred to as "bioengineered".
- **Genome editing:** a targeted method to cut, paste, or replace portions of DNA in an organism. Types include Transcription Activator-Like Effector Nucleases (TALENs,) Zinc-Finger Nucleases (ZFNs), or Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR).
- Humans have modified the genetics of plants and animals since 7000 BC when humans began to selectively breed for advantageous traits in grains.
- For additional history of genetic modification in agriculture, please visit "The Progress of Science Timeline" developed by HudsonAlpha Institute for Biotechnology (timeline.hudsonalpha.org). Altering an organism at the genetic level requires careful considerations about the future of the species. This lesson specifically focuses on five common techniques that scientists use for genetic modification: selective breeding/artificial selection, hybridization, induced mutation/mutagenesis, genetic engineering (use of rDNA), and genome editing (TALENs, ZFNs or CRISPR).

- Teach.genetics.utah.edu is a great resource for both middle and high school teachers looking to provide a more solid background for students to avoid misconceptions.
- Hybridization method of crop improvement
  biologydiscussion.com/crops/improvement/hybridization-method-of-crop-improvement/17701
- Plant breeding: Induced mutation technology for crop improvement article
  iaea.org/sites/default/files/34405682533.pdf
- Genetic Literacy Project website
  geneticliteracyproject.org/gmo-faqs
- Plant breeding techniques, including CRISPR, elearning
  elearning.grownextgen.org/plant-breeding-crispr/
- CRISPR-Cas9 Mechanism & Applications interactive website
  biointeractive.org/classroom-resources/crispr-cas-9-mechanism-applications

Teaching suggestions

- Additional support should be offered for students who lack prior knowledge of genetic modification techniques.
- Students generally have a variety of misconceptions about this topic since many associate genetic modification with science fiction and pop culture. The teacher must be clear and concise with teaching materials in order to clear up misconceptions associated with incorrect ideas that students might have regarding genetic modifications.

Career connections

- **Geneticist:** investigates how traits are inherited, how they manifest in individuals and populations, and how genetic variations contribute to animal health, diseases, and evolution.
- **Veterinarian:** specializes in the diagnosis, treatment, and prevention of illnesses and injuries in animals. Veterinarians provide medical care to a wide range of animals, including pets, livestock, zoo animals, and wildlife.
- **Animal scientist:** helps with monitoring flocks for their health and well-being and ensuring they have constant access to fresh food and water and a safe living environment.
- **Poultry production manager:** leads teams in various areas of farm operations, including animal care, food processing/packaging, feed production, shipping, etc.

KWL chart

	What do you know about the topic?	What do you want to know?	What did you learn?	What ethical questions are involved?
Selective breeding				
Hybridization				
Induced mutation / mutagenesis				
Genetic engineering (use of rDNA, GMOs)				
Genome editing (TALENs, ZFNs, CRISPR)				

DAY 1

Assigned genetic modification method:

Facts you learn: (advantages, disadvantages, examples, any ethical issues)	Reference for facts:

DAY 2

Share your information with others. Take note of what you learn from others above on your KWL chart.

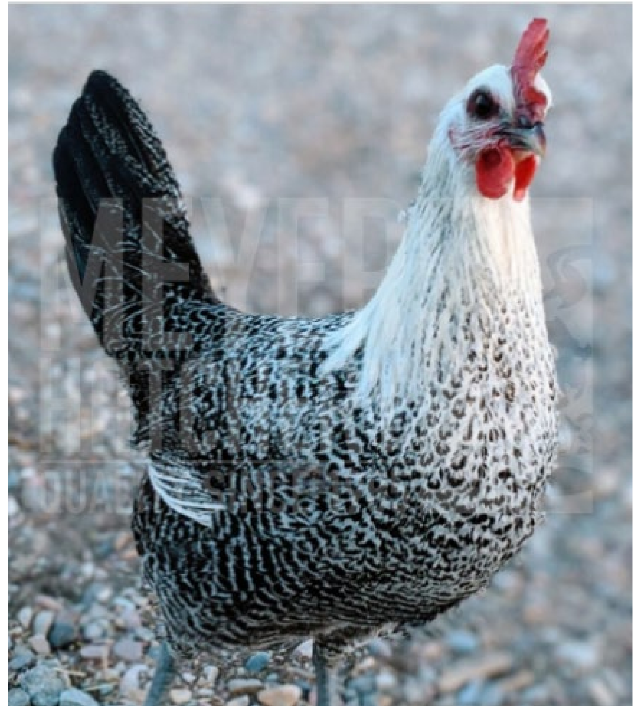
Agricultural challenge #____

1. Discuss the challenge with your group.
2. Research the particular problem.

3. Brainstorm ideas for how to solve it.

4. Write your proposed solution using a claim based on evidence and reasoning to persuade others that yours is the best solution. Use a slide presentation or other digital format to share your solution.

Cornish Cross



Fayoumi

Plymouth Rock (Barred Rock)

Naked Neck (Turken)

Fayoumi

PROS

- Highly resistant to many common poultry diseases.
- Extremely well-suited to hot climates.
- Excellent foragers; good for free-range systems.

CONS

- Moderate egg layers, producing around 150–200 eggs per year.
- Can be flighty and less docile than other breeds.

Cornish Cross

PROS

- Fast growth and high feed conversion efficiency, making them ideal for meat production.
- Produce a large amount of tender meat in a short time.

CONS

- Prone to health problems such as heart and leg issues due to rapid growth.
- Not suitable for long-term keeping beyond the typical harvest period.
- Less active, requiring careful management to avoid obesity.

Naked Neck (Turken)

PROS

- Exceptional tolerance to hot climates due to their reduced feathering.
- Good for both meat and egg production.
- Generally hardy and resistant to disease.

CONS

- Unusual appearance which might not be appealing to all.
- Less suited to cold climates without proper shelter.

Plymouth Rock (Barred Rock)

PROS

- Good for both egg production and meat.
- Friendly and docile, making them suitable for backyard flocks.
- Adaptable to various climates, particularly cold weather.

CONS

- Slower growth compared to some commercial hybrids.
- Larger size requires more feed.

Leghorn

Rhode Island Red

Sussex

Australorp

Rhode Island Red

PROS

- Excellent layers, producing around 250–300 brown eggs per year.
- Adaptable to various climates, including cold temperatures.
- Suitable for both egg and meat production.
- Generally calm and easy to handle.

CONS

- Roosters can be aggressive.
- They require more feed compared to smaller breeds.

Leghorn

PROS

- High egg production, with hens laying around 280–320 white eggs per year.
- Excellent feed-to-egg conversion ratio, making them cost-effective.
- Well-suited to hot climates.

CONS

- Can be flighty and nervous, less friendly than some other breeds.
- Rarely go broody, which can be a downside if natural hatching is desired.

Australorp

PROS

- Excellent layers, known for producing up to 300 brown eggs per year.
- Calm and friendly, making them great for backyard flocks.
- Hardy in cold climates.
- Suitable for both meat and eggs.

CONS

- Less tolerant of extremely hot climates.
- Heavier, which means higher feed costs.

Sussex

PROS

- Good for both egg and meat production.
- Friendly and curious; good for free-range systems.
- Reliable layers, producing around 250–300 eggs per year.
- Excellent foragers, which can reduce feed costs in free-range systems.

CONS

- Less tolerant to extreme heat.
- Can go broody which might interrupt egg production.

Freedom Ranger

Isa Brown

Orpington

Isa Brown

PROS

- Very high egg production, often exceeding 300 brown eggs per year.
- Good feed-to-egg conversion ratio.
- Generally friendly and easy to handle.

CONS

- Often have a shorter productive lifespan due to the high rate of egg laying.
- Can be prone to reproductive issues due to intensive laying.

Freedom Ranger

PROS

- Slower growth rate compared to Cornish Cross, reaching market weight in 9–12 weeks, which often results in healthier birds.
- Good for free-range systems; they forage well and are more active.
- Produces flavorful meat with a firmer texture, often preferred in gourmet markets.

CONS

- Slower growth rate compared to Cornish Cross, which can increase production time and costs.
- Slightly less feed-efficient compared to Cornish Cross.

Orpington

PROS

- Very friendly and easy to handle, excellent for families.
- Good layers of large brown eggs, around 200–280 per year.
- Suitable for both meat and egg production.
- Well-suited to colder climates due to their heavy feathering.

CONS

- Can be very broody, which might reduce egg production periods.
- Larger body size requires more feed.

Jersey Giant

Bresse

Bresse

PROS

- Considered one of the best-tasting chickens in the world.
- Excellent foragers, making them suitable for free-range systems.
- Good for both meat and eggs.

CONS

- More expensive to purchase and raise compared to other breeds.
- Moderate layers, producing around 200 eggs per year.
- Requires specific feeding and management practices to achieve the best meat quality.

Jersey Giant

PROS

- One of the largest chicken breeds, producing a significant amount of meat.
- Hardy in cold climates due to their large size and feathering.

CONS

- Takes longer to reach market weight, often up to 6 months.
- Requires more feed due to their large size and longer growing period.
- Needs more space due to their size, which can increase housing costs.

POULTRY CHALLENGE 1
Egg allergies are very common in humans. Most egg allergies are associated with a specific protein found within the egg. How might you produce hypoallergenic eggs?

POULTRY CHALLENGE 2
Events like the COVID–19 pandemic can disrupt supply chains, affecting production and distribution. How might you create a chicken that can hold back egg production?

POULTRY CHALLENGE 3
Climate change leads to more frequent and severe weather events, which can disrupt operations and affect bird health. How might you create a climate-adaptable chicken?

POULTRY CHALLENGE 4
Feed constitutes a significant portion of production costs, and fluctuations in feed prices can affect profitability. Ensuring the feed is nutritionally balanced and free from contaminants is crucial for bird health and productivity. How might a farmer decrease the amount of food a chicken needs to survive?

POULTRY CHALLENGE 5
Poultry farms are susceptible to various diseases such as Avian Influenza, Newcastle disease, and Salmonella. Outbreaks can lead to significant economic losses. How might a farmer produce a disease-resistant chicken or eradicate a disease?

POULTRY CHALLENGE 6
Farmers have met consumer demands by breeding chickens with more lean white muscle mass (larger chicken breasts). Chicken bones are hollow and can break easier under the increased mass. How might you produce a chicken with stronger bones?

POULTRY CHALLENGE 7

A soybean farmer wants to increase his crop yield and reduce the use of herbicides on his soybean crop. How might you both increase the crop yield of the soybean farmer and decrease the use of herbicides on the crop? Soybeans are an important protein in the turkey's diet.

POULTRY CHALLENGE 8

Corn is a crop that needs added nitrogen in order to grow to its full potential. Soybeans are legumes (symbiotic relationship with Rhizobia bacteria), so they do not need added nitrogen. How might scientists create corn that is a legume? Corn is an important energy source in a chicken's diet.

POULTRY CHALLENGE 9

Chickens and chicken eggs are a good source of protein. How might we create a chicken or an egg with a higher protein content?

POULTRY CHALLENGE 10

Events like the avian flu can disrupt supply chains, affecting production and distribution. How might you create a chicken that can produce eggs at a faster rate?