A Study of Traits
Lesson 7: DNA is Packaged into Chromosomes

Grade: 9-10 General Biology

Length of lesson: 120 minutes

Placement of lesson: Lesson 7 of 9

Unit Overarching Goal

In plants and animals, similarities and differences among individuals within a species result from proteins coded for by the DNA inherited from their parents. Variations among individuals are the result of mutation, meiosis, and recombination through sexual reproduction.

Unit Central Question

What is the best explanation for the similarities and differences we see in individuals within a species—not only for one species, but for every species of plant and animal?

Lesson 7 Main Learning Goal

DNA is packaged into chromosomes, which allows for new genetic combinations and variation through meiosis.

Lesson 7 Focus Question

If individuals have the same version of one trait, will they also have the same version of other traits?

Ideal student response

DNA is packaged into chromosomes in order to fit into the nucleus of a cell. Individuals have a pair of each chromosome. One chromosome of the pair comes from their mother and the other from their father. The chromosome pairs, and the genes on each chromosome, are separated and sorted during meiosis to produce haploid gametes. Genes on different chromosomes separate independently of each other in meiosis. The process of meiosis and sexual reproduction produces different combinations of alleles that can lead to variation in the traits of individuals.

Science Content Storyline

Alleles for a trait are passed from parents to offspring on chromosomes. Although an individual jaguar can be homozygous or heterozygous for a trait, such as fur color, it inherits different alleles in different patterns for other traits. This is possible because jaguars have multiple chromosomes that are sorted independently during meiosis.

Materials

- 2-cm (20-mm) gelatin capsule (1 per team of two students)
- 10 m of thread (1 per team of two students)
- Coffee stir stick (1 per team of two students)
- Snack or sandwich size baggie (4 per team of four students)
- 4 craft sticks of the same color (1 set per teams of four students)
    - 2 of the craft sticks have “F” written on one side
    - 2 of the craft sticks have “f” written on one side
- 4 craft sticks of a second color (1 set per teams of four students)
    - 2 of the craft sticks have “E” written on one side
    - 2 of the craft sticks have “e” written on one side
- Baggies (2 per team of four students)
- Chart paper (1 per team of four students)
- Markers

Advance Preparation

- Cut one 10 m length of thread for each team of two students. An easy way to do this is to measure a 10 m distance from a wall. Place a stir rod through the spool of thread to act as an axel. Tape each end of the rod to the wall just above the floor, leaving space between the wall and rod so the spool can spin easily. This will allow you to quickly pull the thread out to the 10 m mark. Place the thread, one stir stick, and one gelatin capsule in a baggie. Make one baggie of supplies for each team of <u>two</u> students. Note: These supplies cannot be reused in multiple classes.
- For the first use, prepare the craft sticks by writing letters on one side of each stick with a black permanent marker:
  - On half of the craft sticks of one color write an “F”. On the other half, write an “f”. Place two of each letter in one baggie for a total of 4 craft sticks. Each team of <u>four</u> students will need one baggie of sticks.
  - On half of the craft sticks of the other color write an “E”. On the other half, write an “e”. Place two of each of letter in one baggie for a total of 4 craft sticks. Each team of <u>four</u> students will need one baggie of sticks.

  Note: These supplies can be reused in multiple classes.

Lesson 7 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**Link to Previous Lesson** The teacher helps students review ideas about inheritance of alleles. **Lesson Focus Question**: **If individuals have the same version of one trait, will they also have the same version of other traits?** The teacher introduces the lesson focus question.	
90	**Chromosomes and Alleles: From Parents to Offspring** <u>Activity Setup</u> Students work to determine how a large amount of DNA can fit into the nucleus of a cell. <u>Activity</u> Students read about meiosis and model the process using craft sticks. They model the process with one chromosome. <u>Activity Follow-up</u> Students model meiosis with two chromosomes and consider the possible combinations of the twenty-three pairs of chromosomes in humans.	Alleles for a trait are passed from parents to offspring on chromosomes. Although an individual jaguar can be homozygous or heterozygous for a trait, such as fur color, it inherits different alleles in different patterns for other traits. This is possible because jaguars have multiple chromosomes that are sorted independently during meiosis.
15	**Synthesize and Summarize** Students revisit the focus question and add to their ideas.	
5	**Summarize and Link to Next Lesson** The teacher and students summarize the lesson and link to the next lesson.	

Lesson 7: DNA is Packaged into Chromosomes

Phase of Lesson: *Link to Previous Lesson and Lesson Focus Question: If individuals have the same version of one trait, will they also have the same version of other traits?*

Main Learning Goal: DNA is packaged into chromosomes, which allow for new genetic combinations and variation through meiosis.

Focus Question: If individuals have the same version of one trait, will they also have the same version of other traits?

Unit Overarching Goal:

In plants and animals, similarities and differences among individuals within a species result from proteins coded for by the DNA inherited from their parents. Variations among individuals are the result of mutation, meiosis, and recombination through sexual reproduction.

Notes:

Time: 10 Minutes

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions
- ❖ Strategy 2: Ask questions to probe student ideas and predictions

Science Ideas

- Individual organisms have characteristics that differ from other individuals of the same species.
- The characteristics (different versions of a trait) of an individual organism are the result of the proteins in that organism.
- There are different explanations, including parents, genes, and mutations, for why these variations occur.
- Evidence helps scientists evaluate the strengths and limitations of explanations.

Common Student Ideas

- Genes are traits.
- Each parent contributes genetic information for certain traits and not others (i.e., he has his mother's eyes and father's nose).
- Different cell types (skin, muscle, bone) found in an individual's body contain different DNA.
- Some characteristics of offspring are determined by the parents' environmentally acquired characteristics.
- DNA is made of proteins and/or amino acids.
- Organisms eat protein; they do not make proteins.

Lesson 7: DNA is Packaged into Chromosomes

Introduction

You have learned that an individual's traits are determined by the combination of alleles they get from their parents. In the last lesson, you considered a single trait. In this lesson, you will think about how individuals inherit the alleles for multiple traits.

Process and Procedure

Lesson Focus Question

1. Write the focus question for this lesson in the box below. After you have written the focus question, turn and talk with your table group about your ideas. As you discuss your ideas, consider which ideas are similar and which are different. Be prepared to share your discussion with the whole class.

If individuals have the same version of one trait, will they also have the same version of other traits?

Focus on Student Thinking

Use appropriate elicit (STeLLA Strategy 1) and probe questions (STeLLA Strategy 2) to reveal student ideas about the inheritance of multiple traits.

- Following are some question examples:
  - Does the inheritance of one trait, such as black vs. white fur in cats, determine the inheritance of another trait, such as short vs. long fur? **(Elicit)**
  - Say more about why you think they do not influence each other. **(Probe)**
  - Does anyone have a different idea? **(Elicit)**
  - What do you mean when you say white fur and long fur "go together?" **(Probe)**

Implementation	Notes

Link to Previous Unit
● Invite teams to summarize what they learned in the previous lesson. Then have several teams share their summary. Ideas to highlight from the discussion include:
  ○ Offspring have two alleles for each trait. They received one allele from their mother and the other from their father.
  ○ As a result of the alleles they inherit from each parent, an individual can be heterozygous or homozygous for a trait.
  ○ Alleles can be dominant or recessive, and they work together to determine the genotype and phenotype of the individual.
Lesson Focus Question
● **STEP 1:** Ask a student to read the focus question aloud. Then ask another student to paraphrase what the focus question is asking.
● Allow time for students to write the focus question in the box in their workbooks. Reassure them that they are just beginning the lesson, so they may not know the answer, but they should think about their best ideas about the question. Share that they will have a chance to revise their ideas as they work through the lesson.
● Once students have written the focus question in their workbooks, provide time for teams to discuss their ideas. Begin with the elicit question, "Does the inheritance of one trait, such as black vs. white fur in cats, determine the inheritance of another trait, such as short vs. long fur?" This is not a time to challenge their ideas, but rather make their current thinking about the focus question visible through the use of Strategy 1: Ask questions to elicit student ideas and predictions and Strategy 2: Ask questions to probe student ideas and predictions.
Use the information in "Focus on Student Thinking" in the SE key to see examples of ways to elicit and probe student ideas.	

Lesson 7: DNA is Packaged into Chromosomes

Phase of Lesson: *Chromosomes and Alleles: From Parents to Offspring*

Main Learning Goal: DNA is packaged into chromosomes, which allow for new genetic combinations and variation through meiosis.

Focus Question: If individuals have the same version of one trait, will they also have the same version of other traits?

Unit Overarching Goal:

In plants and animals, similarities and differences among individuals within a species result from proteins coded for by the DNA inherited from their parents. Variations among individuals are the result of mutation, meiosis, and recombination through sexual reproduction.

Notes:

Time: 80 Minutes

STeLLA Strategies

- Strategy 1: Ask questions to elicit student ideas and predictions
- Strategy 2: Ask questions to probe student ideas and predictions
- Strategy 3: Ask questions to challenge student thinking
- Strategy 6: Engage students in developing and using models

Science Ideas

- DNA is packaged into chromosomes in order to fit into the nucleus of a cell.
- Individuals have a pair of each chromosome. One chromosome of the pair comes from their mother and the other from their father.
- The chromosome pairs, and the genes on each chromosome, are separated and sorted during meiosis to produce haploid gametes.
- Genes on different chromosomes separate independently of each other in meiosis.
- The process of meiosis and sexual reproduction produces different combinations of alleles that can lead to variation in the traits of individuals.

Common Student Ideas

- Genes are traits.
- Each parent contributes genetic information for certain traits and not others (i.e., he has his mother's eyes and father's nose).
- Different cell types (skin, muscle, bone) found in an individual's body contain different DNA.
- Some characteristics of offspring are determined by the parents' environmentally acquired characteristics.
- DNA is made of proteins and/or amino acids.
- Organisms eat protein; they do not make proteins.

Chromosomes and Alleles: From Parents to Offspring

2. Fur color is one trait that jaguars have, but there are many other traits we could study. Each trait is determined by the structure and function of a protein that is coded for by the DNA sequence of the gene for that trait. Although scientists have not determined the exact amount of DNA in a jaguar cell, they know that tigers have 2.9 billion nucleotides that make up the DNA in each cell. It is likely jaguars have a similar amount of DNA in each cell.

   If you stretched the DNA in a single cell out into a single thread, it would be about 2 meters (6 feet) long. How does all that DNA fit into the nucleus of a cell that can only be seen with a microscope? Write your best ideas below.

3. You will have a chance to test your ideas by using a model with parts you can see. Follow your teacher's directions to learn more about how you will complete this task. As you work, write down notes about what works well as you fit your "DNA" into the "cell."

4. Read *Packing DNA into Cells* to learn more about how DNA fits into the nucleus of cells. As you read, underline any ideas that help explain the information you learned in previous lessons. Be ready to discuss the ideas you underlined.

   Examples of ideas students might underline are shown.

   Packing DNA into Cells

   In all multicellular organisms, the genetic material consists of one or more long DNA molecules. The DNA is tightly coiled into chromosomes. In each of your cells, except red blood cells and gametes (eggs and sperm), you have 23 pairs of chromosomes. One set of 23 chromosomes came from your father and one set of 23 chromosomes came from your mother. Each chromosome contains one long DNA molecule and many protein molecules. The DNA and proteins pack together tightly to form the structure of a chromosome. This is the compact structure we see when we look at dividing cells under a microscope.

   Based on this reading, how might you change what you tried with the thread and the capsule?

Implementation	Notes
Activity Setup: Chromosomes and Alleles: From Parents to Offspring • **STEP 2:** Have a student read the information in Step 2 aloud. Ask students why a tiger might be a good animal to use as a comparison for jaguars. If students have studied evolution, they are likely to say that the two species are related and had a common ancestor. If they have not studied evolution, they may say that both are big cats and their DNA might be similar. Either answer is acceptable; the purpose of the question is to establish why using the length of tiger DNA is acceptable for jaguars. • Allow students time to individually write their best ideas about how a very long length of DNA could fit into a cell. Ask several students to share their ideas. They may have ideas about twisting or packing it tightly into the nucleus. Some students may use the term chromosome. At this point, accept all ideas. • **STEP 3:** Distribute a baggie of thread, stir stick, and gelatin capsule to each student pair. Tell students that the thread represents DNA and the gelatin capsule represents the nucleus of a cell. Using their ideas from Step 2, they should try to fit all the thread into the capsule. As they work, they should note additional ideas about the best way to fit all the DNA into the nucleus. o Do not give students too much time to complete this task as the purpose is to think about how much DNA is in a cell and how it might be compacted to fit. The process of DNA compaction around histone proteins will not be discussed in this unit. o Many teams will not be able to fit all the thread into the capsule. Teams may find the gelatin capsule begins to get sticky if their hands are warm and sweaty. • **STEP 4:** Have students read *Packing DNA into Cells*. Once they have had time to read and underline, have them discuss the ideas they underlined with their teammates. o Have students reflect on how they might change what they tried as they fit the thread into the gelatin capsule. Although they did not have proteins to incorporate, they may have the idea that the thread needs to be tightly coiled in order to fit all of it in the gelatin capsule.	

5. Think back to the paragraph you wrote at the end of Lesson 6. How do you think chromosomes influence the traits that a jaguar, human, or other organism inherits?

   Sample responses include:

   - We said that offspring get one allele from each parent. Here it says that we get one of each chromosome from each parent. Maybe alleles and chromosomes go together.
   - Traits are based on what you inherit from each parent, and you get one chromosome from each parent.
   - I think chromosomes have to do with genotype and traits have to do with phenotype.

Focus on Student Thinking

Use appropriate elicit (STeLLA Strategy 1), probe (STeLLA Strategy 2), and challenge (STeLLA Strategy 3) questions to reveal student ideas about the role of chromosomes in inheritance.

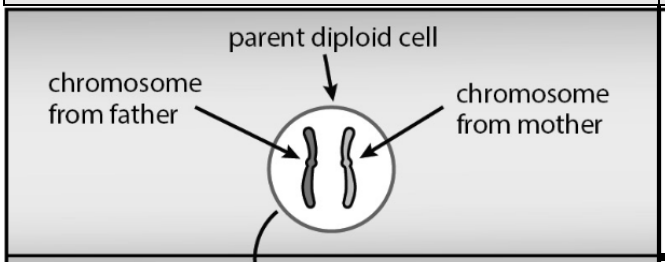
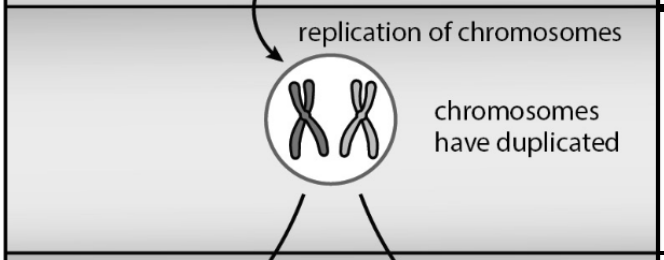
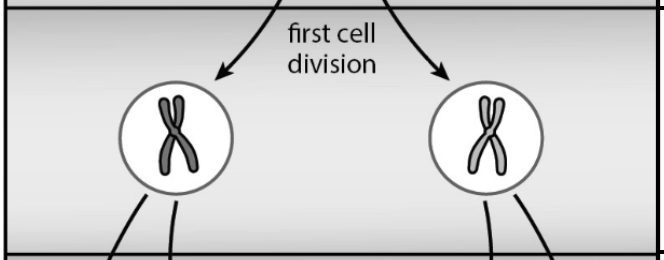
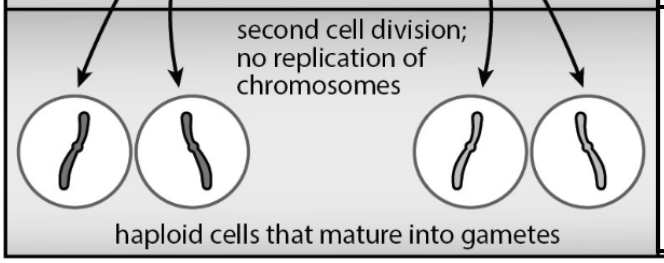
- The following are examples of these questions:
  - How do you think chromosomes are related to inheritance? **(Elicit)**
  - Say more about why you think chromosomes and alleles are the same. **(Probe)**
  - What is the relationship between chromosomes and DNA? **(Challenge)**
  - What do you mean when you say chromosomes have DNA? **(Probe)**
- The following is an example of a dialogue that engages students in using their models (STeLLA Strategy 6) for thinking about how DNA is packed into the nucleus.
  - T: Now that you've read the paragraph about packing DNA into cells, how would you change the way you tried to fit the thread into the capsule? **(Elicit)**
  - S1: Yeah, I'd wrap and scrunch the thread up first and then try to put it in the capsule.
  - T: Tell us how that represents what actually happens with DNA in the nucleus. **(Probe question that engages student in using their model to think about the phenomenon)**
  - S1: Well, we read that DNA and protein pack together tightly, like what I said we should do with the thread.
  - T: What is the relationship between chromosomes and DNA? **(Challenge)**

Implementation	Notes

• **STEP 5:** The purpose of this question is to help students begin to think about the role of chromosomes in inheritance. Have students discuss this question with their teammates and record the key ideas of their discussion in the space below the question.
  o Some students may realize that the alleles are contained in the DNA that is tightly coiled into a chromosome. They may also realize that because an offspring receives one chromosome set from each parent, this helps to explain the idea that offspring receive one allele from each parent. The idea that genes are located on chromosomes is an important idea to highlight prior to the reading in Step 7.
  o Students may not have a full understanding of the relationship between alleles and chromosomes at this point; they will learn more in the next activity. Use elicit and probe questions to learn more about what students are thinking.
 	
Refer to "Focus on Student Thinking" in the SE key for possible questions to elicit, probe, and challenge student ideas, and for examples of dialogue using STeLLA Strategy 6: Engage students in developing and using content representations and models.	

6. We will learn more about one process that leads to the variation we see in individuals of the same species. To begin learning about this process, examine the table below. For each picture on the left, use the box on the right to describe what you observe happening.

   Example responses are shown.

Illustration	Observations
	The chromosome from the father and mother line up next to each other.
	The chromosomes make copies of themselves.
	The cell divides in two. One cell has the copied chromosome from the father and the other one has the copied chromosome from the mother.
	Both of the cells above divide in two. Two of the cells have one, uncopied chromosome from the father and two of them have one, uncopied chromosome from the mother.

Implementation	Notes
Activity: Chromosomes and Alleles: From Parents to Offspring • **STEP 6:** Invite students to look at the pictures on the left side of the table. On the right side, they should write a summary sentence describing what is happening in the picture. Encourage students to write down all their ideas, reminding them that they are not expected to have all the correct ideas at this point. • Ask the whole class to share questions they have about the images and what they see happening.	

7. Read *The Process of Meiosis* to learn more about what happens to chromosomes as cells produce gametes, or eggs and sperm. As you read, add to your ideas in Step 6.

The Process of Meiosis

In sexual reproduction, genetic information is passed from parents to offspring by the **gametes** (egg and sperm). Gametes have only *half* the genetic information of other body cells. That means these cells have half the number of chromosomes (one copy of each chromosome) and thus half the alleles of other body cells. For example, in humans, the gametes have 23 chromosomes in each cell. Body cells have 46 chromosomes.

The process of reducing the number of chromosomes is called **meiosis**. Meiosis accomplishes three major tasks: (1) It forms cells that allow each parent to contribute equal amounts of genetic information to the offspring. (2) It reduces the number of chromosomes in the gametes to half the number of chromosomes found in body cells. (3) It is an important source of variation in offspring.

Following the chromosomes during meiosis provides a way to understand certain patterns of inheritance. In all cells other than gametes, chromosomes occur in matching pairs. For each pair, one chromosome came from the mother's egg cell and one chromosome came from the father's sperm cell. These cells are called **diploid** (*diplous = double*). The chromosomes of each pair contain genes that code for proteins for the same traits. As you learned in the previous lessons, the alleles for each gene may be different.

In contrast, gametes contain *one* chromosome from each matching pair. Gametes are **haploid** (*haploos = single*); they contain one copy of each chromosome. In sexual reproduction, a sperm fertilizes the egg, and the cells fuse to form a new cell with the same number of chromosomes found in body cells. The single cell that results from the joining of the egg and the sperm is called a *zygote*. In humans, the zygote will have 23 matching pairs of chromosomes. Each pair is composed of one chromosome from the egg and one chromosome from the sperm. In this way, fertilization restores the diploid number of chromosomes in the zygote.

Let's examine the process in more detail. Just before meiosis begins, each chromosome of each doubles to make two identical copies. During the first cell division, the doubled chromosomes separate into two cells. Each of the two new cells contains one doubled chromosome. That chromosome may have originally come from either the individual's mother or father.

During the second cell division, the doubled chromosomes in each cell separate, and the cell divides into two more cells. This second cell division results in a total of four haploid cells. Each cell contains one chromosome from the original pair.

The diagram in Step 6 showed one pair of chromosomes. However, a diploid human cell has 23 pairs of chromosomes (46 total). One chromosome of each pair came from the mother and the other chromosome came from the father. Through meiosis, the chromosome pairs are separated randomly. For example, in a human gamete, 20 chromosomes may have come from the mother and 3 may have come from the father. Or perhaps 8 chromosomes in the gamete came from the mother and 15 from the father. There are many different combinations of chromosomes that can be produced by meiosis. This leads to a great deal of variation between individuals in a population.

Implementation	Notes

• **STEP 7:** Ask students to read *The Process of Meiosis.* Encourage them to use a literacy strategy such as having one student in the pair read a paragraph and the other partner summarize what they heard. Both partners can annotate the paragraph and add to the chart in Step 6.
• Once pairs have added to the chart in Step 6, have them compare their ideas with several other pairs with the goal of enhancing their notes further.
• Lead a class discussion of the essay. Key points to highlight include:
  ○ Most body cells are diploid and have two pairs of each chromosome. Gametes, egg and sperm cells, are haploid and have one pair of each chromosome.
  ○ One chromosome of each chromosome pair in a cell came from the mother and the other from the father.
  ○ In the process of meiosis, each chromosome first doubles. Then, in the first cell division, the chromosome pairs separate into two cells. At this point, each cell contains a chromosome that came either from the mother or the father.
  ○ In the second division, the doubled chromosomes separate into separate cells. The second division results in four haploid cells that will become gametes (egg or sperm).
  ○ When an egg and sperm fuse to form a zygote, the chromosome number is restored to diploid.
  ○ Each chromosome is composed of one DNA molecule. Segments of this DNA that code for a protein are genes. Each gene may have different alleles, such as the alleles for back and spotted fur in jaguars. As chromosome pairs are separated in meiosis and recombined in sexual reproduction, different combinations of chromosomes and alleles may be created.	

8. You will now consider how meiosis affects the alleles that an offspring inherits by modeling the process using craft sticks. To do this,
   a. Draw circles similar to those in Step 6 on your chart paper. Do not draw the chromosomes. Draw the correct number of circles for each row.
   b. Place two craft sticks, one labeled “F” and one labeled “f” in the top circle with the letters facing up.
   c. Model the process of meiosis, adding craft sticks and moving them down the rows as needed.
   d. When you have finished the process, record the alleles for each of the gametes in order, left to right, in the table below:

Gametes Produced Through Meiosis			

Focus on Student Thinking

Use appropriate elicit (STeLLA Strategy 1), probe (STeLLA Strategy 2), and challenge (STeLLA Strategy 3) questions to reveal student thinking about the process of meiosis.

- The following are examples of these questions:
  - How did you show the chromosomes after they replicated? **(Elicit)**
  - What does it mean here where you have four craft sticks in the circle? **(Probe)**
  - Tell me more about why you show the chromosomes this way here. **(Probe)**
  - Explain how your model shows how the original diploid cell became four haploid cells. **(Challenge)**
- Notice how the teacher in the following dialogue engages students in using their models (STeLLA Strategy 6) to explain the movement of chromosomes during meiosis.
  - T: How did you represent the chromosomes after they replicated? (Elicit question that emphasizes the craft sticks as representations of chromosomes)
  - S1: We added the extra two craft sticks.
  - T: Say more about how you knew how to pair up the sticks. (Probe)
  - S1: Umm, I don’t think it matters.
  - T: Does anyone have a different idea about this? (Elicit)
  - S2: It does matter, because they’re supposed to be copies. So, the extra big F craft stick goes next to the big F stick in the cell and the extra little craft stick goes next to the little f one in the cell.
  - T: S1, do you still think you could pair them anyway, or did S2 convince you?
  - S1: Yeah, if they’re copies then the two big Fs and two little fs should be together.
  - T: Use your model to talk me through how one diploid cell becomes four haploid cells through the process of meiosis. **(Question that challenges students to use the content representations to explain a real event in cells)**

Implementation	Notes

• **STEP 8:** Distribute the following to each team of four students:
  o Baggie with four craft sticks, 2 of each labeled "F" and "f"
  o 1 sheet chart paper
  o Marker
• Have students draw circles in rows to replicate those in the table in Step 6. Make sure the circles are big enough that eight craft sticks could fit inside the circles. Ask teams what the crafts sticks, letters, and circles represent, to make sure they know the craft sticks represent chromosomes, the letters represent an allele or gene, and the circles represent the nucleus or cell.
• Students should use the information in Steps 6 and 7 to model the process of meiosis. As students work, circulate around the room asking probe and challenge questions to make sure each group is following the reading and has an understanding of each step.
  o When they replicate the chromosomes, they should add the two craft sticks to represent the doubling of the chromosomes, making sure the correct letters are paired with the original sticks. Ask elicit and probe questions to make sure students understand the process.
  o The goal in this step is to help students understand the general process of meiosis in which the chromosomes are replicated, and cell division occurs twice, leading to haploid gametes. Students should not be expected to memorize the stages of meiosis or the positions of chromosomes at each step in the process.
  o Ask teams to share the order in which their gametes appeared. Some teams will have the order F, F, f, f while others will have f, f, F, F. Students should not have the order F, f, F, f or f, F, f, F.
  o Remind students that in the previous lesson, "F" represented the allele for black fur and "f" represented the allele for spotted fur. One parent has been represented on the chart in this activity. Because the parent was heterozygous for fur color (the original circle had one F and one f craft stick), half of the gametes contain the allele for black fur color and half the gametes contain the allele for spotted fur color. The color of the offspring will depend upon which gamete of this parent and which gamete of the other parent fuse to make the zygote.
• Based on students' thinking made visible in their responses to elicit, probe, and challenge questions, you may decide to have students model the process without referring to the reading or table in Steps 6 and 7. If you feel students have a good understanding of the process, proceed to Step 9.
 	
Refer to "Focus on Student Thinking" in the SE key for possible questions to elicit, probe, and challenge student ideas, and for an example of dialogue using STeLLA Strategy 6: Engage students in developing and using content representations and models.	

9. Carry out the process of meiosis again. This time, you will use two different chromosomes to start.

   a. Use the same chart paper from Step 8.

   b. Place four craft sticks, one labeled “F”, one labeled “f”, one labeled “E”, and one labeled “e” in the top circle with the letters facing up.

   c. Model the process of meiosis, moving the craft sticks down the rows as needed. Remember that each cell will have one of each different chromosome.

   d. When you have finished the process, record the alleles for each of the gametes, in order, in the table below:

Gametes Produced Through Meiosis			

Focus on Student Thinking

Use appropriate probe (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) to reveal student ideas about the relationship between different traits and their understanding of the strengths and limitations of their models.

- Following are examples of some questions you might ask:
  - Say more about why you have two orange craft sticks in one cell and two red craft sticks in the other one. **(Probe)**
  - What did you mean when you said the gametes either have both of the same or one of each? **(Probe)**
  - Will black jaguars always have reddish yellow eyes, or could they also have golden eyes? Use your models to explain your answer. **(Challenge)**
  - What is a limitation of your craft stick models for showing how multiple traits are inherited? **(Challenge)**

Implementation	Notes

Activity Follow-up: Chromosomes and Alleles: From Parents to Offspring
• **STEP 9:** Distribute a baggie with the second color craft sticks labeled "e" and "E" to each team. Have students place four craft sticks, one with each letter (F, f, E, e) in the first circle.
  ○ Ask students how many pairs chromosomes are represented by the craft sticks in the cell (two pairs of chromosomes represented by the two different colors of craft sticks).
• Have students model the process of meiosis, reminding them that one of each different chromosome (one of each color craft stick) should be present in each cell. Ask teams to try to model the process without looking back at the reading or table from Steps 6 and 7. If they get stuck, they should refer to the reading and table. As teams work, circulate through the room asking probe and challenge questions.
• Students should finish the process with two craft sticks, one of each color, in each of the gamete circles. They should record the alleles in each gamete in the table in their workbook. Students should have combinations that include either FE and fe or Fe and fE.
  ○ As groups finish, note the combination of alleles they produced in their gametes and ask them to see if they can produce the other combination of gametes.
• When groups have finished, draw the class together to discuss their findings. Highlight that each team started with the same combination of chromosomes, yet the gametes had different combinations of alleles depending on the way in which chromosome pairs were separated in the first cell division.
• Remind students that the letter f on the craft sticks represents fur color. "F" represents the black allele and "f" represents the spotted allele. Share that the letter e on the other color craft stick represents eye color. "E" represents reddish yellow eyes and "e" represents golden eyes. Ask if black jaguars will always have the same color eyes. Use probe and challenge questions to help students share their thinking. Students should realize that the two traits are independent of each other because they are inherited on different chromosomes.
• Ask students how many combinations of alleles they could make with 23 pairs of chromosomes. Students should come to the conclusion that there are many different combinations. If you have students that excel at math, consider having them do the calculation to determine the number of possibilities. To do this, students would calculate 2^{23} to represent two choices for each of the 23 chromosomes. The result is 8,388,608 possible combinations. This leads to a lot of possible variations in traits among individuals—even individuals who have the same two parents
• Ask students to consider how the craft stick model helped them understand meiosis and explain the relationship between different traits. Then ask students to consider the strengths and limitations of the craft stick models.
Refer to "Focus on Student Thinking" in the SE key for possible questions to probe and challenge student ideas.	

Lesson 7: DNA is Packaged into Chromosomes

Phase of Lesson: *Synthesize and Summarize*

Main Learning Goal: DNA is packaged into chromosomes, which allow for new genetic combinations and variation through meiosis.

Focus Question: If individuals have the same version of one trait, will they also have the same version of other traits?

Unit Overarching Goal:

In plants and animals, similarities and differences among individuals within a species result from proteins coded for by the DNA inherited from their parents. Variations among individuals are the result of mutation, meiosis, and recombination through sexual reproduction.

Notes:

Time: 15 Minutes

STeLLA Strategies

- ❖ Strategy 9: Engage students in making connections by synthesizing and summarizing key science ideas

Science Ideas

- Individual organisms have characteristics that differ from other individuals of the same species.
- The characteristics (different versions of a trait) of an individual organism are the result of the proteins in that organism.
- There are different explanations, including parents, genes, and mutations, for why these variations occur.
- Evidence helps scientists evaluate the strengths and limitations of explanations.

Common Student Ideas

- Genes are traits.
- Each parent contributes genetic information for certain traits and not others (i.e., he has his mother's eyes and father's nose).
- Different cell types (skin, muscle, bone) found in an individual's body contain different DNA.
- Some characteristics of offspring are determined by the parents' environmentally acquired characteristics.
- DNA is made of proteins and/or amino acids.
- Organisms eat protein; they do not make proteins.

Synthesize and Summarize Key Science Ideas

10. Look back at your initial answer to the focus question. Revise or add to your ideas using a different color.

11. In Lesson 1, you saw three possible explanations to answer the unit central question, "What is the best explanation for the similarities and differences we see in individuals within a species—not only for one species, but for every species of plant and animal?"
Look back over what you have learned in Lessons 6 and 7. In the table below, write evidence that will help you answer the unit central question.

    Place a check mark in the column for any explanation the evidence supports.

    Example responses are shown.

Lesson	Evidence	Parents	Genes	Mutation
6	Two black jaguars, or one black and one spotted jaguar, could have either black or spotted offspring. Two spotted jaguars have only spotted offspring.	✓	✓	
7	Parents pass their alleles on to their offspring by making gametes that have one of their two alleles for each gene.	✓	✓	

Implementation	Notes

Synthesize and summarize key science ideas
• **STEP 10:** Have students revise or add to their answer to the lesson focus question in a different color. Invite several students to share how their thinking changed over the course of the lesson with the whole class.
• **STEP 11:** Remind the class of the unit central question, "What is the best explanation for the similarities and differences we see in individuals within a species – not only for one species, but for every species of plant and animal?" Note that, in Lesson 1, we considered three possible explanations: parents, genes, and mutation.
• Have students work as a team to review Lessons 6 and 7, recording evidence that will help them answer the unit central question. Students should check the explanation that the evidence best supports. In some cases, more than one explanation may be checked.
  ○ Have teams compare their evidence and explanations they support with several other teams.
  ○ Invite teams to use STeLLA Strategy 4: Engage students in communicating in scientific ways as they compare their ideas.	

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Implementation	Notes
Summarize • Share that, in this lesson, we learned how the DNA of genes is packaged into a chromosome. Individuals have a pair of each chromosome. One chromosome of the pair comes from their mother and the other from their father. The chromosome pairs are separated and sorted during meiosis to produce haploid gametes. Genes on different chromosomes separate independently of each other in meiosis. The process of meiosis and sexual reproduction produces different combinations of alleles that can lead to variation in the traits of individuals. *Link to Next Lesson* • Share that in the next lesson they will have a chance to use the information from the last several lessons to look at how traits can vary between individuals of the same family.	