A Study of Traits
Lesson 5: How to Make a Protein

Grade: 9-10 General Biology

Length of lesson: 145 minutes

Placement of lesson: Lesson 5 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 5 Main Learning Goal

An intermediate molecule, RNA, transfers the DNA code for amino acid sequence from the nucleus to the cytoplasm where the protein is made. Mutations may result in proteins with different structures and functions.

Lesson 5 Focus Question

How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?

Ideal student response

DNA is the code for all the instructions about an organism. DNA is located in the nucleus. When a protein is made, the process starts with mRNA being transcribed from the DNA sequence. The mRNA is complementary to the DNA so if there are any changes in the DNA sequence, the mRNA shows those changes. The mRNA then moves to the cytoplasm where the code is read again. This time, amino acids are joined based on the code in mRNA. The amino acids are the building blocks of proteins, so once the whole mRNA sequence is read and the amino acids bonded together, the complete protein is made. When there are changes in the DNA, it may lead to changes in the protein. This can lead to changes in function and in the appearance of traits.

Science Content Storyline

DNA and its code for the amino acid sequence of proteins is contained in the nucleus of cells. However, proteins are made outside the nucleus in the cytoplasm of cells. RNA is an intermediate molecule that allows DNA to stay protected in the nucleus and proteins to be made in the cytoplasm. Mutations in DNA may result in a protein with a different structure and function.

Materials

- None

Lesson 5 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**Link to Previous Lesson** The teacher reviews connections students identified between amino acid sequence and DNA nucleotide sequence. **Lesson Focus Question**: **How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?** The teacher introduces the lesson focus question.	
90	**Getting Information from One Part of a Cell to Another** <u>Activity Setup</u> Students add symbols to a cell diagram to show the location of DNA, amino acids and proteins. They consider how information in DNA, which is located in the nucleus gets to the cytoplasm where amino acids are assembled into proteins. <u>Activity</u> Students examine a portion of the DNA sequence for MC1R in a spotted jaguar and break the code to create a strand of mRNA. They complete an Etch-a-Sketch graphic organizer to show how mRNA is transcribed in the nucleus. Students read an article describing how mRNA is translated into an amino acid sequence <u>Activity Follow-up</u> Students determine the amino acid sequence of a portion of the jaguar MC1R protein that results in black fur.	DNA, and its code for the amino acid sequence of proteins, is contained in the nucleus of cells. However, proteins are made outside the nucleus in the cytoplasm of cells. RNA is an intermediate molecule that allows DNA to stay protected in the nucleus and proteins to be made in the cytoplasm.
20	**Changing the Information** <u>Activity Setup</u> Students annotate a reading about mutations. <u>Activity</u> Students identify the mutation and resulting amino acids that results in insecticide resistance in mosquitos. <u>Activity Follow-up</u> Students consider the question, “Are mutations always bad for the organism?”	Mutations in DNA may result in a protein with a different structure and function.
20	**Synthesize and Summarize** Students revisit the focus question and add to their ideas. They consider the evidence gathered throughout the five lessons to support the three possible explanations that answer the unit central question. They complete a chart to show which of the three possible explanations the evidence from each lesson best supports.	

5	**Summarize and Link to Next Lesson** The teacher summarizes the lesson and links to te next lesson.	

Lesson 5: How to Make a Protein

Phase of Lesson: *Link to Previous Lesson and Lesson Focus Question: How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?*

Main Learning Goal: An intermediate molecule, RNA, transfers the DNA code for amino acid sequence from the nucleus to the cytoplasm where the protein is made. Mutations may result in proteins with different structures and functions.

Focus Question:

How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?

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 5: How to Make a Protein

Introduction

You have learned that both proteins and DNA are chains made from smaller molecules. Proteins are composed of amino acids bonded in a specific sequence, while DNA is composed of four nucleotides bonded in a specific sequence. The sequence of nucleotides in a segment of DNA called a gene codes for the amino acid sequence of a particular protein. In this lesson, you will learn more about how the sequence of nucleotides in a gene codes for a specific protein.

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, write your best ideas in the space below the box, leaving room to revise your ideas.

How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?

Focus on Student Thinking

- Use appropriate elicit (STeLLA Strategy 1) and probe questions (STeLLA Strategy 2) to reveal student ideas about how the information in DNA gets from the nucleus to the cytoplasm.
    - Following are some question examples:
        - What are your ideas about how the information in DNA gets from the nucleus to the cytoplasm where proteins are made? **(Elicit)**
        - Tell me more about how DNA could move back and forth from the nucleus to the cytoplasm. **(Probe)**
        - Does anyone have a different idea? **(Elicit)**
        - Can you say more about your idea of a "messenger"? **(Probe)**

Implementation	Notes

Link to Previous Unit
● Remind students that we are exploring ideas that will help us answer the unit central question: What's 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 we are gathering evidence to evaluate three candidate explanations: genes, parents, and mutation.
● Share that we have learned that one source of variation is differences in proteins. Differences in the amino acid sequences that make up proteins leads to different structures and functions of proteins.
● Highlight the science ideas from the previous lesson:
  ○ DNA is found in the nucleus of cells and has a double helix structure composed of pairs of nucleotides with complementary nitrogenous bases (A pairs with T and C pairs with G).
  ○ The instructions for making a protein are found in a sequence of DNA nucleotides called a gene.
  ○ The sequence of nucleotides in a gene contains the information for assembling amino acids into a specific protein.
● Note that there is some information missing because DNA is located in the nucleus and proteins are made in the cytoplasm of a cell.
 	
Lesson Focus Question
● **STEP 1:** Ask 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. This is not a time to challenge their ideas, but rather to 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 5: How to Make a Protein

Phase of Lesson: *Getting Information from One Part of a Cell to Another*

Main Learning Goal: An intermediate molecule, RNA, transfers the DNA code for amino acid sequence from the nucleus to the cytoplasm where the protein is made. Mutations may result in proteins with different structures and functions.

Focus Question:

How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?

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: 90 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 content representations and models
- Strategy G: Link science ideas to other science ideas

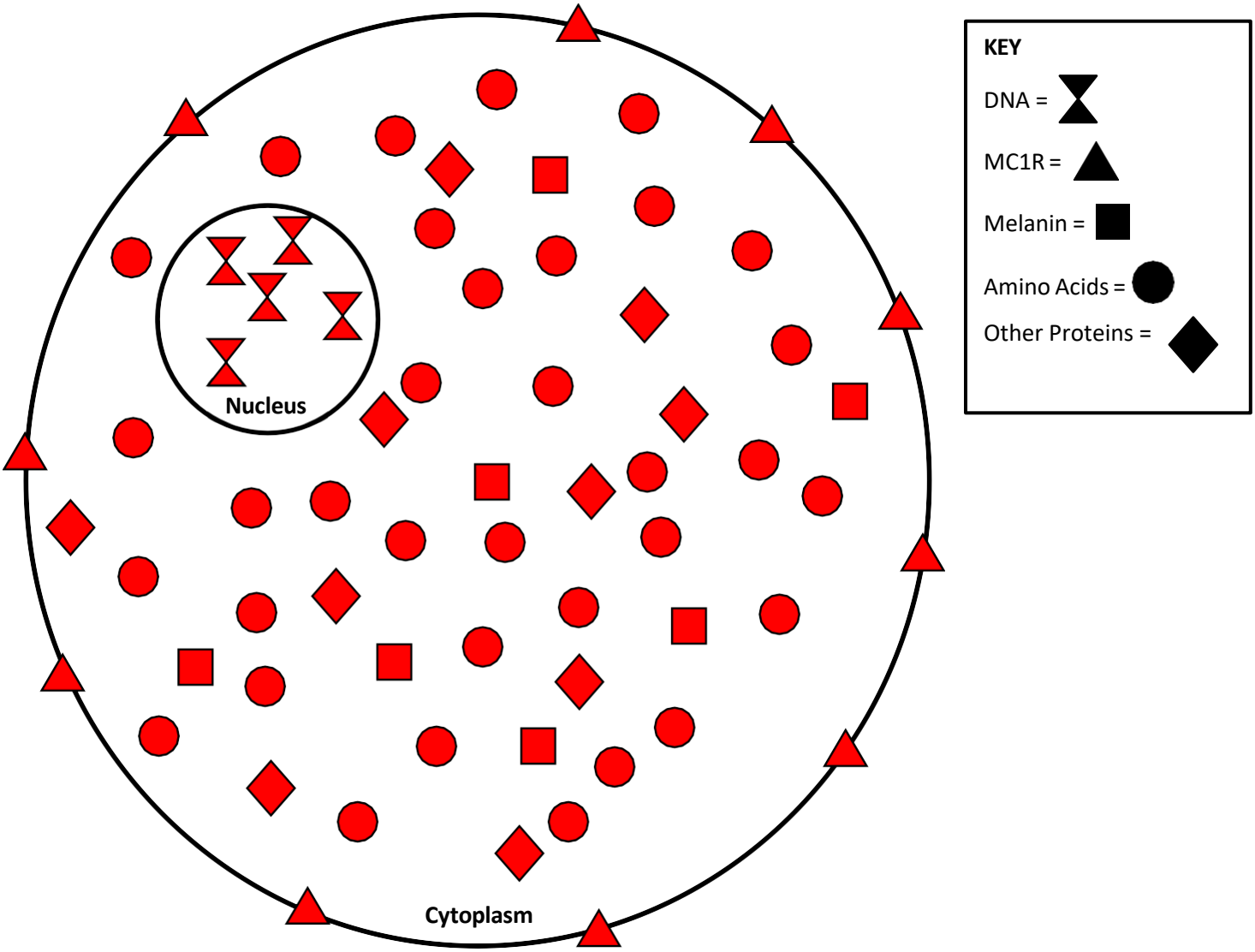
Science Ideas

- RNA is an intermediate molecule that carries the information from the DNA found in the nucleus to the cytoplasm of cells were amino acids are assembled into a protein.

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.

2. Add the symbols in the key to the cell diagram in the proper quantity and location within the cell.



Implementation	Notes

Activity Setup: Getting Information from One Part of a Cell to Another
• The purpose of the activity set up is to raise questions about how DNA nucleotide sequence information in the nucleus gets to the cytoplasm where amino acids are located and assembled into proteins.
• **STEP 2:** Have students consider the science ideas about DNA and proteins, specifically MC1R and other proteins from prior lessons. Have students use the key to add the symbols representing the various molecules to their cell diagram in the proper location and quantities. They may need to refer to earlier lessons as they complete the cell diagram.
• As students complete their cell diagram, circulate through the room looking for proper placement and quantity of symbols:
  o DNA is located in the nucleus and should be represented in a smaller quantity than the rest of the molecules.
  o Amino acids and proteins are located in the cytoplasm. Amino acids should be present in the largest quantity as they are the building blocks of proteins.
  o MC1R is embedded in the cell membrane. Students may remember this from the reading in Lesson 3. However, some may draw the MC1R protein in the cytoplasm. Remind students of the figure in the reading from Lesson 3.
• Have students compare their drawing with a partner's drawing. Ask them to pay careful attention to the drawings to make sure the DNA and proteins are placed in the proper part of the cell.
• Before moving on to the next page, ask if any questions arise from what they observe in their diagrams. Ideally, students will ask the following questions based on their observations:
  o DNA contains the instructions for the amino acid sequence of a protein. But DNA is located in the nucleus and the amino acids and proteins are in the cytoplasm. How do the DNA instructions get from the nucleus to the cytoplasm?
  o There are fewer DNA molecules than proteins. How can so many proteins be made from a single set of directions?
If students do not ask these questions, you can model the process by making the observation and asking students what questions a scientist might ask about this observation. For example: "From looking at your diagrams, I see that the DNA is located in the nucleus and the amino acids and proteins are in the cytoplasm. I also know that DNA contains the instructions for putting the amino acids in the correct sequence to make a protein. What questions might a scientist ask about these ideas?"	

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 how the information in DNA gets from the nucleus to the cytoplasm.
    - Following are some question examples:
        - Show me where in the cell you placed the various molecules. **(Elicit)**
        - Can you share why you put the MC1R protein symbols on the circle representing the whole cell? **(Probe)**
        - What is your thinking about placing amino acids in the cytoplasm? **(Probe)**
        - What evidence can you point to for putting all the DNA molecules in the nucleus? **(Challenge)**
    - A dialogue with students about their cell models might sound something like the following. Notice how the teacher consistently asks students to look at their diagrams, which engages students in using their content representations (STeLLA Strategy 6).
        - T: From looking at your diagrams, I see that the DNA is located in the nucleus and the amino acids and proteins are in the cytoplasm. I also know that DNA contains the instructions for putting the amino acids in the correct sequence to make a protein. What questions might a scientist ask about these ideas? **(Elicit)**
        - S1: A scientist could say; how does DNA direct the order of amino acids in a protein from the nucleus?
        - S2: Or maybe, how does DNA get from the nucleus to the cytoplasm to give the instructions to make specific proteins?
        - T: Look at your diagrams some more. What other questions might scientists ask? **(Elicit)**
        - S3: Why don't amino acids get assembled to make proteins in the nucleus?
        - T: Say more about your thinking. **(Probe)**
        - S3: Well, our model shows that the DNA is in the nucleus, and in the last lesson we said that DNA has the instructions for making proteins. So, it seems like proteins should be made where the instructions are. But our models don't show that.
        - T: Can you think of an experiment that would give evidence to help determine if proteins are or are not made in the nucleus? **(Challenge)**

Implementation	Notes
• Elicit additional questions students have about DNA, proteins, and the process to assemble proteins from their observations of the cell diagram. As students share questions and ideas, use STeLLA Strategy G: Link science ideas to other science ideas. Chart student questions and ideas about possible answers. Possible questions might include: o How does the sequence of nucleotides tell the correct order of amino acids in a protein? o Why doesn't DNA leave the nucleus? o Why don't amino acids get assembled into proteins in the nucleus? o Where do the amino acids that make proteins come from? Share that we will begin to explore answers to these questions in the next activity, beginning with the question, how do the directions in the structure of the DNA molecule get from the cytoplasm to the nucleus? Refer to "Focus on Student Thinking" in the SE key for possible questions to elicit, probe, and challenge student ideas. Refer to "Focus on Student Thinking" in the SE key for examples of dialogue using STeLLA Strategy 6: Engage students in developing and using content representations and models.	

3. You have been studying the MC1R protein in jaguars and have learned that a portion of the MC1R protein is missing in black jaguars. This difference in the MC1R protein can explain some of the variations we see among individual jaguars.

   To learn more about MC1R and how it is different in jaguars, we will explore the process by which DNA provides the instructions to make a protein.

   To begin, examine the DNA sequence of a small part of the gene for MC1R in a spotted jaguar:

   GTG CTG GAG ACG GCC GTC ATG CTG CTG CTG GAG GCG GGC ACC CTG GCC GGC

   What do you notice about the sequence?

   Sample student responses include:

   - There are 51 nucleotides.
   - The nucleotides include G, T, C, and A.
   - The nucleotides are shown 3 in a group.
   - It doesn't show DNA as a double strand—there's only one sequence.

   Next, use the key below to write the sequence for a strand that is complementary to the one given. The sequence is copied again below. Write the letters that go with each of the nucleotides.

   Key:
   For every G, write a C.
   For every C, write a G.
   For every A, write a U.
   For every T, write an A.

GTG CTG GAG ACG GCC GTC ATG CTG CTG CTG GAG GCG GGC ACC CTG GCC GGC
CAC GAC CUC UGC CGG CAG UAC GAC GAC GAC CUC CGC CCG UGGGAC CGG CCG

Implementation	Notes

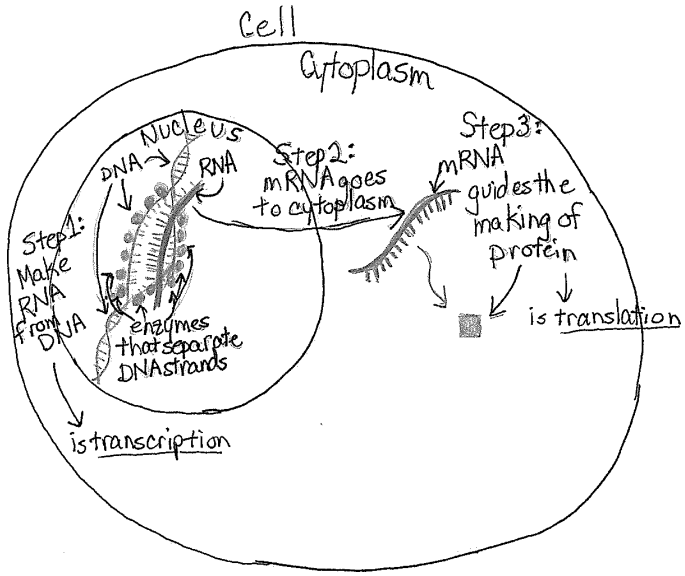
Activity: Getting Information from One Part of a Cell to Another
• **STEP 3:** Remind students that they have been studying the MC1R gene. Share that they will have a chance to study this protein as they learn more about how DNA provides the instructions for proteins.
• Have students examine the DNA sequence. Remind them that this is just a small part of the MC1R gene. Students should record three observations such as:
  ○ The sequence contains the four different nucleotides of DNA
  ○ The nucleotides are grouped in sets of three
  ○ The sequence only shows one strand of DNA
  ○ A total of 51 nucleotides are shown.
• Give students time to use the key to write the sequence that is complementary to the sequence in the DNA strand given. Be intentional with your language at this point as students will learn in the next step that they are generating a sequence of mRNA.	

4. Draw a cell that fills the lower section of this page. Then, complete the Etch-a-Sketch for the reading: *Making a Protein: What Happens in the Nucleus*

Making a Protein: What Happens in the Nucleus

Step 1: You represented the first step in making a protein at the end of step 3! In cells, enzymes in the nucleus do the same process you did on paper. These enzymes are able to separate the two strands of DNA. The enzymes make a new strand of a slightly different nucleic acid, called ribonucleic acid, or RNA. The DNA is available to be transcribed again and again. The process of making an RNA copy of the DNA is called **transcription**. The enzymes complete the process by using the following base pairing rules: If there is a G in DNA, RNA pairs a C. If there is a C in DNA, RNA pairs a G. If there is a A in DNA, RNA pairs a U. If there is a T in DNA, RNA pairs an A.	Step 2: Once the DNA is transcribed into RNA, the RNA moves out of the nucleus into the cytoplasm. The RNA that is made in the nucleus of a cell is called messenger RNA, or mRNA. It is named that because it carries the *message* between the nucleus, where the DNA is, and the cytoplasm of the cell, where proteins are made. The DNA stays in the nucleus where it is protected from chemicals and enzymes in the cytoplasm.	Step 3: The mRNA copy of genetic information serves as a guide for making proteins in the cytoplasm. The process of making a protein from mRNA is called **translation.**

An example of a student drawing is shown:



Implementation	Notes
• **STEP 4:** Have students read the three sections of *Making a Protein: What Happens in the Nucleus.* As students read each section, they should add detail to a drawing of the cell that fills the lower section of the table. You may wish to have one student in each team read a section aloud, then the team can add to their Etch-a-Sketch drawings.	

5. Read and annotate the article below.

   Example student annotations are shown.

Making a Protein: Translating the Message in mRNA

mRNA acts like a blueprint for making a protein, the same way blueprints guide the construction of a building or a machine. The process of converting the code in mRNA to a sequence of amino acids in protein is called **translation**. The same way someone can translate words from English to another language, cells can translate the language of RNA into an amino acid sequence, the language of proteins. Because the mRNA travels out of the nucleus, the process of translation takes place in the cytoplasm of the cell.

Step 3 in our drawing

Shown in our drawing

The Genetic Code

Even though there are just 20 amino acids, they can be put in different orders to make an amazing number of proteins. Each amino acid must be identified specifically by the information in the mRNA. But it cannot be a 1:1 translation. If every nucleotide coded for an amino acid, then there could only be four different amino acids. If there were two RNA nucleotides to code for an amino acid, that would mean there could only be 16 amino acids (4 nucleotide possibilities in the first position multiplied by four nucleotide possibilities in the second position). Instead, the genetic code involves three nucleotides per one amino acid. Each three-letter sequence is called a **codon.** By having three-nucleotide codes, there are 64 possible sequences. Because there are only 20 amino acids, that means that several codons may code for the same amino acid.

Seems like too many

?? I don't understand this

That's why the sequence in step 4 was separated in 3s! New idea & vocabulary

First letter	Second letter				Third letter
	U	C	A	G	
U	phenylalanine phe	serine ser	tyrosine tyr	cysteine cys	U
	phenylalanine phe	serine ser	tyrosine tyr	cysteine cys	C
	leucine leu	serine ser	stop	stop	A
	leucine leu	serine ser	stop	tryptophan trp	G
C	leucine leu	proline pro	histidine his	arginine arg	U
	leucine leu	proline pro	histidine his	arginine arg	C
	leucine leu	proline pro	glutamine gln	arginine arg	A
	leucine leu	proline pro	glutamine gln	arginine arg	G
A	isoleucine ile	threonine thr	asparagine asn	serine ser	U
	isoleucine ile	threonine thr	asparagine asn	serine ser	C
	isoleucine ile	threonine thr	lysine lys	arginine arg	A
	(start) methionine met	threonine thr	lysine lys	arginine arg	G
G	valine val	alanine ala	aspartate asp	glycine gly	U
	valine val	alanine ala	aspartate asp	glycine gly	C
	valine val	alanine ala	glutamate glu	glycine gly	A
	valine val	alanine ala	glutamate glu	glycine gly	G

Starting and Stopping

Study the chart for the genetic code again. You will see that some codons do not specify an amino acid. These codons signal a *stop* in translation, meaning the end of the protein. Another special codon is AUG. This codon specifies the amino acid methionine. It also signals the *start* of translation, to begin building a protein. It can occur in the middle of a gene's sequence as well, but there it means add the amino acid methionine.

Special codons

Implementation	Notes
• **STEP 5:** Share that in the last step we learned that mRNA carries the information in DNA from the nucleus to the cytoplasm. We will now explore how the message in mRNA is translated into the specific order of amino acids in a protein. • Have students read and annotate the article, *Making a Protein: Translating the Message in mRNA*. They should mark key ideas about the process of translation. • Once students have read the article individually, they should discuss key ideas with their team. Ask several groups to summarize the key ideas they discussed, asking probe and challenge questions as needed to make student thinking visible. • To confirm that students are reading the chart correctly, ask students to identify the amino acid for several mRNA codons.	

The Genetic Code is Universal

One of the most remarkable things about the genetic code is that it is universal. Only a small number of organisms have been discovered that have variations in the code. Although bacteria, reptiles, and mammals all have very different features, they all use the same genetic code. That similarity is an important piece of evidence that supports the idea that all life evolved from one common ancestor.

??

Whoa!

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 genetic code.
    - Following are some examples of questions you may ask:
        - What ideas were new to you? **(Elicit)**
        - Can you say more about what you mean by "codon"? **(Probe)**
        - Why did you say some codons are special? **(Probe)**
        - What did you mean when you said *one* codon for proline is CAU? What does this mean about the genetic code? **(Probe)**
        - Why is a sequence of 3 nucleotides the minimum number that could be use in the genetic code? In other words, why couldn't the code use just one nucleotide or two nucleotides? **(Challenge)**
        - If we put human genes into bacteria, the bacteria will produce human proteins. Why is this possible? **(Challenge)**

Implementation	Notes
Refer to “Focus on Student Thinking” in the SE key for possible questions to elicit, probe, and challenge student ideas.	

6. Use what you have learned about transcription and translation to determine the amino acid sequence of a short segment of the MC1R gene in a black jaguar:

Correct responses are shown.

DNA	GTG		CTG		GAG		ACG		GCC		GTC		ATG		CTG		CTG		ACG		GCC		GGC
RNA	CAC		GAC		CUC		UGC		CGG		CAG		UAC		GAC		GAC		UGC		CGG		CCG
Amino Acid	His		Asp		Leu		Cys		Arg		Gln		Tyr		Asp		Asp		Cys		Arg		Pro

Focus on Student Thinking

- Use appropriate probe (STeLLA Strategy 2) and challenge (STeLLA Strategy 3) questions to make student thinking visible.
    - Following are some examples of questions you may ask:
        - Can you tell us why you transcribed the DNA sequence GAG as CUC and not CTC? **(Probe)**
        - Show us how you used the genetic code to translate CAG to mean glutamine. **(Probe)**
        - What is the difference between transcription and translation? **(Challenge)**
        - Why do biologists say that the genetic code is an RNA code? **(Challenge)**

Implementation	Notes
Activity Follow-up: Getting Information from One Part of a Cell to Another • **STEP 6:** In pairs, students should first transcribe the DNA sequence into mRNA, using Steps 3 and 4 for support. Each pair should confirm their mRNA sequence with another pair in their team. • Pairs should then translate their mRNA sequence into the resulting amino acid sequence using the table in Step 6. Each pair should confirm their amino acid sequence with other pairs in their team. Refer to "Focus on Student Thinking" in the SE key for possible questions to probe and challenge student ideas.	

Lesson 5: How to Make a Protein

Phase of Lesson: *Changing the Information*

Main Learning Goal: An intermediate molecule, RNA, transfers the DNA code for amino acid sequence from the nucleus to the cytoplasm where the protein is made. Mutations may result in proteins with different structures and functions.

Focus Question:

How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?

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: 20 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 5: Engage students in analyzing and interpreting data and observations

Science Ideas

- Mutations in DNA may result in a protein with a different sequence of amino acids because amino acids may be added, deleted, or substituted.
- A change in protein structure may cause the protein to function differently.
- The deletion and substitution of amino acids in the MC1R protein causes the protein to produce a different type of melanin which results in different coloration.
- Some mutations are beneficial to the organism.

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.

Changing the Information

7. In Lesson 3 and in this lesson, you have observed that a piece of the MC1R protein is missing in black jaguars. The protein has a different structure because the DNA sequence is different. You may wonder how the DNA sequence changed. Read *DNA Mutations* to find out more.
   - As you read, underline any information that helps you explain how the DNA sequence changed.
   - Put a star next to any information that helps you predict what the offspring of a black jaguar might look like.
   - Put a question mark next to any sentence you do not understand.

Example annotations are shown.

DNA Mutations

Using a template is generally a good way to transmit accurate information. However, no matter what you are using a template to do, there can be changes to the original information. In DNA, these changes are rare, but when they do happen, it is oftenduring a process called **replication**. Every time your cells divide--which can be pretty often--the DNA has to be copied correctly and completely. If it were not, the new cells would not have all the genetic information they need. ?

Cells divide for many reasons. It might be because an organism is growing or has an injury that needs to be repaired. Some types of cells, such as skin cells, are replaced every few weeks. At any given time, DNA is being copied somewhere in your body. Enzymes carry out this work of copying all 3 billion nucleotides. Any time a change is made in the DNA, it is called a **mutation**.

Types of Mutations

One type of mutation happens when the enzyme slips over one or more nucleotides and does not copy them. This makes a DNA molecule that is missing that small piece. This is called a **deletion mutation**. Another type of mutation occurs when the enzyme adds one or more nucleotides to the DNA molecule. This is called an **insertion mutation**. A third type of mutation is called a **substitution mutation**. In this case, the wrong nucleotide is added at a place along the sequence. ?

Organisms have enzymes that detect and repair mutations. However, they are not always able to find and correct all mutations. That means that sometimes mutations become a permanent change in DNA.

Effects of Mutations ?

If a mutation takes place in a single cell, it often does not have serious effects. If a mutation takes place in a cell that makes gametes, such as sperm and eggs, that mutation can be passed down to offspring. ★

However, some mutations are in areas of DNA that are not used by cells. These mutations have no consequences. ? Other mutations can cause only mild effects. Sometimes these are helpful and sometimes they are harmful. These mild mutations can be passed from generation to generation and lead to more variation in a population. ★

★ Other mutations can have larger effects. These may be beneficial, such as a mutation that causes a change in the coloration of an animal. Other mutations can cause serious developmental problems. These mutations are so harmful that they may kill the organism long before it is able to reproduce. Natural selection is a strong mechanism to keep these mutations from accumulating in a species.

Implementation	Notes

Activity Setup: Changing the Information
• The purpose of the activity set up is to raise questions about how differences in the DNA nucleotide sequence arise and introduce the science idea of mutation.
• **STEP 7:** Remind students that in Lesson 3 as well as this lesson, they learned that the MC1R protein has a different structure, and thus a different function in black and spotted jaguars. The difference in the MC1R protein is a result of differences in the DNA sequence. Share that we will read the short essay, *DNA Mutations* to learn more.
• Review the annotation directions with students:
  ○ Underline information that helps explain how the DNA sequence changed.
  ○ Star information that helps predict what the offspring of a black jaguar might look like.
  ○ Put a question mark next to any sentence you do not understand.
• If appropriate, use a literary strategy to complete the reading. For example, at each table, have one student read one paragraph. The next student should summarize what was read.	

Focus on Student Thinking

- Use appropriate elicit (STeLLA Strategy 1), probe (STeLLA Strategy 2), and challenge (STeLLA Strategy 3) questions to make student thinking about mutations visible.
    - Following are some question examples:
        - What can you tell me about the different types of mutations? **(Elicit)**
        - Why might adding or deleting nucleotides in DNA cause a problem? **(Probe)**
        - You said that a mutation is only a problem when it happens in sperm and eggs. Can you say more about why you think that? **(Probe)**
        - How does substituting one nucleotide for another cause a problem? **(Challenge)**
        - Can you think of how a mutation could be an advantage for an organism? **(Challenge)**
    - A dialogue with students about their understanding about mutations might sound something like the following. The teacher reminds students that they learned in Lesson 3 that there is a piece missing from the MC1R protein in black jaguars and asks them to interpret this information based on the reading they just completed (STeLLA Strategy 5).
        - T: Back in Lesson 3, we learned that the MC1R protein in black jaguars is missing several amino acids. Flip back to that lesson to remind yourself if you need to. Based on the DNA Mutations reading, what kind of mutation do you think resulted in the form of the MC1R protein found in black jaguars? **(Elicit)**
        - S1: Probably a deletion mutation.
        - T: Say more about why you think this. **(Probe)**
        - S1: Well, a deletion mutation is when some of the nucleotides in DNA aren't copied, so that means the protein will be missing some amino acids.
        - T: Does anyone have a different idea? **(Elicit)**
        - Ss: No, that makes sense.
        - T: Can anyone think of a way that an insertion or substitution mutation could result in a shorter protein? Here's a hint: Look back at the genetic code. **(Challenge)**
        - S2: Oh! Maybe if a substitution makes a codon that doesn't code for an amino acid?
        - T: Good thinking. That does happen sometimes, and it can happen with insertion mutations too. But I agree with your first idea that it was probably a deletion mutation. Look back at the amino acid sequence in step 9 of Lesson 3 to see if you can tell me why I think that. **(This challenges students to analyze data about the MC1R protein in jaguars, based on what they now understand about how proteins are made.)**

Implementation	Notes
Refer to “Focus on Student Thinking” in the SE key for possible questions to elicit, probe, and challenge student ideas. Refer to "Focus on Student Thinking" in the SE key for an example of dialogue use STeLLA Strategy 5: Engage students in analyzing and interpreting data and observations.	

8. In Lesson 1, you read about mosquitos that are resistant to insecticides. The resistance is the result of a mutation. Study the DNA sequences below for mosquitoes that are affected by insecticide and for those that are not. Note that only a small portion of the DNA sequence is shown. The whole gene is made of several thousand DNA nucleotides and begins with a start codon and ends with a stop codon.

   Example responses are shown.

   Typical mosquito DNA:

   CGG CGG CAG TAC GAC ACC TAG AAG CCC CCA CCG AAG ATG AGG CCC TGA CGG

   Insecticide resistant mosquito DNA:

   CGG CGG CAG TAC GAC ACC TAG AAG CCC CCA TCG AAG ATG AGG CCC TGA CGG

   a. Draw a circle around the mutation.

   b. What type of mutation caused some mosquitoes to be resistant to insecticide? What is your evidence?

      It was a substitution mutation. Both sequences have the same number of nucleotides (51), so it can't be a deletion or insertion. And, the T that is circled is a C in the sequence for mosquitos that are affected by insecticide.

   c. What is the effect of the mutation? Be specific about the amino acids that would be changed from the typical mosquito to the insecticide resistant mosquito. Remember that the sequences above are DNA sequences.

      The DNA where the change is CCG or TCG. That means the mRNA would have the codon GGC for mosquitos that aren't resistant and AGC for mosquitos that are. GGC codes for the amino acid glycine and AGC codes for serine. So, the usual protein (not resistant to insecticide) that is made from the gene has a glycine amino acid at a place where the gene that makes the mutant protein (resistant to insecticide) has a serine amino acid.

Focus on Student Thinking

- The following is a sample dialogue among teacher and students about the cause of insecticide resistance among mosquitos. Note how the teacher refers students to the DNA sequence data in this step and asks them to analyze and interpret this information (STeLLA Strategy 5).
  - T: What do you think happened that made some mosquitos resistant to insecticide? **(Elicit)**
  - S: It's probably some protein. You know, like there's a protein that is different in spotted and black jaguars.
  - T: Look at the DNA sequence information here. Is there evidence to support your idea? **(Student is challenged to engage in analyzing the data.)**
  - S: Oh, yeah, it's from mosquitos. Well, there's one nucleotide that's different between resistant and non-resistant mosquitos.
  - T: Explain how a difference of one nucleotide could result in a different protein. **(Challenge)**
  - S: Um, the mRNA that gets made from it would have a different codon—AGC instead of GGC. Then that would mean a different amino acid in the protein—umm, serine instead of glycine.
  - T: Now look at the DNA sequence again. What kind of mutation do you see there? **(This question also challenges the student to interpret the data in the step.)**

Implementation	Notes
Activity: Changing the Information • **STEP 8:** Remind students that, in Lesson 1 they learned about mosquitos that are resistant to insecticide. Have a student read the sentences at the beginning of step 8 aloud, then ask another student to summarize what was read. • Students should work as a table group to compare the two DNA sequences and circle the mutation in the insecticide resistant mosquito sequence. Invite several tables to share the part of the sequence they circled with the whole class. Ask probe questions to make student thinking visible. • Have students work with an elbow partner to identify the type of mutation (substitution mutation) based on the reading in Step 7. Have pairs compare their ideas with others in their team. Ask probe and challenge questions to make student thinking visible. • Have pairs determine the effect of the mutation on the amino acid sequence for the changed DNA. Remind students that the sequences shown are DNA sequences. They will need to follow the base pairing rules in Steps 3 and 4 to determine the mRNA sequence and refer to Step 5 to determine the amino acid coded for by the mRNA codon. ○ If some pairs finish before others, they can transcribe and translate additional codons in the DNA sequence. • Pairs should compare their findings with others at their table. Ask several groups to share their answers with the whole class. Ask probe and challenge questions to make visible the steps students followed to determine the changes in amino acid sequence. Refer to "Focus on Student Thinking" in the SE key for examples of dialogue using STeLLA Strategy 5: Engage students in analyzing and interpreting data.	

Focus on Student Thinking

The following is a sample dialogue among teacher and students about the ways in which mutations can have harmful, beneficial, or neutral effects on organisms.

- T: Are mutations always bad for the organism? **(Elicit)** Take a bit of time to think for yourselves and then turn to a partner and share your initial ideas.
- T: So what do you think? Are mutations always bad for the organism? **(Elicit)** let's see thumbs. Thumbs up if you agree-mutations are always bad, thumbs down if you disagree, and out to the side if you aren't sure.
- T: Let's hear a reason why you think mutations are always bad. **(Probe)**
- 51: Well. Resistant mosquitoes are bad. We can't kill them.
- S2: Cancer is caused by mutations, like skin cancer.
- T: Now let's hear a reason why you disagree. **(Probe)**
- S3: Some mutations are bad, but not all. The mutation on mosquitoes was good for them.
- S4: The MC1R mutation just made fur different. It didn't seem good or bad for the jaguar. Just different fur color.
- T: Raise your hand if you have changed your mind. What made you change your mind? **(Challenge)**
- S1: I see now that I was thinking about good or bad for people, not mosquitoes.
- S5: I would say not sure now, because some mutations are good, some bad, and some don't matter.
- T: You claim that some mutations are good, some bad, and some don't matter. Can you come up with an example of each type? **(Probe)**
- S5: Ummm.
- T: Let's turn that to the whole class. In your small group, see if you can come up with examples of each type-good mutation, bad mutation, and neutral mutation. **(Challenge: if not all student have changed their minds and agree with the statement; Probe: if all students agree that mutations can be good, bad, or neutral.)**

Implementation	Notes
Activity Follow-up: Changing the Information • Ask students the elicit question, "Are mutations always bad for the organism?". Lead a class discussion about the effects of mutations on organisms. Ask probe and challenge questions to support students in identifying the effects of mutations that could be harmful, beneficial, or not affect the organism in a way that is either beneficial or harmful. In this example, the mutation benefits the mosquito. Refer to "Focus on Student Thinking" in the SE key for possible questions to probe and challenge student ideas.	

Lesson 5: How to Make a Protein

Phase of Lesson: *Synthesize and Summarize*

Main Learning Goal: An intermediate molecule, RNA, transfers the DNA code for amino acid sequence from the nucleus to the cytoplasm where the protein is made. Mutations may result in proteins with different structures and functions.

Focus Question:

How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?

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: 20 Minutes

STeLLA Strategies

- Strategy 4: Engage students in communicating in scientific ways
- 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

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

10. 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 1 through 5. 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.

    Sample responses are shown.

Lesson	Evidence	Parents	Genes	Mutation
1	Organisms within a species have different traits. For example, jaguars may have black or spotted fur, mosquitos may or may not be resistant to insecticides, and geese may or may not be able to fly at high altitude.	✓	✓	✓
2	There are differences in some of the proteins found in individuals with different traits. In jaguars, black ones have higher levels of eumelanin than spotted ones. Also, part of the MC1R protein in black jaguars is missing compared to the MC1R protein in spotted jaguars.		✓	✓
3	Spotted jaguars have 6 more amino acids in their MC1R protein than black jaguars.		✓	✓
4	DNA is a molecule that has the instructions for putting amino acids in the right order to make the proteins that give individuals their traits. A sequence of nucleotides in DNA that codes for a protein is a gene.		✓	
5	A gene in mosquitos that are resistant to insecticides has a different nucleotide in one place compared to that gene in mosquitos that are not resistant. It looks like it was a substitution mutation.		✓	✓

Implementation	Notes

Synthesize and summarize key science ideas
• **STEP 9:** 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 10:** 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 the first five lessons, 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.	

Lesson 5: How to Make a Protein

Phase of Lesson: *Summarize and Link*

Main Learning Goal: An intermediate molecule, RNA, transfers the DNA code for amino acid sequence from the nucleus to the cytoplasm where the protein is made. Mutations may result in proteins with different structures and functions.

Focus Question:

How does the information in a DNA sequence found in the nucleus get to the cytoplasm where proteins are made?

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: 5 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.

Implementation	Notes
Summarize • Share that, in this lesson, we learned how mRNA transfers DNA nucleotide information contained in the nucleus of the cells to the cytoplasm where amino acids are assembled into proteins. We also learned how changes in the DNA nucleotide sequence, called mutations, occur. These changes may result in changes in amino acid sequences that result in differences in protein structure and function. *Link to Next Lesson* • Note that up to this point, we've been focused on understanding how traits are the result of proteins. Protein structure and function are determined by the DNA sequence found in a particular individual. But you have also likely heard statements such as, "You got your eyes from your mother," or "You are tall, just like your father." How do these comments relate to the traits of an individual? • You know that you get some traits from your parents, yet you aren't exactly like either parent. Share that we will consider why parents sometimes have children that have the same version of a trait as they do and sometimes have children with a different version of the trait.	