A Study of Traits
Lesson 4: The Code for Building Proteins

Grade: 9-10 General Biology

Length of lesson: 110 minutes

Placement of lesson: Lesson 4 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 4 Main Learning Goal

The structure of DNA contains information (code) for assembling amino acids into proteins. A segment of DNA nucleotides that codes for a specific protein is called a gene.

Lesson 4 Focus Question

How does a cell assemble amino acids in the correct sequence to make a protein that can do its job in the cell?

Ideal student response

DNA is found in the nucleus of cells. DNA has a double helix structure made of four nucleotides. The order of nucleotides in a gene contains the information for putting amino acids together in the correct sequence to make a protein.

Science Content Storyline

Amino acid sequence is determined by DNA. DNA is found in the nucleus of cells and has a double helix structure composed of pairs of nucleotides with complementary nitrogenous bases. A sequence of DNA nucleotides, called a gene, contains the information (code) for assembling amino acids into a specific protein.

Materials

- Sticky notes (one pad per team)
- Add Statements (printed on 11 x 14 paper)
- DNA model supply baggie (one per team)
  - Pop beads in 4 colors – 10 beads of each color)
  - 2-4 strands of yarn, string, pipe cleaner, or twist ties

Advance Preparation

- Make copies of the Add Statements and post them around the room so that students will be able to add sticky notes to the statements.
- Prepare DNA model supply baggies. Each baggie should include ~10 pop beads in each of four colors and 2-4 strands of yarn, string, pieces of pipe cleaner, or twist ties.

Lesson 4 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**Link to Previous Lesson** The teacher reviews student ideas about proteins and how differences in proteins are due to differences in amino acid sequence. The sequence of amino acids determines the structure of the protein which, in turn, determines the function of the protein. **Lesson Focus Question**: **How does a cell assemble amino acids in the correct sequence to make a protein that can do its job in the cell?** The teacher introduces the lesson focus question.	
90	**DNA: A Molecular Code** Activity Setup Students share prior information they have about DNA. Activity Students record the science ideas they have learned thus far and add them to statements posted around the room. Students read an essay and add additional sticky notes to the statements. They make and revise a model of DNA structure. Activity Follow-up Students complete an analogy map and consider the strengths and limitations of their model.	Amino acid sequence is determined by DNA. DNA is found in the nucleus of cells and has a double helix structure composed of pairs of nucleotides with complementary nitrogenous bases. A sequence of DNA nucleotides, called a gene, contains the information (code) for assembling amino acids into a specific protein.
10	**Summarize and Link to Next Lesson** Students revise their answer to the focus question to summarize the lesson. The teacher summarizes key science ideas and links to the next lesson.	

Lesson 4: The Code for Building Proteins

Phase of Lesson: *Link to Previous Lesson and Lesson Focus Question: How does a cell assemble amino acids in the correct sequence to make a protein that can do its job in the cell?*

Main Learning Goal: The structure of DNA contains information (code) for assembling amino acids into proteins. A segment of DNA nucleotides that codes for a specific protein is called a gene.

Focus Question:

How does a cell assemble amino acids in the correct sequence to make a protein that can do its job in the cell?

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.
- The structure of a protein determines its function.
- The sequence of amino acids determines the protein's structure. If the amino acid sequence changes, the shape of the protein can change which can influence its function.

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 4: The Code for Building Proteins

Introduction

In the last two lessons, you saw that many of an organism's traits are the result of proteins. The structure and function of these proteins results from the specific order of amino acids joined together in the protein. What determines the specific order of amino acids in a protein? That question will focus our work in this lesson.

Process and Procedure

Lesson Focus Question

1. Write the focus question for this lesson in the box below. Write your best ideas about the question below the box. Be sure to leave space to revise your ideas in a different color as the class discusses the focus question.

How does a cell assemble amino acids in the correct sequence to make a protein that can do its job in the cell?

Focus on Student Thinking

- Use appropriate elicit (STeLLA Strategy 1) and probe questions (STeLLA Strategy 2) to reveal student ideas about how cells assemble amino acids in the right order for a protein.
    - Following are some question examples:
        - How do you think cells are able to link amino acids together in the right way to make a specific protein, such as MC1R? **(Elicit)**
        - Can you say more about what DNA has to do with proteins? **(Probe)**
        - Does anyone have a different idea? **(Elicit)**
        - Tell us more about your idea. **(Probe)**

Implementation	Notes
Link to Previous Unit • Invite students to turn and talk with an elbow partner and share the story of the lessons thus far. Ask several pairs to share their story with the whole group. • Share that the ideas from the shared stories will help prepare us for answering today's focus question. *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 and write their best ideas below the box. 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 students to share their ideas with the whole class. 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 4: The Code for Building Proteins

Phase of Lesson: *The Code for Proteins: DNA*

Main Learning Goal: The structure of DNA contains information (code) for assembling amino acids into proteins. A segment of DNA nucleotides that codes for a specific protein is called a gene.

Focus Question:

How does a cell assemble amino acids in the correct sequence to make a protein that can do its job in the cell?

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

- The amino acid sequence of a protein is determined by DNA.
- DNA is found in the nucleus of cells and has a double helix structure composed of pairs of nucleotides with complementary nitrogenous bases.
- A sequence of DNA nucleotides, called a gene, contains the information (code) for assembling amino acids into a specific 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.

Proteins Do the Work of the Body

2. Read the information about proteins. As you read each paragraph, annotate the text to show science ideas that you and your classmates already wrote on a sticky note and those ideas you could add to a chart. Use the space below to record ideas that should be added to a chart on a new sticky note.

Proteins Have Many Jobs

You may think a protein is just something you find in meat, nuts, and dairy products. There are proteins in those foods. However, in a living organism, proteins are much more than that. Proteins play a role in almost all of life's processes. For example, enzymes are proteins that help chemical reactions take place. Some enzymes in your stomach help break down the food you eat. Insulin is another protein. It is a type of protein hormone that aids in controlling the level of sugar in your body. Other proteins, like melanin, produce pigments that determine the color of your eyes and hair. Collagen is a protein that helps make your skin and bones strong. Proteins such as hemoglobin help move oxygen around your body. Antibody proteins help your body fight off illness. Proteins help give cells their structure and shape. Those are just a few examples of the variety of proteins and what they do. As you saw in the jaguar example, there can be different amounts of each protein in cells.

What Are Proteins Made Of?

Regardless of the type of protein, all of them are made up of a chain of building blocks, or subunits, called amino acids. In the cytoplasm of a cell, amino acids are first put together in a long, linear molecule. Proteins fold into particular shapes based on the order of amino acids. Proteins will function properly only when they have folded into a very specific shape. But what determines the order in which amino acids are put together?

DNA is the Code of Life

Even though proteins are responsible for many jobs in cells, there is another molecule that has the instructions to make proteins. Those instructions are found in deoxyribonucleic acid, or DNA. People sometimes say that DNA has the instructions for all of life. DNA is found in every living thing, from bacteria to sunflowers to humans to whales. It contains the blueprints to assemble amino acids in the proper order to make all the different types of proteins in your body. DNA is found in the nucleus of your cells. But how can a molecule contain instructions? Just as the structure of a protein determines its job, or function, in a cell, the structure of DNA holds the information needed to make proteins.

Focus on Student Thinking

- Use appropriate elicit (STeLLA Strategy 1), probe (STeLLA Strategy 2), and challenge (STeLLA Strategy 3) questions to make student thinking visible as they share their annotations and ideas on their sticky notes.
  - Following are sample question:
    - What ideas did you put on a new sticky note? **(Elicit)**
    - Can you clarify where that idea is already included on a sticky note? **(Probe)**
    - Can you put that idea in a complete sentence? **(Probe)**
    - Tell us why you think that sticky note belongs with this statement. **(Challenge)**

Implementation	Notes

Activity Setup: The Code for Proteins: DNA
• The purpose of the activity set up is to support students in considering what they have learned that will help them answer the unit central question and what additional information will be needed to answer the unit central question.
• Invite students to individually write science ideas on sticky notes from the previous lessons that will help them answer the unit central question: What is the best explanation for the similarities and differences among individuals within a species – not only for one species, but for every species of plant and animal? Remind students that the focus questions we have considered thus far include:
  ○ What might cause individuals to have versions of a trait that are different from others of the same species?
  ○ What differences would you expect to find in two organisms of the same species that have different traits?
  ○ How can a protein determine the traits, and versions of a trait, of an individual organism?
• Mark that they should write each idea in complete sentences on separate sticky notes.
• Direct students' attention to the statements posted around the room. Have a student nearest each statement read it aloud to the class. Invite students to place each of their sticky notes on the statement that best matches their ideas. Note that if they have an idea that does not seem to fit on one of the statements, they should keep it for the next step.
  ○ Ask students to share any sticky notes that they did not think fit on any of the statements. Invite others to suggest possible statements that might fit with that idea.
  ○ Read the statements that have the greatest number of sticky notes. Then read the statements that have few or no sticky notes. Note that there are ideas we need to learn more about in order to answer the unit central question.
• **STEP 2:** Have students read the short essay, Proteins Do the Work of the Body. As they read, they should annotate the text and record ideas that should be written on sticky notes to add to the statements.
• As teams finish reading, they should share their annotations and make new sticky notes to add to the statements around the room.
 	
Refer to "Focus on Student Thinking" in the SE key for possible questions to elicit, probe, and challenge student ideas.	

3. Imagine that you are on a team of research scientists trying to describe the structure of the DNA molecule. You have decided to tackle the problem by constructing a physical model. As new information becomes available, you will change your model to reflect the new information, much like Watson and Crick did.

Model 1

- Like proteins, DNA is a polymer. A polymer is a long, chainlike molecule composed of smaller parts or subunit molecules. Subunit molecules are like the links in a chain. They are attached to each other by chemical bonds.
- There are four different types of DNA subunit molecules.

Model 2

- DNA consists of two long chains of subunits twisted around each other to form a double helix. A helix is a spiral. This of the shape of a pipe cleaner wrapped around a pencil.

- The two helical chains are weakly bonded together. The subunits of one strand bond to subunits on the other strand.
- The diameter of the DNA molecule is the same along its length. It does not get wider or thinner from one end of the molecule to the other.

Model 3

- The order of subunits in one strand of DNA determines the order of the subunits on the other strand.
- The subunits are not paired with those of the same type on the other strand. For example, a red pop bead on one strand would not be paired with a red pop bead on the other strand.

Implementation	Notes

Activity: The Code for Proteins: DNA
• **STEP 3:** Briefly share the story of Watson and Crick's discovery of DNA structure, including Rosalind Franklin's contributions. Share that we will go back in time and invite a student to read the introductory paragraph in the student workbook.
  o Consider having students cover up the information for Models 2 and 3 until they have completed the previous model. You can note that this will make the process more authentic as scientists continue to revise their models as more information becomes available.
• Distribute one DNA model supply baggie to each team.
• Invite teams to read the information about <u>Model 1</u> in their workbooks, underlining key information that will help them construct their model.
  o Each team should discuss the key ideas in the Model 1 reading and how they will represent these ideas with just the materials in their baggies. Note that they may not use all the materials in the baggie in their model.
  o Teams should be prepared to share their models with the whole group. They should be able to show how the information in the Model 1 reading is represented in their physical model.
  o Invite several teams to share their model and how the information in the reading is represented in their model. As groups share their models, ask probe and challenge questions to make student thinking about the reading and their models visible.
• Have teams read the three new ideas presented in <u>Model 2</u>. As they read, they should underline new information that will inform the revision of their model.
  o Have groups incorporate the new ideas into their model and be prepared to share their model with the whole group.
  o Have teams share their models with the whole group by holding up their model. Encourage teams to look for similarities and differences between each group's models.
• Have team members take turns reading the new ideas presented in <u>Model 3.</u> The team should then discuss the new ideas and how they will incorporate the ideas into their model.
  o After all ideas have been discussed, teams should revise their model.
  o Ask groups to hold up their models for the whole class to see.
  o Ask several groups to share how they revised their model based on the new information.	

4. Read the information about DNA structure. As you read each paragraph, annotate the text to show ideas that are represented in your model and ideas that are new.

DNA Structure Suggests it is a Code

Possible student annotations are shown.

Sometimes a very simple code can provide complex information. For example, information in a computer is sent using only the numbers 0 and 1. The order of these two numbers provides very complex information to the computer. We propose that DNA is a code that provides the complex information for producing every kind of protein.

This is a new idea

This report is based on our research about the structure of DNA. The building blocks of DNA are smaller molecules called nucleotides. There are four different nucleotides in DNA: adenine (A), cytosine (C), guanine (G), and thymine (T). DNA is a double-stranded molecule. Two long strands of DNA are connected by weak bonds between nucleotides on each strand. The two strands twist into a double helix shape that looks like a twisted ladder.

This is shown in our model

Our model shows this, too

We have found that the nucleotides on one strand pair with nucleotides on the other strand in predictable ways. Adenine (A) always pairs with thymine (T), and cytosine (C) always pairs with guanine (G). This means the order of the nucleotides on each strand is complementary, not identical. For example, if nucleotides on one strand are in the order A-T-C, the nucleotides on the complementary strand will be in the order T-A-G.

Our model doesn't show this very well

We found that the four nucleotides *within* a strand are bonded together in any order. This suggests that the nucleotides are like the letters in a word. Consider how the order of letters in a word conveys information to someone who is reading. For example, placing the three letters A, T, and C in the order C-A-T is the "code" for "CAT", meaning a small, furry mammal. Placing the same letters in the order A-C-T is code for the verb "ACT" that means to behave. Similarly, the nucleotides in a DNA strand may stand for specific amino acids. This means that the order of the nucleotides in DNA gives the information for the order of amino acids in a protein. The order of the amino acids in a protein give it a unique structure and function.

This is definitely a new idea not shown in our model

Our idea also indicates what a gene is. Earlier research describes the "gene" as the basic unit of heredity. However, this research has little to say about the physical nature of the gene. We suggest that a gene is a segment of DNA that contains the code for assembling amino acids in the correct order to make a specific protein. This definition of a gene is based on the structure of DNA and the idea that DNA is a code. Each gene in DNA has a unique sequence of nucleotides that codes for a specific protein. We encourage further research for collecting evidence that supports or contradicts our hypothesis that DNA is a code.

Implementation	Notes
• **STEP 4:** Share that another team of scientists have also been working on the structure of DNA and they have just published a report with their findings. Invite students to read the article silently and annotate ideas that are represented in their model as well as ideas that are new. • Have students share their annotations with their team. Using the reading and their models, teams should write and add new sticky notes to the statements posted around the room. (You may want to give them sticky notes in a different color to make it obvious which notes are new.) They should note statements that had no or few sticky notes at the beginning of the lesson and work to add sticky notes to those charts. o After teams have added sticky notes to the chart, highlight charts to which sticky notes were added. If there are still charts with few or no sticky notes, ask the whole class to suggest science ideas that could be added from their models or reading.	

Focus on Student Thinking

- Use appropriate elicit (STeLLA Strategy 1), probe (STeLLA Strategy 2), and challenge (STeLLA Strategy 3) questions to make student thinking visible as they share their models with the class.
    - Following are sample question:
        - How are the key ideas in Model 1 represented in your DNA model? **(Elicit)**
        - What part of your model represents the subunit molecules? **(Probe)**
        - How did you show that there are 4 different types of subunits? **(Probe)**
        - Can you say more about how your model shows a double helix? **(Probe)**
        - What are your ideas for how the two strands are bonded together? How do you show that in your model? **(Challenge)**
        - The diameter of DNA is that same all along its length. What does that tell you about how the subunits bond the two strands together? **(Challenge)**
    - The following dialogue shows how students may be engaged in STeLLA Strategy 6: Engage students in developing and using content representations and models. Note how the teacher consistently asks students what each part of their model represents. The final challenge question reminds students that models do not always represent every aspect of the real phenomenon.
        - T: How are the key ideas from all three Models represented in your DNA model? **(Elicit)**
        - S1: (holding up model and pointing) Here we have the two strands, and they're wrapped around each other—it's supposed to be a helix.
        - T: What part of your model represents the 4 types of subunit molecules? **(Probe)**
        - S2: The pop beads here—and we used tape between the pop beads on each strand to show how they bond together.
        - T: Can you clarify how your model represents the 4 different types of subunit molecules? **(Probe)**
        - S2: The different colors stand for the different subunits. Like this red one is for A and this blue one is for G.
        - T: Are there any key ideas that you were *not* able to represent in your models? If not, why not? **(Challenge)**

Implementation	Notes
Refer to “Focus on Student Thinking” in the SE key for possible questions to elicit, probe, and challenge student ideas, as well as an example dialogue using STeLLA Strategy 6: Engage students in developing and using content representations and models.	

5. DNA Analogy Map

Part of Model	Represents…	What the part represents	They are alike because:
one pop bead		One nucleotide	They are subunits that link together in a long chain
four different colors of pop beads		The four different kinds of nucleotides (A, G, C, T)	they're all subunits but they are a little different from each other
Two chains of pop beads twisted around each other		double helix	They have two chains or strands (the double part) and the twisting is like a helix
Red bead connecting only to yellow bead and blue bead connecting only to green bead		complementary base pairing	A only pairs with T and G only pairs with C

What are the strengths and limitations of this model?

It's hard to show the twisting in the model.

We had a hard time figuring out how to show weak bonding between subunits on the two different chains

Implementation	Notes
Activity Follow-up: The Code for Proteins: DNA • **STEP 5:** Have teams work together to complete the analogy map, making sure that each team member agrees on the ideas. Note that the last column must be completed for each row. The last row is blank for any additional ideas they may have. • As teams work to complete the analogy map, circulate among groups asking probe and challenge questions to make thinking visible. • Lead a whole class discussion to allow groups to share any analogies they added to the blank row.	

Focus on Student Thinking

- Use probe (STeLLA Strategy 2) and challenge (STeLLA Strategy 3) questions to make student thinking visible as they work with their teams on the DNA analogy map.
  - Following are sample question:
    - How are the 4 different colors of pop beads like the 4 different types of subunit molecules? **(Probe)**
    - Say more about how you used the 4 different colors of pop beads to show complementary base pairing. **(Probe)**
    - You have two chains of subunits for your model, but it doesn't really show a helix. How could you make your model show that? **(Challenge)**
    - Based on what you have learned about the structure of DNA, what do you see as the biggest limitation of your model? **(Challenge)**

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

Lesson 4: The Code for Building Proteins

Phase of Lesson: *Summarize and Link*

Main Learning Goal: The structure of DNA contains information (code) for assembling amino acids into proteins. A segment of DNA nucleotides that codes for a specific protein is called a gene.

Focus Question:

How does a cell assemble amino acids in the correct sequence to make a protein that can do its job in the cell?

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

Science Ideas

- The amino acid sequence of a protein is determined by DNA.
- DNA is found in the nucleus of cells and has a double helix structure composed of pairs of nucleotides with complementary nitrogenous bases.
- A sequence of DNA nucleotides, called a gene, contains the information (code) for assembling amino acids into a specific 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.

Summarize Key Science Ideas

6. The focus question for this lesson was: *How does a cell assemble amino acids in the correct sequence to make a protein that can do its job in the cell?* Return to your original answer and revise your ideas in a different color. Your goal is to give the most accurate answer that includes all the information you have learned.

Implementation	Notes
Summarize • **STEP 6:** Have students work individually to answer or revise their answer to the focus question for the lesson, writing in a different color. • Invite students to share their revised answer to the focus question with their team. Teams should add any additional evidence that helped them answer the focus question to the statements around the room with additional sticky notes. *Link to Next Lesson* • Remind students that in this lesson they learned about how the sequence of nucleotides in the DNA determines the sequence of amino acids that form a protein. The sequence of amino acids determines the structure and function of the protein. • Share that, in the next lesson, we will consider how the sequence of nucleotides in DNA can account for all the variation we see in the proteins found in organisms of the same species.	