THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

Lost in Translation

How do mutations in DNA affect protein synthesis?

GRADES 9–12

Life Science

VAN ANDEL EDUCATION INSTITUTE
VAEI.ORG

INQUIRY-BASED SCIENCE

Lost in Translation

Grade Level/Content	9–12/Life Science
Lesson Summary	In this lesson, students will discover how changes in DNA sequences can lead to changes in protein structure.
Estimated Time	2, 45-minute class periods
Materials (per team)	Computer with Internet access, Investigation Plan, Observation Form, Journal
Secondary Resources	• BBC Bitesize: RNA and Protein Synthesis • Learn.Genetics: How do Cells Read Genes? • The Tech Museum: Mutations and Disease
NGSS Connection	**HS-LS1-1** Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
Learning Objectives	• Students will describe how all cells contain DNA with specialized regions called genes. • Students will describe how genes contain instructions for the formation of proteins. • Students will collect data about the relationship between DNA sequences and protein structure.

How do mutations in DNA affect protein synthesis?

Two sisters can look very different. One might have curly, light-colored hair, and the other might have straight, dark-colored hair. While sisters have very similar DNA, small genetic differences can add up to big differences in appearance. Similarly, small changes in DNA (mutations) can have large, body-wide effects if the mutated section of DNA carries genes that control proteins that support essential life functions.

Genes carry the information required to make proteins. When mutations alter this message, genetic information may be lost in translation. As a result, unintended or even harmful proteins can be produced. These altered proteins may not be able to perform functions necessary to support life. In this lesson, students will discover how changes in DNA structure can lead to changes in protein structure.

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

Students will need a computer with Internet access. Students will be using an online simulation available from the Concord Consortium: Mutations in Genes. Ensure that you test and familiarize yourself with the computer simulation before asking your students to access the simulation. The recommended student group size for this simulation is 2 or 3.

- Computer with Internet access
- Investigation Plan
- Observation Form
- Journal

Part 2

INVESTIGATION FACILITATION

Question

Introduce the investigation question.

How do mutations in DNA affect protein synthesis?

OPENNESS TO NEW IDEAS

Present images of an easily visible genetic mutation, such as a typical mouse and an albino mouse. Ideally this genetic mutation should be something students have not previously encountered. Encourage students to ask questions about what makes the two organisms different. Ask them to consider differences at the cellular level, while steering them toward genetic differences. Highlight the concept that individual genes are responsible for differences in fur color, eye color, and eye function in organisms. Then, introduce the investigation question.

Personal Knowledge

Students capture what they already know about cells, DNA, genes, mutations, and proteins.

- Find out what students already know about cells, DNA, genes, mutations, and proteins.
- Have each student make a vocabulary list that includes these and related topics based on their background knowledge. Have them list and briefly define in their own words all terms on their vocabulary list. Encourage them to avoid looking up definitions during this exercise.

RICH LANGUAGE

Challenge each student to use all of the vocabulary terms they identified when speaking with classmates during their investigation. Remind students that science has its own language. Focus on strategies and a classroom culture that supports the evolving use of science terms in context to build confidence and reinforce meaning.

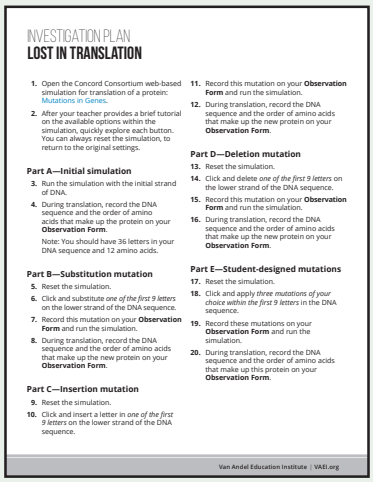
Investigation Plan

Students conduct web-based simulations to determine how genetic mutations affect protein structure.

- Divide the students into groups of 2 or 3, and provide each group with a computer with Internet access.
- Introduce the computer simulation from the Concord Consortium: Mutations in Genes.
- Have the students follow the Investigation Plan. It guides students through five scenarios starting with a baseline DNA sequence followed by four mutations.
- Give students a brief tutorial explaining what each button does within the simulation. Demonstrate how to create a mutation.

CRITICAL THINKING

Use the Fair Test checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plans, the more confident they can be in their results.



INVESTIGATION PLAN
LOST IN TRANSLATION

1. Open the Concord Consortium web-based simulation for translation of a protein: Mutations in Genes.
2. After your teacher provides a brief tutorial on the available options within the simulation, quickly explore each button. You can always reset the simulation, to return to the original settings.

Part A—Initial simulation

3. Run the simulation with the initial strand of DNA.
4. During translation, record the DNA sequence and the order of amino acids that make up the protein on your **Observation Form.**

Note: You should have 36 letters in your DNA sequence and 12 amino acids.

Part B—Substitution mutation

5. Reset the simulation.
6. Click and substitute *one of the first 9 letters* on the lower strand of the DNA sequence.
7. Record this mutation on your **Observation Form** and run the simulation.
8. During translation, record the DNA sequence and the order of amino acids that make up the new protein on your **Observation Form.**

Part C—Insertion mutation

9. Reset the simulation.
10. Click and insert a letter in *one of the first 9 letters* on the lower strand of the DNA sequence.
11. Record this mutation on your **Observation Form** and run the simulation.
12. During translation, record the DNA sequence and the order of amino acids that make up the new protein on your **Observation Form.**

Part D—Deletion mutation

13. Reset the simulation.
14. Click and delete *one of the first 9 letters* on the lower strand of the DNA sequence.
15. Record this mutation on your **Observation Form** and run the simulation.
16. During translation, record the DNA sequence and the order of amino acids that make up the new protein on your **Observation Form.**

Part E—Student-designed mutations

17. Reset the simulation.
18. Click and apply *three mutations of your choice within the first 9 letters* in the DNA sequence.
19. Record these mutations on your **Observation Form** and run the simulation.
20. During translation, record the DNA sequence and the order of amino acids that make up this protein on your **Observation Form.**

Van Andel Education Institute | VAEI.org

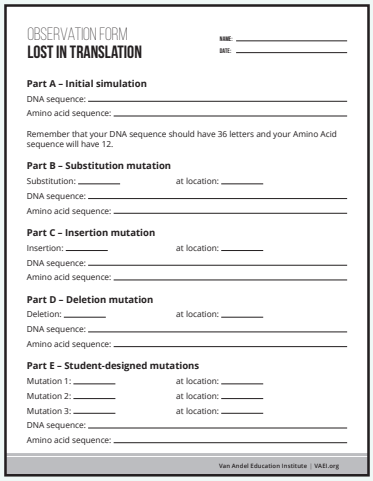
Investigation Plan

Observation

Students record how changes in DNA structure affect protein structure.

Part A—Initial simulation

- Students will run the simulation without mutations by clicking the "Continue one step" or "Start/continue model" buttons. The simulation demonstrates transcription, translation and the resulting protein from a sequence of 36 nucleotides.
- Students will record the upper strand nucleotide sequence (36) shown in translation and the resulting protein structure (12 amino acids) on their Observation Form.
- Suggest that students use the "Continue one step" button to provide time to record their observations.



OBSERVATION FORM
LOST IN TRANSLATION

NAME: _____
DATE: _____

Part A – Initial simulation
DNA sequence: _____
Amino acid sequence: _____

Remember that your DNA sequence should have 36 letters and your Amino Acid sequence will have 12.

Part B – Substitution mutation
Substitution: _____ at location: _____
DNA sequence: _____
Amino acid sequence: _____

Part C – Insertion mutation
Insertion: _____ at location: _____
DNA sequence: _____
Amino acid sequence: _____

Part D – Deletion mutation
Deletion: _____ at location: _____
DNA sequence: _____
Amino acid sequence: _____

Part E – Student-designed mutations
Mutation 1: _____ at location: _____
Mutation 2: _____ at location: _____
Mutation 3: _____ at location: _____
DNA sequence: _____
Amino acid sequence: _____

Van Andel Education Institute | VAEI.org

Observation Form

Part B—Substitution mutations

- After resetting the simulation, instruct students to click and substitute one of the first nine nucleotide bases (to better keep track of the substitution) from the lower strand.
- Students record their mutation and the resulting nucleotide sequence and protein structure on their **Observation Form**.

Part C—Insertion mutation

- Students continue with the simulation recording a single insertion mutation and the resulting nucleotide sequence and protein structure on their **Observation Form**.

Part D—Deletion mutation

- Students continue recording a single deletion mutation and the resulting nucleotide sequence and protein structure on their **Observation Form**.

Continued

Part E—Student-designed mutations

- For the final simulation, students apply *three different mutations* of their choice within the first nine nucleotide bases from the lower strand.
- Students record their three mutations and the resulting nucleotide sequence and protein structure on their **Observation Form**.

STUDENT CHOICE

Allow students to choose which mutations and combinations to test. Giving them control over the experiment offers them ownership of the experience and provides a variety of data for analysis across student groups.

SELF-DIRECTION

Encourage students to stay focused and on-task while completing the online simulations and recording their results.

Part 3 INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIM

Data Analysis

Students make sense of their data by organizing it and representing it visually.

Have students analyze their data. They may wish to use the Data Analysis prompt as a guide.

- Have students **evaluate** their data for trustworthiness.
- Then, have them analyze their data to find patterns and trends. They may **organize** the data and/or **represent** it visually to construct meaning.
- The data for this investigation is more qualitative than quantitative. Encourage students to be creative with their visual representations (ex. showing an example of a dramatically shortened protein, a protein with no changes following different mutations, or a quantitative sense of how different the corresponding proteins are based on the amino acids that it contains).
- Have students **interpret** what the identified patterns or trends mean.
- Ensure they have enough data that it can be used as evidence to support a claim.

Secondary Knowledge

Students use secondary sources to more deeply understand how DNA structure determines protein structure, which supports or hinders life functions.

- Use these resources (along with your own) to expand students' understanding of translation and mutations:

  BBC Bitesize: RNA and Protein Synthesis

  Learn.Genetics: How do Cells Read Genes?

  The Tech Museum: Mutations and Disease

Continued

- After reviewing these resources, students should understand how mutations in the genetic code of DNA lead to a change in proteins and the role of altered proteins in genetic diseases.

CONSTRUCTION OF MEANING

This secondary knowledge will confirm and expand upon the concepts surfaced when students developed their vocabulary list based on their personal knowledge and then discovered in the online simulation. As students review these resources remind them of the larger context and importance of DNA as it relates to organism health and genetic diseases.

Explanation

Students write a claim and provide evidence and reasoning to support it.

- Have students use what they've discovered from the analyzed data to write an explanation that answers their investigation question. Students may wish to use the Explanation prompt as a guide. Have them write their explanations in their journals.
- Have students develop a **Claim** to answer the question: How do mutations in DNA affect protein synthesis?
- Then, have them add **Evidence** (the analyzed data) to support their claim.
- Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as science principles they have learned.

Claim

We claim that simple mutations in the DNA found in an organism's cells change the resulting protein that is made during translation. The scope of these changes can range from minor to severe.

Evidence

The evidence that supports our claim is our observations from simulations and the findings from our online research. We saw that changing the DNA sequence through substitutions, insertions, or deletions changed the order of amino acids in the protein.

Reasoning

Investigation: We generated evidence from our investigation. We tested four different mutations using the simulation, and all four of them changed the protein produced. We did a fair test and determined our data is trustworthy.

Science: We learned from readings and class discussion that genes are stretches of DNA found in cells that hold information to make proteins. If the DNA changes or mutates, the genetic information used to make these proteins can be affected. The scope of these changes can range from simple to severe depending upon the nature of the protein that is produced.

Evaluation

Students reflect on the investigation.

Ask students these questions:

- How confident are you in your results?
- How might you set up your tests differently if you had unlimited time?
- What question would you like to pursue next?

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Students demonstrate understanding of DNA and proteins by applying their learning in multiple contexts.

- Students can apply their knowledge of mutations by learning about how genetic changes are related to cancer. National Cancer Institute: The Genetics of Cancer
- Students may think that mutations are always negative, but they can explore the positive aspects of mutation in this article about mutations and evolution.

Assessment

Evaluate students' explanations based on how well they:

- describe how all cells contain DNA with specialized regions called genes.
- describe how genes contain instructions for the formation of proteins.
- collect and analyze data about the relationship between DNA sequences and protein structure.

For additional lessons or to customize this lesson, go to www.nexgeninquiry.org.

nexgen inquiry®
Empowering Teachers. Engaging Students.

INVESTIGATION PLAN
LOST IN TRANSLATION

1. Open the Concord Consortium web-based simulation for translation of a protein: Mutations in Genes.
2. After your teacher provides a brief tutorial on the available options within the simulation, quickly explore each button. You can always reset the simulation, to return to the original settings.

Part A—Initial simulation

3. Run the simulation with the initial strand of DNA.
4. During translation, record the DNA sequence and the order of amino acids that make up the protein on your **Observation Form**.

   Note: You should have 36 letters in your DNA sequence and 12 amino acids.

Part B—Substitution mutation

5. Reset the simulation.
6. Click and substitute *one of the first 9 letters* on the lower strand of the DNA sequence.
7. Record this mutation on your **Observation Form** and run the simulation.
8. During translation, record the DNA sequence and the order of amino acids that make up the new protein on your **Observation Form**.

Part C—Insertion mutation

9. Reset the simulation.
10. Click and insert a letter in *one of the first 9 letters* on the lower strand of the DNA sequence.
11. Record this mutation on your **Observation Form** and run the simulation.
12. During translation, record the DNA sequence and the order of amino acids that make up the new protein on your **Observation Form**.

Part D—Deletion mutation

13. Reset the simulation.
14. Click and delete *one of the first 9 letters* on the lower strand of the DNA sequence.
15. Record this mutation on your **Observation Form** and run the simulation.
16. During translation, record the DNA sequence and the order of amino acids that make up the new protein on your **Observation Form**.

Part E—Student-designed mutations

17. Reset the simulation.
18. Click and apply *three mutations of your choice within the first 9 letters* in the DNA sequence.
19. Record these mutations on your **Observation Form** and run the simulation.
20. During translation, record the DNA sequence and the order of amino acids that make up this protein on your **Observation Form**.

OBSERVATION FORM
LOST IN TRANSLATION

NAME: _____

DATE: _____

Part A – Initial simulation

DNA sequence: _____

Amino acid sequence: _____

Remember that your DNA sequence should have 36 letters and your Amino Acid sequence will have 12.

Part B – Substitution mutation

Substitution: _____ at location: _____

DNA sequence: _____

Amino acid sequence: _____

Part C – Insertion mutation

Insertion: _____ at location: _____

DNA sequence: _____

Amino acid sequence: _____

Part D – Deletion mutation

Deletion: _____ at location: _____

DNA sequence: _____

Amino acid sequence: _____

Part E – Student-designed mutations

Mutation 1: _____ at location: _____

Mutation 2: _____ at location: _____

Mutation 3: _____ at location: _____

DNA sequence: _____

Amino acid sequence: _____