DNA Structure, Nucleic Acids, and Proteins

Strands Life at the Molecular and Cellular Level; Scientific Investigation

Topic Investigating DNA structure, nucleic acids, and protein synthesis

Primary SOL BIO.5 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include
- e) historical development of the structural model of DNA;
- g) the structure, function, and replication of nucleic acids;
- h) events involved in the construction of proteins.

Related SOL BIO.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which
- a) observations of living organisms are recorded in the lab and in the field;
- b) hypotheses are formulated based on direct observations and information from scientific literature;
- c) variables are defined and investigations are designed to test hypotheses;
- d) graphing and arithmetic calculations are used as tools in data analysis;
- e) conclusions are formed based on recorded quantitative and qualitative data;
- h) chemicals and equipment are used in a safe manner;
- i) appropriate technology, including computers, graphing calculators, and probeware, is used for gathering and analyzing data, communicating results, modeling concepts, and simulating experimental conditions;
- j) research utilizes scientific literature;

BIO.5 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include
- c) cell specialization.

Background Information

DNA is a relatively recent discovery in science; therefore, biotechnology is a relatively recent scientific field. The makeup of genes at a molecular level was a mystery before discovery of DNA, and the study of determining traits has developed from this important discovery.

What makes people different genetically from other species as well as each other is determined by DNA. All the information that makes up who you are is in your DNA. These are called **"traits,"** which are stored in a base pair sequence in your DNA. DNA is divided into 23 chromosomes, each with thousands of genes (segment of a chromosome). These genes are code for specific traits.

DNA can go through many processes to ensure that genes and traits are passed on to every cell in the body. When new cells are made, DNA must replicate itself in them. This ensures that the new cells are clones of the parent cells. Protein synthesis is another process that DNA does. These proteins determine which traits are made. DNA does this with the help of the single stranded nucleic acid RNA and several other cell parts.

Materials

Activity 1

- Scoring Guide for Writing Assignment (attached)

Activity 2

- Paper, macaroni, pipe cleaners, beads, clay, wire, glue, cardboard, other craft supplies, Scoring Guide for DNA Model (attached)

Activity 3

- Materials from which to extract DNA (e.g., liver, kiwi, strawberry, banana), detergent, mortar and pestle, salt, distilled water, meat tenderizer, pineapple juice, isopropyl or methyl alcohol, test tubes, funnels, filter paper, beakers, toothpicks, stirring rod, micropipettes, graduated cylinder, Extracting DNA handout (attached) and Scoring Guide for Experimental Design (attached)

Activity 4

- Large "nucleus" poster, Role-Playing Protein Synthesis Activity Sheet (attached), index cards showing different passive DNA strands such as
  - GGGCGTATGAATACTTATCATTAAGTCGTA
  - TTCCTAATGGATACGGCTCAATAGGTGTCA
  - AGGATGAACACCGGTTGTTGAGGGAAGGCA
  - CACCGCCCCATGGACAGTAGATAAATC
- Codon Chart for Amino Acids (attached), signs identifying the different parts of protein synthesis (optional)

Vocabulary

adenine, amino acid, anticodon, codon, cytoplasm, cytosine, deoxyribose, DNA, DNA replication, double helix, extraction, gene, guanine, hydrogen bond, messenger RNA, nitrogen base, nucleic acid, nucleotide, nucleus, phosphate, purine, pyramidine, ribose, ribosomal RNA, ribosome, RNA, Rosalind Franklin, sugar, thymine, trait, transcription, transfer RNA, translation, uracil, James Watson and Francis Crick, Maurice Wilkins, X-ray diffraction

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

The first three activities in this lesson explain and describe the history and structure of DNA. The fourth activity is a role-playing one that uses the DNA concepts learned in the first three to explain the processes of protein synthesis. The lesson can be used as during-learning activities. Some of the activities are inquiry-based, and some are not. The lesson should begin with a review of modern genetics and how traits are determined.

Prior to engaging in this lesson, students should complete the lesson entitled "The Parts of an Experiment: Introduction to Inquiry and the Scientific Process" in order to gain more experience in designing experiments and writing lab reports. That lesson also includes generic differentiation strategies for general inquiry lessons.

Activity 1: A Historical View of DNA

1. Begin by asking students the question, "How are a person's traits and characteristics determined at the cellular level?" Have the class brainstorm this question, and use this brainstorming session to assess students' prior knowledge of DNA and genetics.

2. Explain that DNA is a fairly recent discovery in science and that scientists have only scratched the surface of this scientific field. Display pictures of Rosalind Franklin, Maurice Wilkins, James Watson, and Francis Crick, and identify them, having students note in their journals the contributions of each.
3. Distribute copies of the attached Scoring Guide for Writing Assignment for students to use as a checklist. Present the following activity options, and ask each student to choose one.
   - Write from the perspective of one of the four scientists a personal diary entry that he/she could have written at the time when the discovery of DNA made the news.
   - Write a short article for the newspaper about one of the four scientists and his/her contributions to the discovery of DNA.
   - Write the lyrics of a song about one of the four scientists and his/her contributions to the discovery of DNA.
   - Write from the perspective of one of the four scientists a letter to another scientist about your contributions to the discovery of DNA.

   Have each student research additional information about his/her chosen scientist, using the textbook and other resources.
4. When students have finished their research, direct them to write their chosen piece. As they work, circulate in the classroom to address questions and provide help as needed.

Activity 2: Modeling DNA

1. Inform students that in this activity, they will learn about the structures of DNA and RNA by creating models of DNA, using a variety of materials. Provide the materials listed under "Materials – Activity 2."
2. Direct students to research the exact structure of DNA, using the textbook, the Internet, and other resources to find out what DNA looks like at the molecular level.
3. When students know what DNA is composed of and how its structure looks, instruct them to create their DNA models however they choose. Distribute copies of the attached Scoring Guide for DNA Model to use as a checklist as they build their models. As students work, circulate in the classroom to address questions and provide help as needed.

Activity 3: Extracting DNA

1. By the time students undertake this activity, they should understand that DNA exists in every living thing. Tell students that in this activity, they will design and do an experiment to extract DNA from a real, live cell, thereby seeing what DNA actually looks like.
2. Distribute copies of the Scoring Guide for Experimental Design for students to use to design an experiment that will answer the question, "How much DNA is in different kinds of cells?" Have students choose the kind of cell from which they want to extract DNA. Some examples are listed under "Materials" above, but there are many other possibilities.
3. Have each student research the process for extracting DNA from a living cell. When they are somewhat familiar with the process, distribute copies of the attached Extracting DNA handout, and review it with students, making sure they understand each step.
4. Have students describe in writing the experiments they will do, including lists of materials they will use and detailed descriptions of the procedures they will perform on their cell

sample. Also, have them explain the safety precautions they will take with any dangerous chemicals or equipment.

5. Have students perform their DNA extraction on their chosen cell samples. Direct them to record their data individually.
6. When all data have been recorded, guide students in creating a class data table to display all the individual data.
7. Have students make conclusions from the class data. Then, hold a class discussion in which students share their conclusions. Have them refer to the Scoring Guide for Experimental Design for guidance.
8. Explain to students that this activity required collaboration—a pooling of everyone's data to find an answer to the question, "How much DNA is in different kinds of cells?" Explain the importance of such collaboration in the world of science.

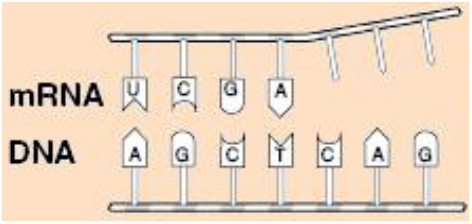
Activity 4: Role-playing protein synthesis

1. Tell students to imagine that the classroom is a cell: the walls are the cell membrane, the tables/desks are the ribosomes, and the large poster on the wall represents the nucleus. Tell students that they will work in groups of four to role-play protein synthesis.
2. Distribute copies of the attached Role-Playing Protein Synthesis Activity Sheet. Put each group of four students at one table or desk, and direct each group to assign each member a role—either mRNA, tRNA, rRNA, or DNA.
3. When every student has a role, have all the DNAs move to the poster nucleus, where they must stay: they cannot leave because DNA is too big to leave the nucleus. Give each DNA an index card showing a *different* passive DNA strand—i.e., a different sequence of nitrogen bases. Tell students that the DNA holds the instructions for which protein will be made. Have each DNA copy the complementary bases of his/her passive DNA strand on the activity sheet to create a template DNA that can be copied for protein synthesis.
4. Next, have each mRNA move to the nucleus, find his/her DNA, and transcribe to the activity sheet the template DNA strand into mRNA codons. Show them how to do this, as follows: Take the newly drawn DNA template strand, and copy the complementary RNA bases from it. This new strand now becomes a single-stranded mRNA. Every three bases on this mRNA strand is called a "codon." Each codon codes for a specific amino acid. The DNAs will share their passive DNA strands with their mRNAs so they can share the strands with the others in their groups.
5. Have each mRNA then leave the nucleus and move to the others of his/her group at their "ribosome" (table or desk), moving through the "cytoplasm" (open space in the classroom). This is where translation starts—where the amino acids are arranged into a protein.
6. Have the rRNAs read the codons to their groups and transcribe them into tRNA anticodons. Distribute copies of the attached Codon Chart for Amino Acids. Have the tRNAs examine the chart and translate each anticodon into a protein by copying down the amino acid from the chart. Show students how to use the chart: there are 20 amino acids; a chain of amino acids makes a protein; every different arrangement of amino acids makes a different protein.

7. After the entire DNA has been made into an amino acid sequence (protein), have each group member share the information from his/her role with the entire group.
8. Repeat steps 3–7 three times with each student playing a different role each time to ensure every student understands and has simulated the entire process of protein synthesis. Every student is responsible for filling in his/her activity sheet completely. (To make the process more easily understood, you might use signs identifying each component involved in protein synthesis: mRNA, DNA, nucleus, ribosomes, tRNA, rRNA, and cytoplasm.)

Assessment

- **Questions**
  - What did Watson and Crick discover?
  - What did Rosalind Franklin discover?
  - What are the major components of a strand of DNA?
  - What are the major components of a strand of RNA?
  - Create a Venn diagram comparing DNA and RNA.
  - What does DNA look like outside of the cell? Explain.
  - How can you explain the process of DNA replication? Why is it important?
  - What is the role of each of the following during protein synthesis: nucleus, ribosomes, mRNA, DNA, rRNA, tRNA?
  - How is the attached Codon Chart for Amino Acids used?
  - What is happening in the diagram at right? Explain.
  - What is the process of translation? Describe it.
  - What is the role of detergent in a DNA extraction lab?
  - What is the role of alcohol in a DNA extraction lab?



- **Other**
  - Use the Scoring Guide for Writing Assignment and students' writings in Activity 1 for assessment.
  - Use the Scoring Guide for DNA Model and students' Activity 2 models for assessment.
  - Use the Scoring Guide for Experimental Design and students' Activity 3 DNA extraction experiments for assessment.
  - Use the completed Role-Playing Protein Synthesis Activity Sheets from Activity 4 for assessment.

Extensions and Connections (for all students)

- Have each student find and read a scientific journal article on DNA and/or protein synthesis. After they read the article, have them give a two-minute presentation on it that includes the source, the author, a summary of what it is about, what it has to do with DNA, and at least eight vocabulary words found in it used correctly. Also, have students explain why the chosen articles interested them in the first place.

Strategies for Differentiation

- Employ flexible groupings of students by grouping them according to common readiness levels, shared interests, or diverse strengths.

Scoring Guide for Writing Assignment

Item	Possible Points (100 Total)	Points Earned
Grammar and punctuation	25	
Scientists' discovery; use of 10 vocabulary words	25	
Experiment that was used to make discovery	25	
Date and year when discovery was made	10	
Awards for discovery, if any	10	
Picture and/or description	5	

Scoring Guide for DNA Model

Labeling of DNA Model Parts	Possible Points (100 Total)	Points Earned
Correctness (shape and construction)	30	
Phosphates	20	
Sugars	20	
Nitrogen bases (7 each)	28	
Bonds	12	

Simplified Procedure for Extracting DNA

1. Crush in mortar and pestle the sample being tested.
2. Add small amount (10 mL) of salt or salt solution.
3. Add small amount (15 mL) of detergent solution.
4. Filter out sample solution into test tube or container.
5. Add 2 mL of alcohol solution to the filtrate.
6. Stir with skewer or stirring rod. The resulting white, stringy material is DNA.

Scoring Guide for Experimental Design

Item	Possible Points (200 Total)	Points Earned
Title: A descriptive title identifies the basic concept.	**10**	
Problem: The problem is stated clearly and succinctly.	**10**	
Hypothesis: "If…, then…." statement is included.	**15**	
Independent variables: Units and measuring tools are identified.	**10**	
Dependent variables: Units and measuring tools are identified.	**10**	
Controls and constants: All controls and constants are identified.	**10**	
Materials: All materials needed for experiment are listed.	**15**	
Safety: Harmful chemicals or organisms are listed; dangers are identified and explained; needed safety equipment is identified.	**10**	
Procedure: Very detailed steps are included.	**40**	
Data and observations: Data tables are used; observations are made and recorded.	**40**	
Conclusions and analysis of data: Graphs are used; conclusions are drawn and recorded; hypothesis are evaluated.	**30**	
TOTAL POINTS EARNED		

Role-Playing Protein Synthesis Activity Sheet

Trial 1

Passive DNA strand (every 3)										
DNA template (every 3)										
mRNA codons										
tRNA codons										
Protein amino acid sequence										

Trial 2

Passive DNA strand (every 3)										
DNA template (every 3)										
mRNA codons										
tRNA codons										
Protein amino acid sequence										

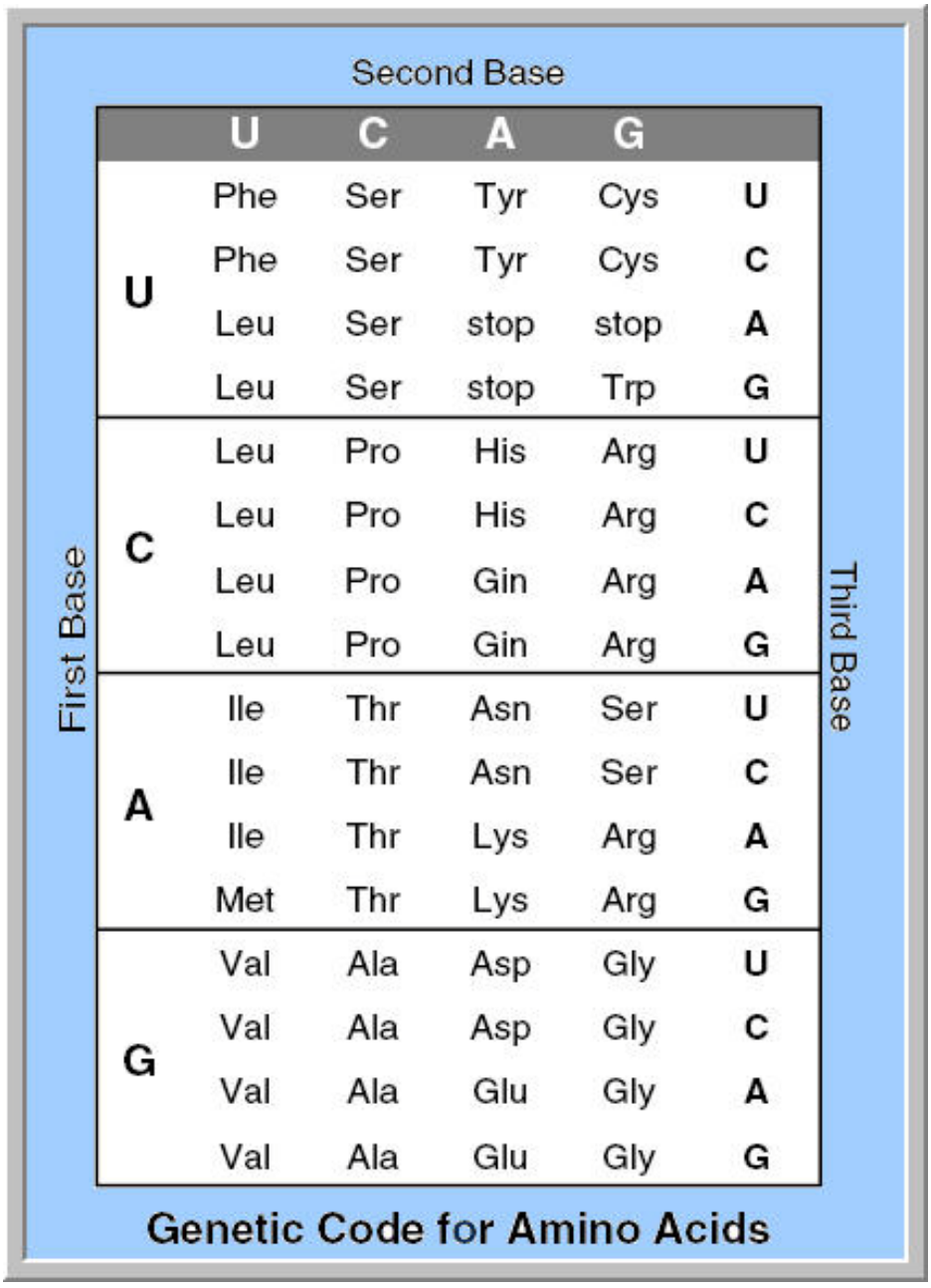
Trial 3

Passive DNA strand (every 3)										
DNA template (every 3)										
mRNA codons										
tRNA codons										
Protein amino acid sequence										

Trial 4

Passive DNA strand (every 3)										
DNA template (every 3)										
mRNA codons										
tRNA codons										
Protein amino acid sequence										

Codon Chart for Amino Acids



First Base	U	C	A	G	Third Base
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	stop	stop	A
	Leu	Ser	stop	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gin	Arg	A
	Leu	Pro	Gin	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G