Overview
Students examine the structure of DNA and the processes of translation and transcription, and then explore the impact of various kinds of mutations.

Learning Objectives
Students will be able to:
• Describe how DNA, consisting of four bases, can store the genetic code for proteins, which are made from a sequence of twenty different types of amino acids.
• Describe the processes of translation and transcription.
• Manipulate the DNA code and predict how it will change the sequence of mRNA and potentially a protein.
• Explain the effects of various types of mutations, including substitutions, insertions and deletions, on the resulting transcription and translation of a gene.
• Demonstrate how substituting one nucleotide for another often makes no significant change in the shape of a protein, unless it occurs at a critical location.

Possible Student Pre/Misconceptions
• DNA and RNA are structurally identical.
• Transcription and translation are somewhat random processes.
• Transcription and translation both happen in the nucleus.
• Information is stored somewhere within the nucleotides and not in their sequence.

Note: There are many animations (and simulation models) of transcription and translation found on the Web. The SAM transcription and translation models, though simplified in representation, are powerful tools and are different in the following ways:
• This interactive model allows the users to control the sequence of DNA being transcribed and then translated.
• The model has an emergent properties aspect; users can see that, when they alter the sequence, the resulting peptide chain will have a different characteristic, say, a fold, or behavior in solution.
• Changes in the model happen almost instantaneously, reinforcing the link between the sequence of nucleotides in the gene and the structure of the protein.

Models to Highlight and Possible Discussion Questions

Page 1 – The Architecture of DNA
Model: DNA Structure
• Highlight the organization of DNA, including the subunits that make up nucleotides, the base pairs, and especially the hydrogen bonds.
Possible Discussion questions
• Discuss why having weak bonds makes it easy to “unzip” the DNA, and why this is an advantage.

Page 2 – Transcription
Model: Transcription
• Highlight the complementary base pairing between strands. Point out which strand is the template, and that mRNA is single stranded and detaches from the DNA. Note how this model represents the RNA (red band) and that the amino acids are in a water environment.
• Link to other SAM activities: Intermolecular Attractions.

Possible Discussion questions
• Where does the model fall short of representing transcription accurately? (For example, incoming nucleotides are not shown.) Is there a good reason or trade-off for the omission or simplification by the model? (Showing incoming nucleotides might overly complicate the image, making it difficult to focus on transcription itself).
• Link to other SAM Activities: Molecular Geometry. Highlight the importance of the 3D structure of both DNA and RNA in the processes of transcription and translation.

Pages 3-4 – Translation
Model: Translation
• Highlight that three nucleotides encode one amino acid in the chain. Also, review that there are available amino acids (which attach to tRNAs) in the cell.
• Both transcription and translation can be reviewed step-by-step.
• Transfer RNAs (tRNAs) are missing from the model; there is a link at the bottom that orients students towards the relationship of tRNA in the translation process. There is one tRNA for each amino acid codon. Highlight the complementary base-pairing between mRNA and tRNAs.
• What does this model show compared to the animation?

Possible Discussion questions
• Compare and contrast transcription and translation.
• How does the structure of DNA play a role in its function?
• Link to other SAM Activities: Solubility and Nucleic Acids and Proteins. Review why shape is so important. Review polarity and hydrophobicity and their role in protein shape.

Extensions:
• What is non-coding DNA? How much of the human genome is non-coding? (~95-98%) What are some functions of non-coding sequences?
• What are some differences in transcription and translation in eukaryotic vs. prokaryotic cells?
• Where does transcription take place in eukaryotic cells? *(the nucleus)*. Where does translation take place? *(cytoplasm)*. What would be the advantages of this arrangement?

**Demonstration/Laboratory Ideas:**

• DNA replication kits to model transcription/translation.
• Analogy activity with other codes (Morse Code).
• Fit in with PCR or electrophoresis labs.

**Page 6 – Substitution Mutations**
**Model: Making Mutations**
• Point out the means of making a mutation in this model (right-clicking on a DNA nucleotide). This skill is also used on the next pages of the activity.
• Highlight the possible changes that can result from a substitution mutation.

**Possible Discussion questions**
• Discuss the redundancy in the DNA code.
• Discuss why some amino acid changes do not affect protein folding (hydrophobic to hydrophobic or hydrophilic to hydrophilic).
• Highlight some of the effects that a substitution mutation can have: for example, you might want to review sickle cell disease, caused by a single point mutation. (See the MW activity Hemoglobin.)

**Page 7 – Silent Mutations**
**Model: Making Mutations**
• Highlight that many amino acids are coded for by more than one codon.

**Possible Discussion questions**
• Discuss the redundancy in the DNA code.

**Page 8 – Stop Codons**
**Model: Making Mutations**
• Highlight that there are three codons that will cause protein synthesis to end.

**Possible Discussion questions**
• Discuss the utility of stop codons in normal cell function.
• Discuss the impact of a mutation that causes an early stop codon vs. a mutation that causes a delayed stop codon.

**Page 9 – Insertions and Deletions**
**Model: Making Mutations**
• Review how three nucleotides encode a particular amino acid and what happens if the reading frame is shifted.
**Possible Discussion questions**

- Discuss different ways to make insertion and deletion mutations that do not shift the reading frame. Will the proteins produced by these variations have the same number of amino acids? (*No; a series of 3 insertions will increase the length; a series of 3 deletions will decrease the length; an insertion tempered by a deletion will have the same number of amino acids.*)
- Connect to protein functions in the body and how mutations in DNA impact those functions.
- Highlight the possibility of devastating effects from an insertion or deletion.

**Possible Summary Discussion Questions for Mutations**

- Can mutations be good? Help students to think about this from an evolutionary point of view. What role can mutations play in adaptations? (*Be careful not to imply that the environment changes the DNA so that the organism can adapt.*) How are mutations passed on to the next generation?
- Why do some mutations result in small changes? Large changes? No changes?
- Why can some substitution mutations be considered silent?
- How do environmental factors effect alterations in DNA and cause problems such as cancer?

**Demonstration/Laboratory Ideas:**

- Tie in with natural selection activity on mutation/evolution/adaptation.
Connections to Other SAM Activities

The focus of this activity is for students to explore the processes of transcription and translation. They determine how DNA’s structure encodes for proteins.

The DNA to Proteins unit activity is supported by the Electrostatics activity. To predict why the base pairs (A-T, C-G) bond, students first need to appreciate the role of attraction between molecules. A background in electrostatics is also helpful in understanding protein folding. The Chemical Bonds activity allows students to reason about why amino acids might be hydrophobic or hydrophilic. Intermolecular Attractions helps students examine the concepts of base pairing and protein folding with regard to polar (and non-polar) attractions. Finally, Nucleic Acids and Proteins has students explore the basic structure of these molecules.

This activity supports other biology activities including Four Levels of Protein Structure and Structure and Function of Proteins (Molecular Recognition). In DNA to Proteins, students learn how proteins are generated. In Four Levels of Protein Structure, students can then explore in more detail the structure of a protein and four distinct levels of organization. When students complete Molecular Recognition they will have the opportunity to make connections between the protein’s physical structure and the jobs that it does in the cell.
SAM HOMEWORK QUESTIONS
DNA to Proteins

Directions: After completing the unit, answer the following questions to review.

1. What is the three-dimensional structure of a DNA molecule? First, describe it in words. Then, draw and label a sketch of DNA.

   description:

   sketch:

2. What happens during the process of transcription? Where does this happen in a cell?

3. The process of translation is when mRNA is read in order to create a protein chain. What are the subunits within a protein chain called? Where does the cell find these subunits?

4. How many nucleotides must have been in the mRNA chain in order to translate the protein shown on the right?

5. For each type of mutation listed below, describe what happens to change the DNA sequence.

   substitution –

   insertion –

   deletion –

6. Sickle cell disease is an example of a condition that is the result of a substitution mutation. Why do some mutations cause serious conditions while others have no effect?