DNA Mutation Consequences

Introduction
DNA is genetic material made of nucleotides. How does a change in one nucleotide affect the way the message is transcribed to RNA and translated to protein? Explore the effects of point mutations.

Concepts
- Point mutations
- Transcription and translation

Background
DNA is an example of a complex biological polymer called a nucleic acid, which is made up of small subunits called nucleotides. The components of the DNA nucleotide are deoxyribose (a simple sugar), a phosphate group, and a nitrogen base. There are four possible nitrogen bases in DNA—adenine (A), guanine (G), cytosine (C), and thymine (T). In DNA, the nucleotides pair using hydrogen bonds to form a double strand. Because these two strands are twisted, it is referred to as a double helix. The nitrogen bases will preferentially bond with only one other nitrogenous base—adenine with thymine and guanine with cytosine. The bonded nitrogen bases are called a base pair.

How is information from nuclear DNA brought to the ribosomes for protein synthesis? The answer is simple—by a single strand of RNA called messenger RNA (mRNA). RNA is composed of a single strand rather than a double strand as in DNA, RNA contains a sugar called ribose, a phosphate group, and four nitrogen bases. Rather than thymine (T), RNA contains uracil (U). Messenger RNA molecules that are complementary to specific gene sequences in DNA are made in the nucleus by a process called transcription. The genetic information from DNA is transcribed into a single strand RNA “message” to be sent from the nucleus to the ribosomes for protein synthesis.

During protein synthesis at the ribosome, mRNA sequences are read and translated into amino acids. Another area of the tRNA transports a specific amino acid. The amino acids are linked together into chains by enzymes to form proteins. The 20 amino acids are brought to the ribosomes by transfer RNA (tRNA). An infinite variety of proteins can be formed from the 20 amino acids, which can occur in any number and in any order. Table 1 illustrates the 64 possible codons and the amino acid they code for. The anticodon region on the tRNA contains a sequence of nitrogen bases. The nitrogen bases of the tRNA bond to a series of three nitrogen bases on the mRNA called a codon.

Table 1. Universal Codon Chart (mRNA to tRNA + amino acid)

<table>
<thead>
<tr>
<th>U</th>
<th>C</th>
<th>A</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>UUU</td>
<td>phenylalanine</td>
<td>UAU Tyrosine</td>
</tr>
<tr>
<td></td>
<td>UUC</td>
<td>phenylalanine</td>
<td>UAC Tyrosine</td>
</tr>
<tr>
<td></td>
<td>UUA</td>
<td>Leucine</td>
<td>UAA Stop</td>
</tr>
<tr>
<td></td>
<td>UUG</td>
<td>Leucine</td>
<td>UAG Stop</td>
</tr>
<tr>
<td>C</td>
<td>CUU</td>
<td>Leucine</td>
<td>CAU Histidine</td>
</tr>
<tr>
<td></td>
<td>CUC</td>
<td>Leucine</td>
<td>CCC Proline</td>
</tr>
<tr>
<td></td>
<td>CUA</td>
<td>Leucine</td>
<td>CCA Proline</td>
</tr>
<tr>
<td></td>
<td>CUG</td>
<td>Leucine</td>
<td>CCG Proline</td>
</tr>
<tr>
<td>A</td>
<td>AUU</td>
<td>Isoleucine</td>
<td>AAU Asparagine</td>
</tr>
<tr>
<td></td>
<td>AUC</td>
<td>Isoleucine</td>
<td>ACC Throneine</td>
</tr>
<tr>
<td></td>
<td>AUA</td>
<td>Isoleucine</td>
<td>ACA Throneine</td>
</tr>
<tr>
<td></td>
<td>AUG</td>
<td>Methionine</td>
<td>ACC Throneine</td>
</tr>
<tr>
<td>G</td>
<td>GUU</td>
<td>Valine</td>
<td>GAC Aspartic Acid</td>
</tr>
<tr>
<td></td>
<td>GUC</td>
<td>Valine</td>
<td>GAC Aspartic Acid</td>
</tr>
<tr>
<td></td>
<td>GUA</td>
<td>Valine</td>
<td>GAA Glutamic Acid</td>
</tr>
<tr>
<td></td>
<td>GUG</td>
<td>Valine</td>
<td>GAG Glutamic Acid</td>
</tr>
</tbody>
</table>

Mutations are changes in a DNA sequence. A point mutation is a change in a single base pair of a gene. Point mutations, or single nucleotide polymorphisms (SNPs), involve only one nitrogen base change of the three nitrogen bases in a codon. Perform this activity and witness the change a single point mutation in the DNA can have on a resulting protein. Dice will be used to determine the random change that will occur in the specified mutation location.

Materials
DNA Mutation Consequences Worksheet
Universal codon chart

Dice
Procedure
1. Transcribe the DNA on the DNA Mutation Consequences Worksheet into mRNA.
2. Using the Universal Codon Chart translate the mRNA into its corresponding amino acid sequence.
3. Obtain a six sided dice. The first nucleotide that will be mutated is number 4. Roll the die and follow the instructions below.

<table>
<thead>
<tr>
<th>Number Rolled</th>
<th>Corresponding Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Substitute specified nucleotide with an A</td>
</tr>
<tr>
<td>2</td>
<td>Substitute specified nucleotide with a C</td>
</tr>
<tr>
<td>3</td>
<td>Substitute specified nucleotide with a G</td>
</tr>
<tr>
<td>4</td>
<td>Substitute specified nucleotide with a T</td>
</tr>
<tr>
<td>5</td>
<td>Delete the nucleotide</td>
</tr>
<tr>
<td>6</td>
<td>Insert a nucleotide immediately after the specified nucleotide. Toss the die again until you roll 1-4 to determine which nucleotide will be inserted.</td>
</tr>
</tbody>
</table>

4. Write the complete DNA sequence with one mutation in nucleotide 4.
5. Complete the mRNA sequence from the mutated DNA.
6. Translate the amino acid sequence from the mRNA.
7. Circle any differences from the original protein produced.

**DNA Mutation Consequences Worksheet**

| Nucleotide | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|
| mRNA       |   |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Amino Acid Sequence | | | | | | | | | | | | | | | | | | | | | | | | |

Number rolled ________________

| Mutated DNA Sequence |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| mRNA from mutated DNA |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Amino Acid sequence |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

1. Did this mutation cause a change in the Amino Acid sequence produced? Explain why or why not.

2. Is it possible to have a mutation in nucleotide 4 that would produce the same amino acid?

3. Could any mutations have occurred in nucleotide 6 that would produce the same amino acid as was produced from the original DNA sequence?