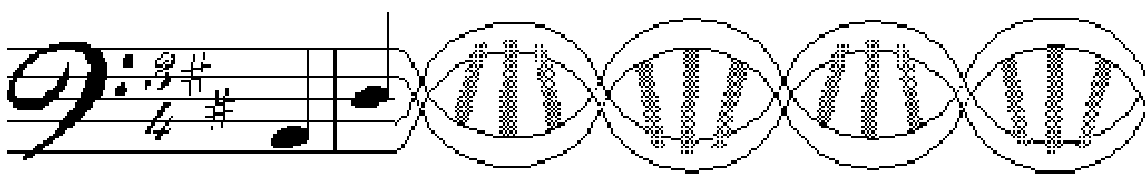
DNA Music



Reverse translating proteins yields microbiological melodies

HAVE YOU EVER LISTENED TO BOVINE pancreatic ribonuclease? Biology students at Scotia-Glenville High School are doing just that and more. They are reverse translating proteins from their amino acid sequences back to their DNA sequences and then assigning musical notes to represent the adenine, guanine, cytosine, and thymine bases, thus creating DNA music.

DNA Music is an enjoyable, multicurricular activity that integrates biology, music, and computer technology. The primary objective of the activity is for students to apply what they learned about the mechanics of protein synthesis to a reversal of the process. Given an amino sequence, students work it backward to obtain a complementary mRNA and ultimately the original DNA sequence of nitrogen bases. A secondary objective is for students to apply the DNA sequence to a comparable musical scale, thus creating a sensory experience for an abstract concept.

BY CAROL MINER AND PAULA DELLA VILLA

The inspiration for this activity came from an article in *Discover* magazine (Zimmer, 1995) that explained how noted biophysicist David Deamer set proteins to music.

Cooperative learning strategies are implemented both in the classroom and in the computer laboratory during the project. The final DNA song is incomplete without input from each team member. In addition, students talented in music can assume leadership roles that enhance the creativity of the teams and the music they produce. Computer-savvy students can assist their teammates in discovering alternative strategies for entering data and using music software.

PROTEIN BEAT

To obtain protein amino acid sequences, we accessed a national protein database from a National Institutes of Health web page: *http://www3.ncbi.nlm.nih.gov/Entrez/index.html*. We chose proteins that were relatively short—approximately 200 amino acids. Our strategy was to provide cooperative learning groups with an adequate, but not overwhelming, number of amino acids to reverse translate. We selected the following proteins:

FIGURE 1.

Student data worksheet.

	Amino acid	mRNA codon	DNA	NOTE		Amino acid	mRNA codon	DNA	Note
1					21				
2					22				
3					23				
4					24				
5					25				
6					26				
7					27				
8					28				
9					29				
10					30				
11					31				
12					32				
13					33				
14					34				
15					35				
16					36				
17					37				
18					38				
19					39				
20					40				

Growth factor hormone
Membrane protein
Epidermal growth factor
Cystic fibrosis transmembrane protein
Synaptic vesicle protein
Smooth muscle protein
Liver glycoprotein
Heart muscle proteinase
Liver protein
Skeletal muscle protein

Students were provided with the amino acid sequence of these proteins. They could access the Internet themselves, but this was optional, depending on time and computer availability.

The activity (see student instructions on page 21) was the culmination of a unit on DNA and protein synthesis. Working in cooperative learning groups of four, students divided their protein into four manageable lengths of approximately 50 amino acids. Using a codon chart, they identified a codon for each of their amino acids. They then converted their codons to DNA sequences. Figure 1 illustrates the worksheet students used to collect and organize their data.

The musical aspect came next. DNA nucleotides are abbreviated using the first letter of each of the bases, thus adenine becomes "A," guanine becomes "G," cytosine becomes "C," and thymine becomes "T." All of these abbreviations except "T" are musical notes. Substituting the note "E" for "T" produces a musical alphabet of A, G, C, and E.

Students assigned a musical note to each of their DNA nitrogen bases. They then spent a class period in our computer lab using software that allows musical notes that students enter to be played, stored, or printed as sheet music. Creative students with a background in music (each cooperative learning group included a student who played a musical instrument) were able to change the rhythm and octave of the notes to produce a melody. Figure 2 is a portion of the DNA music generated by the software.

A musical performance from each group constituted the final class of this three-day activity. Some groups performed their DNA song using the musical instrument of their choice. Others performed using our music department's synthesizer, which replicates the sounds of more than 100 different instruments. By loading computer disks made on the software and choosing an instrument, we were able to listen to proteins played on harp, full orchestra, or saxophone.

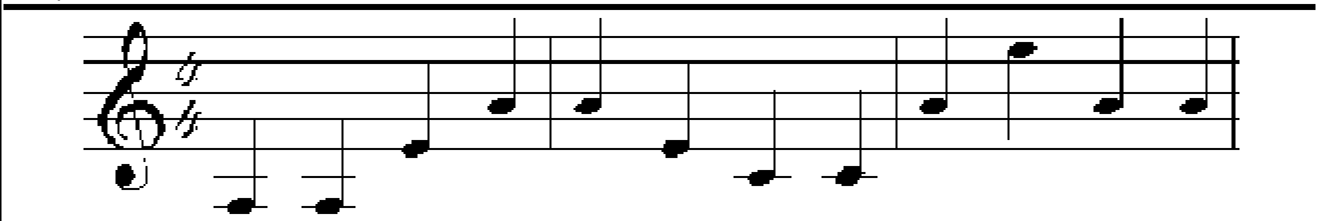
Student Instructions

In contemplating the pattern of nucleotides in DNA, biophysicist David Deamer was reminded of music. He let the letters representing the nucleotides stand for the letters of the musical scale with one variation: the "T" for thymine became the musical note E. Thus, by determining the nucleotide sequence of a gene, one can "hear" the music produced by the DNA code. You will translate and produce such music in this activity.

Procedure:
1. Obtain a protein amino acid sequence from your teacher. Identify it on the data sheet provided.
2. Divide the amino acid sequence equitably among the four people in your group. Do this by numbering the amino acids and assigning a segment of the protein. (For example, student 1 gets sequence 1–35, student 2 gets sequence 36–72, and so on). Place this sequence on the data sheet provided.
3. Using a chart of mRNA codons, determine the mRNA sequence for the amino acids you must translate. Record this sequence on the data sheet provided.
4. Determine the DNA complement for your mRNA sequence. Record this on the data sheet provided.
5. Using the music software, type in your DNA sequence. Remember, a DNA "A" = A, "G" = G, "C" = C, and "T" = E.
6. If a member of your group is a musician, experiment with rhythm and sound by changing whole notes to half or eighth notes or change octaves.
7. Direct the computer to print your music.
8. Save your music to your disk.
9. You now have a choice. You may either:
   a. Play your group's music on an instrument and tape it or
   b. Play your group's music on a synthesizer and tape it.

FIGURE 2.

Sample DNA music.



MUSIC APPRECIATION

Assessment of student learning focused on students' ability to (1) reverse translate amino acid sequences to mRNA and subsequently to DNA, (2) research the role or function of the protein in the cell or the organism, and (3) present DNA music. Our analysis of the criteria on completed worksheets indicated that students were successful in the process of reverse transcription-translation.

We observed that students worked methodically and consistently to arrive at the DNA sequence. The cooperative learning strategy provided a positive interdependence. Each member of the team performed a specific task, and students relied upon one another's special talents. Those skilled with computers assumed leadership roles in the computer lab; those with musical ability varied tempo and octave to produce variations in melody. Teachers can modify the activity to include a presentation on the protein's function along with the music.

Students' reactions to DNA music were mixed. Some the students found the music to be repetitive, others found it melodic, and still others found it to be quite beautiful. One student summed up the music best: "It may not be a tune you can hum or easily remember, but when you realize where it came from—Wow! It's the music of life!" ✧

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REFERENCE

Zimmer, C. 1995. First Cell. *Discover* 16(11):70-78.