QUICK FIX

Shaping tRNA

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Abstract

This model-building activity provides a quick, visual, hands-on tool that allows students to examine more carefully the cloverleaf structure of a typical tRNA molecule. When used as a supplement to lessons that involve gene expression, this exercise reinforces several concepts in molecular genetics, including nucleotide base-pairing rules, the importance of molecular shape, the consequences of genetic mutation, and similarities and differences between DNA and RNA.

Key Words: *tRNA; gene expression; translation; RNA conformation; molecular shape.*

A central theme in biology is that gene expression directs all life processes, from those necessary for basic cell function to those that underlie human disease. Lessons highlight the composition and structure of nucleic acids, DNA as a genetic blueprint, and the processes of transcription and translation. Given a genetic code, students learn to work through the sequential steps of DNA to RNA to protein. To supplement this topic, I challenge my students to construct a simple three-dimensional cloverleaf model of a transfer RNA (tRNA). A few pipe cleaners and beads of four different colors enable a quick, easy, and inexpensive hands-on simulation of the intact molecule. While focusing on the physical model, I ask students to contemplate how encoded information stored in DNA is transformed into vital proteins needed for structure and function.

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This activity fits well following a lesson on gene expression and the role of tRNA in translation. In preparation, I describe the cloverleaf structure of tRNA and the composition of double-stranded hairpin stems with single-stranded loops. I further emphasize how this conformation strategically positions the site for amino acid attachment and the anticodon site needed to deliver a specific amino acid to a growing polypeptide at a ribosome.

I provide a hypothetical ribonucleotide sequence (Figure 1) that can only be folded into a characteristic tRNA cloverleaf (Figure 2). I indicate the underlined ribonucleotides in Figure 1 that will form A:U and C:G base pairs to create each arm of the cloverleaf, reminding students of RNA base-pairing rules and that two sides of a hairpin stem are antiparallel. Students build the polynucleotide and then fold the tRNA into its cloverleaf conformation by aligning the colored-bead pairs. While they are building their models, I ask them to recall and discuss fundamental concepts such as differences between ribonucleotides and deoxyribonucleotides, 5′ to 3′ polymerization of polynucleotides, complementary base pairing through hydrogen bonding, and denaturation and renaturation of nucleotide pairs.

This activity can easily be completed in the classroom, in the laboratory, or at home. It not only stresses the importance of tRNA as a unifying link between a gene and its encoded protein, but provides a convenient visual tool that helps to integrate a number of related themes in biology, including the functional importance of molecular shape and gene mutation as the basis for genetic variation.

○ Activity: Shaping tRNA

Suggested time frame: 10–15 minutes to introduce and distribute materials, 30–45 minutes to build the model, and 15 minutes for follow-up questions.

○ Materials

- Pipe cleaners
- Small beads (four colors)
- Sheet of paper
- Tape
- Hypothetical tRNA ribonucleotide sequence (Figure 1)

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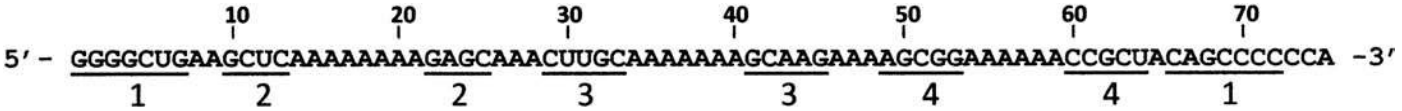

Figure 1. Hypothetical tRNA ribonucleotide sequence. Ribonucleotides are numbered from 5′ to 3′ across the top. Underlined bases make up hairpin stems 1, 2, 3, and 4 of the cloverleaf.

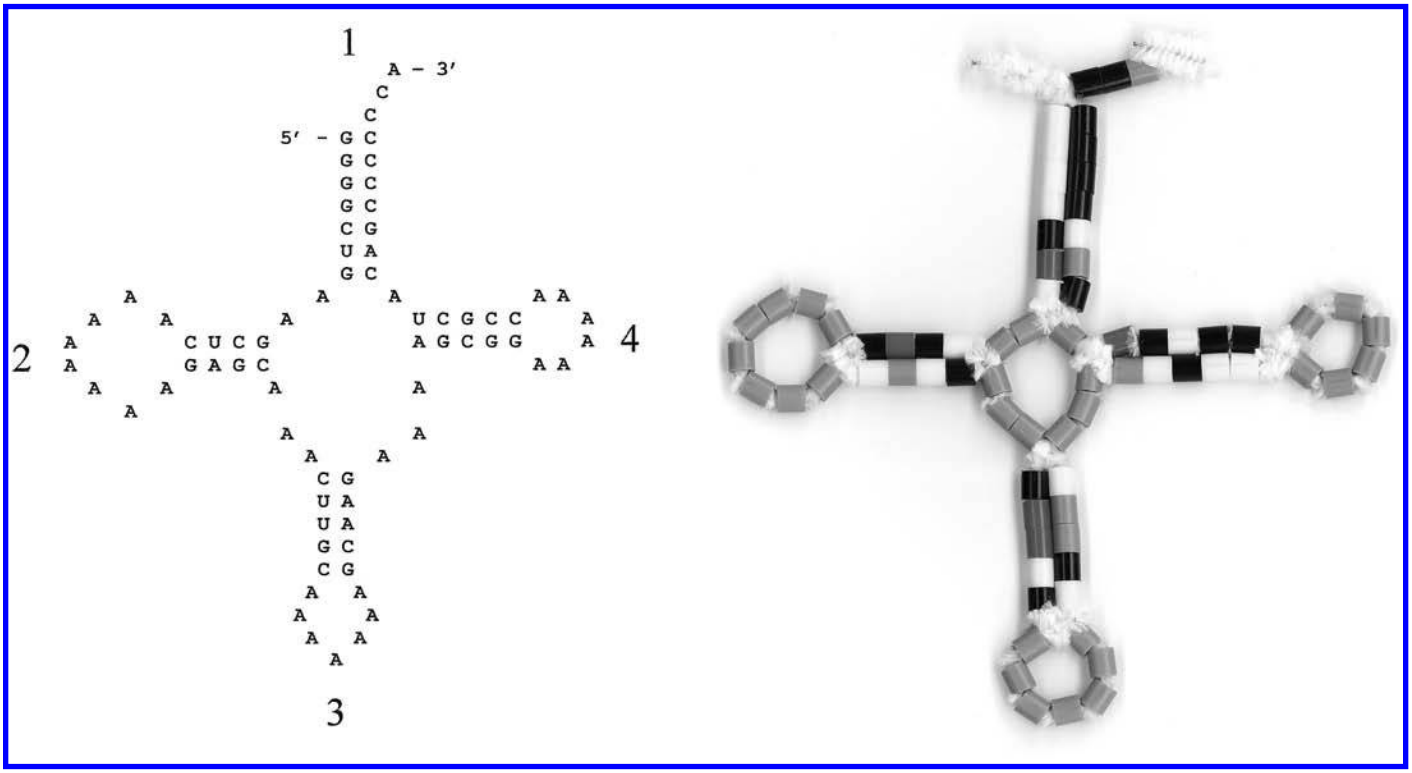

Figure 2. Left: tRNA bases arranged as a cloverleaf. Right: a completed model.

○ Procedure

1. Work with a partner. Assign a different color of bead for each of four ribonucleotides (A, C, G, and U).
2. Locate the 5′ and 3′ ends of the tRNA sequence. Underlined ribonucleotides make up the opposite sides of double-stranded cloverleaf stems numbered 1 through 4.
3. Beginning at the 5′ end, string the ribonucleotide beads onto a pipe cleaner. Attach additional pipe cleaners as needed.
4. Refer to a textbook or the Internet to review the cloverleaf shape of tRNA. To form Stem 1, pair the complementary ribonucleotide beads at the 5′ and 3′ ends. Leave the last three ribonucleotides (CCA-3′) unpaired. Remember that A pairs with U, and C pairs with G.
5. Identify the complementary ribonucleotide beads that can form stems 2, 3, and 4. Notice how the complementary colors are arranged.
6. To hold hairpin stems in place, tape your folded tRNA onto a sheet of paper.

○ Follow-up Questions

(Refer to textbook or Internet.)

1. For this tRNA, where are the amino acid binding site and the anticodon located?
2. What amino acid is carried by this tRNA?
3. What holds the base pairs together in a hairpin stem?
4. How is an RNA hairpin stem similar to a DNA double helix?
5. Predict the consequences in structure or function if mutations occur that cause each of the following changes in the tRNA:
   a. A deletion of one ribonucleotide in any hairpin stem.
   b. A deletion of ribonucleotides 29 through 33.
   c. An A to U substitution at ribonucleotide 17.
   d. An A to U substitution at ribonucleotide 37.

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