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Tips and Tools

A Simple Wooden Ribosome Model: Helping Students Understand Transpeptidation

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INTRODUCTION

In teaching biology, it is critical to communicate broad concepts before considering more specific details of a process. This is particularly important when attempting to communicate the essence of transpeptidation, a key process in translation. Based on my experience in teaching general microbiology, transpeptidation is the most difficult aspect of translation for students to understand.

Typically, figures given in microbiology and biochemistry texts show movement of the nascent peptide attached to the P position t-RNA to the incoming single amino acid attached to the A position amino acid-tRNA by the use of arrows, an approach that makes it difficult to understand the dynamic aspects of this process. To attempt to improve understanding of this process, tutorials also are available (2) that emphasize decoding "messages" and the use of "Do-it-Yourself DNA Kits" where the process of transpeptidation is not specifically discussed. Simple demonstration models also are available to allow the instructor to make this process more easily understandable. These include a foam core construction board and Velcro hook and eye strip model (4) with a movable mRNA bar with varied triplet codon notch patterns, to demonstrate t-RNA-mRNA specificity, and an edible model (which is specifically noted as not to be consumed) comprised of black licorice sticks has been described (3), where the specific process of transpeptidation is not discussed. In addition, sophisticated single ribosome 3-D visuals now are available (1, 5) where single peptide bond formation can be observed in real time, using fluorescent marked components for use in more advanced classes. The simple model described in this communication provides a clear demonstration of the transpeptidation process.

PROCEDURE

Construction. Only approximate sizes are noted; the components can be varied based on the materials available and the teaching objectives. This model was constructed using wood scraps and finishing nails; rigid foam and round wooden swab sticks also could be used. If rigid foam is used for the model ribosome, it could be mounted on a small sheet of thin plywood to keep it in a vertical position.

t-RNA. The individual t-RNA units consist of wood blocks, approximately 3 inches by 4.5 inches, cut from nominal 1-inch thick trim stock. A single larger finishing nail is inserted in the center top of the block, and three 8d 2.5 inch finishing nails are inserted into the bottom at the center and 1 inch either side of the center, representing the triplet codon (Fig. 1). The heads of the finishing nails are cut off. These "tRNA" molecules are painted in desired colors, and triplet dashes are drawn on the bottom of the front side.

mRNA. The "mRNA" (Fig. 2(a)) unit consists of a 2.5 inch (nominal 3 inch) piece of three-quarter-inch trim stock, approximately 39 inches in length. An alignment piece of three-quarter-inch by three-quarter-inch stock, also 39 inches in length, is nailed to the upper back of the trim stock (Fig. 2(b)). Triplet complementary holes (a 7/32 inch drill works well) are drilled in the top of the mRNA,

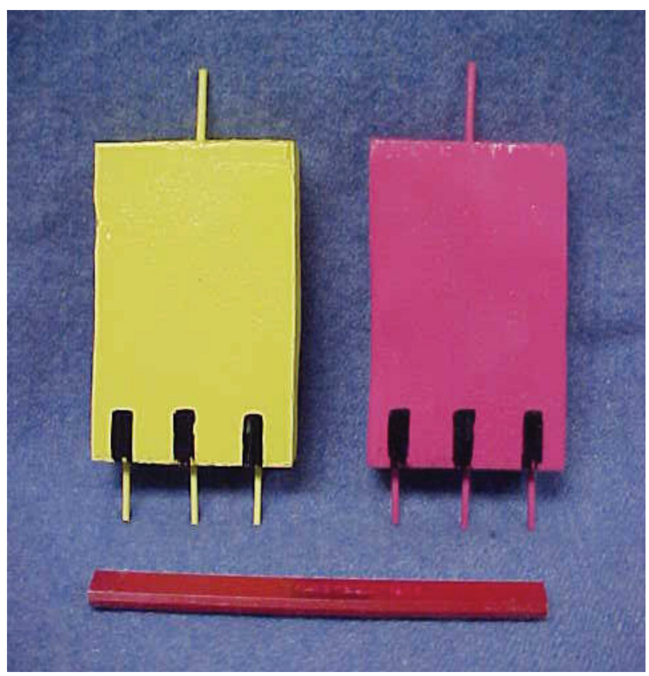

FIGURE 1. t-RNA units. A single larger finishing nail is inserted in the center top of the block, for placement of the "amino acid," and three finishing nails are inserted into the bottom, representing the triplet codon. The size bar is 6 inches in length.

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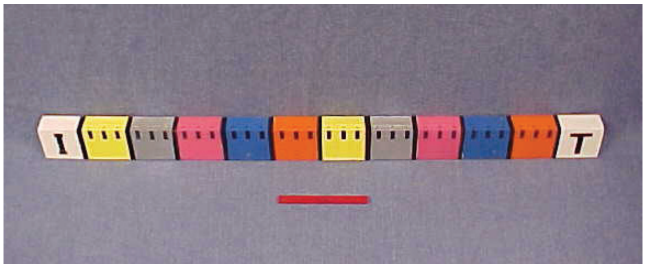

FIGURE 2(a). The "mRNA" with different colors representing the different amino acids. On the left side, an "I" is used to note initiation sequences and, on the right, "T" for termination sequences. The size bar is 6 inches in length.

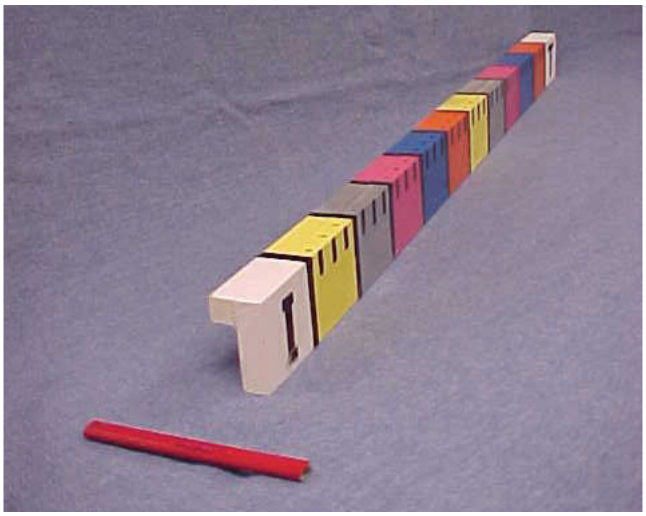

FIGURE 2(b). An end view of the "mRNA" showing the position of the alignment piece that locks the mRNA into the ribosome. The size bar is 6 inches in length.

to allow the individual tRNA units to be inserted, with approximately three-eighths-of-an-inch separations between the individual tRNA blocks. The mRNA individual codons can painted in the same colors as the tRNAs. On the left side, an "I" is used to note initiation sequences and, on the right, "T" for termination sequences.

Ribosome. As shown in Fig. 3(a), the ribosome is cut out of scrap wood and consists of a short piece of 2 by 4 stock (approx 11 inches in length) as the base with a back support (approximate size 11 inches wide and 14 to 15 inches high) made of three-quarter-inch finished plywood cut in the shape of a 70S ribosome, showing the larger 50S on the top and the smaller 30S subunit on the bottom. A two-piece second plywood layer is placed on the front of this back support, to create a slot to allow the mRNA to slide across the front of the ribosome (Fig. 3(b)). To finish the ribosome, a short piece of 2 inch by 2 inch stock is affixed to the front of the 2 by 4 base to hold the mRNA in place. Using a belt sander, the unit can be rounded and smoothed as desired. The A, P and E positions are noted using inexpensive stick-on letters.

Amino acids. The amino acids consist of beverage coasters that have short 1.5 inch lengths of rigid plastic tubing

FIGURE 3(a). Basic profile of the ribosome model. This is cut to illustrate the 50S and 30S subunits of the ribosome. The size bar is 6 inches in length.

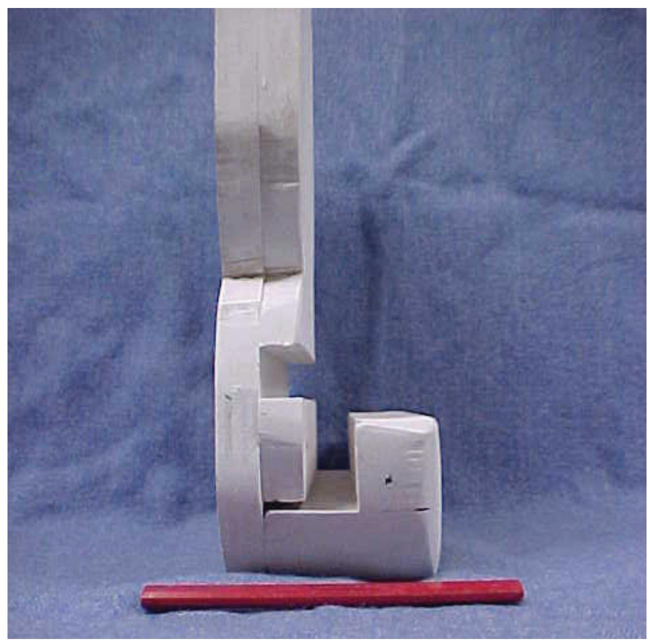

FIGURE 3(b). End view of the ribosome model showing the base, a short length of 2 by 4, the backboard, and the two-part facing board with the slot to allow the mRNA to move across the face of the "ribosome." The lower 2 inch by 2 inch piece holds the "mRNA" in place. The size bar is 6 inches in length.

glued on the back bottom, as well as a piece of round wooden swab handle that extends approximately 1.5 inches above the edge of the coaster (Fig. 4) These amino acids are painted in colors to match the individual tRNA blocks.

Operation of the ribosome model. To demonstrate the process of transpeptidation, the mRNA stick is

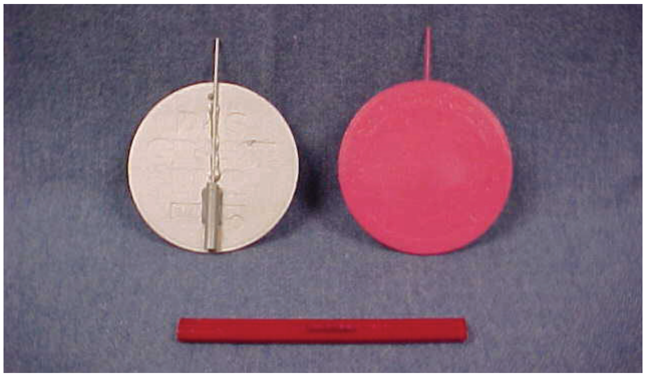

FIGURE 4. The individual amino acids are beverage coasters; on the left, the reverse side is shown. On the reverse, a short piece of rigid plastic tubing is glued to the bottom and a piece of round stick from a swab extends above the top of the coaster approximately 1.5 inches, to allow the amino acids to be "stacked." The size bar is 6 inches in length.

inserted into the ribosome with the first amino acid in the "A" position.

To demonstrate transpeptidation:

1. The student picks a tRNA in the color to match the first codon on the mRNA, and places the corresponding colored amino acid on the top.
2. This incoming amino acid and tRNA then are placed on the m-RNA (in the A position) by inserting the triplet nails into the upper edge of the corresponding similar-colored triplet codon position on the mRNA.
3. The mRNA and the tRNA/amino acid then are moved over to the P position.
4. Another tRNA and associated amino acid are placed on the A position. This step is repeated.
5. As the mRNA is moved to the left, the amino acid/nascent peptide chain now in the P position is MOVED over to the top of the incoming single amino acid-tRNA that originally was in the A position.
6. When this process is repeated, the now empty tRNA that is in the E position can be taken off the mRNA. This results in the creation of a nascent peptide with the same sequence as the codons (based on colors) as shown in Fig. 5.

This process of transpeptidation can be repeated as desired with appropriate discussion, as the nascent peptide gets longer and longer, to be sure the concept has been communicated to the class.

CONCLUSION

This simple, easy-to-visualize model makes it possible to communicate the essence of the transpeptidation process to large classes (typically 150–160 students in a lecture). As noted by Rogerson and Cheney (4), understanding translation, including transpeptidation, "requires students to grasp intermediate steps in the movement and relationships of

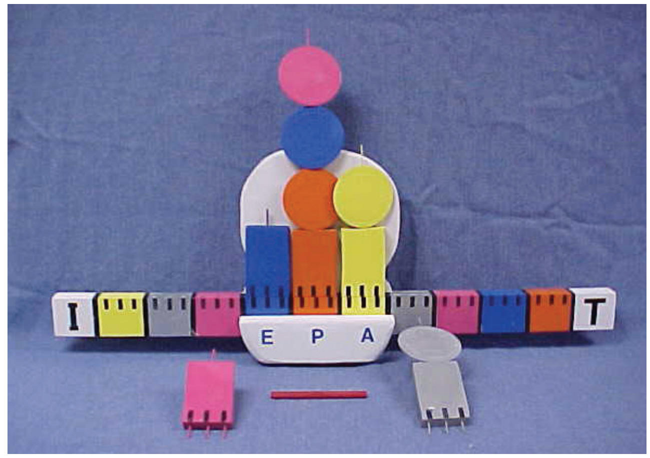

FIGURE 5. The complete ribosome, with the mRNA in place, and the tRNAs and nascent peptide after two transpeptidation steps have been carried out. The locations of the tRNA on the A, P and finally the E site are noted. The size bar is 6 inches in length.

the various components. If students are unable to integrate the steps into a coherent whole we found they had great difficulty understanding protein synthesis as well as other concepts incorporating stepwise polymerization such as nucleic acid synthesis." To increase anticipation and student interest, the individual "protein synthesis bits" can be taken from a large mysterious "black box," followed by careful examination of each component with appropriate asides and comments. This model can assist in conveying the essence of the dynamic process of transpeptidation, an elegant illustration of the nanoengineering that is central to so many biological phenomena.

ACKNOWLEDGMENTS

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