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Tips & Tools

From Pipe Cleaners and Pony Beads to Apps and 3D Glasses: Teaching Protein Structure †

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INTRODUCTION

Students in the biological sciences struggle with many concepts, from the process of transcription and translation to the three-dimensional nature of molecules. Any activity that allows the students to visualize and perhaps even manipulate a structure, even in a model form, is an effective method for learning (10). From simple paper models of DNA and replication (12) to modeling molecular biology using jewelry (2) to folding a cloverleaf tRNA molecule made out of paper (11), using hands-on manipulatives, especially student-made ones, is an excellent method of allowing students to conceptualize, rather than memorize, cellular processes and molecules.

The concept of protein structure can be difficult for students to learn and a variety of methods can be effective to help them 1) learn that proteins are a linear chain of amino acids that has been able to fold in a three-dimensional way to form a molecule, 2) model how proteins fold, and 3) manipulate protein models to better understand structure/function relationships. In this tips and tools article, I briefly describe several models one can make cheaply in the classroom and some mobile apps for viewing protein structure. For more detailed information and a description of the rationale for using active learning, please see Appendix 1. For instructions on how to use several of the apps, please see Appendix 2.

Protein-folding models

Students often appreciate hands-on activities, especially those that model three-dimensional processes or structures. Protein-folding models can be extremely simple and inexpensive, such as paper or overhead transparency plastic (4, 7), or slightly more complicated, such as those made out of wire (13) or pipe cleaners, with pony beads or other small items to symbolize amino acids (Fig. 1) (1, 5, 6). Commercial kits are also available, such as organic chemistry building kits students may already own—purchased for a chemistry class for example, such as a MolyMod kit (http://www.molymod.com/sets.html) (see supplemental materials). There are also more expensive protein-building kits and 3D models from several companies, such as the Tangle Proteins (https://www.tanglecreations.com/products/Details.aspx?p=854), about $35 per kit, which makes three models (Fig. 2). Depending on the needs of the class and the budget, some type of hands-on manipulative demonstrating protein folding is available at every price point.

Mobile apps

The majority of my students have a smart phone as their cellular phone. In addition to the texting and phone call capabilities of a traditional cell phone, these phones, like tablets such as the iPad, also allow the user to download

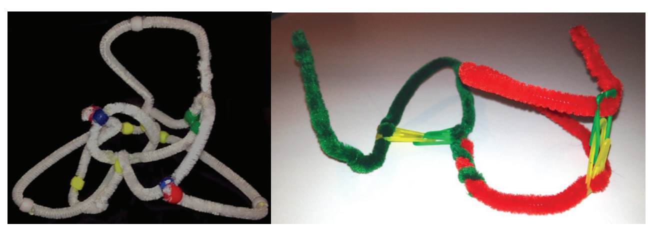

FIGURE 1. Examples of pipe cleaner protein structures. For details please see Appendix 1.

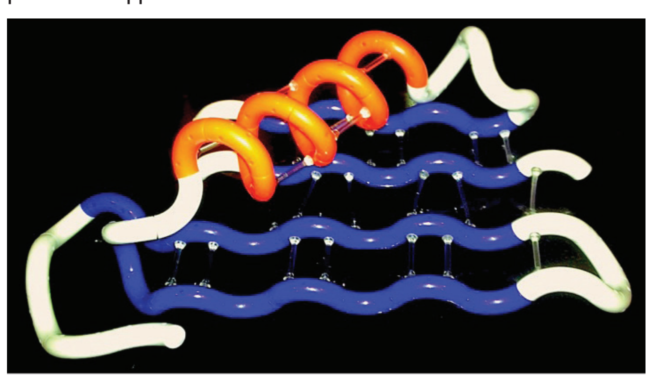

FIGURE 2. Tangle Proteins Building Set, the 3rd IgG binding domain of Streptococcal protein G (3); instructions in the kit.

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small programs, or apps, which generally perform one function. Wonderfully, there are several apps that are free or very inexpensive that allow the user to render the structure information from the Research Collaboratory for Structural Bioinformatics (RCSB) Protein Data Bank (PDB) in the same way one can on a computer (Figs. 3 and 4). Students can manipulate the 3D protein structures with a swipe of the finger or a pinch, and two apps even allow the user to render the molecules in cyan/red (anaglyph) 3D (Fig. 4(b)), which allows students to visualize and manipulate structures in three dimensions. In the accompanying supplements, I describe the apps in detail, and give instructions for using them.

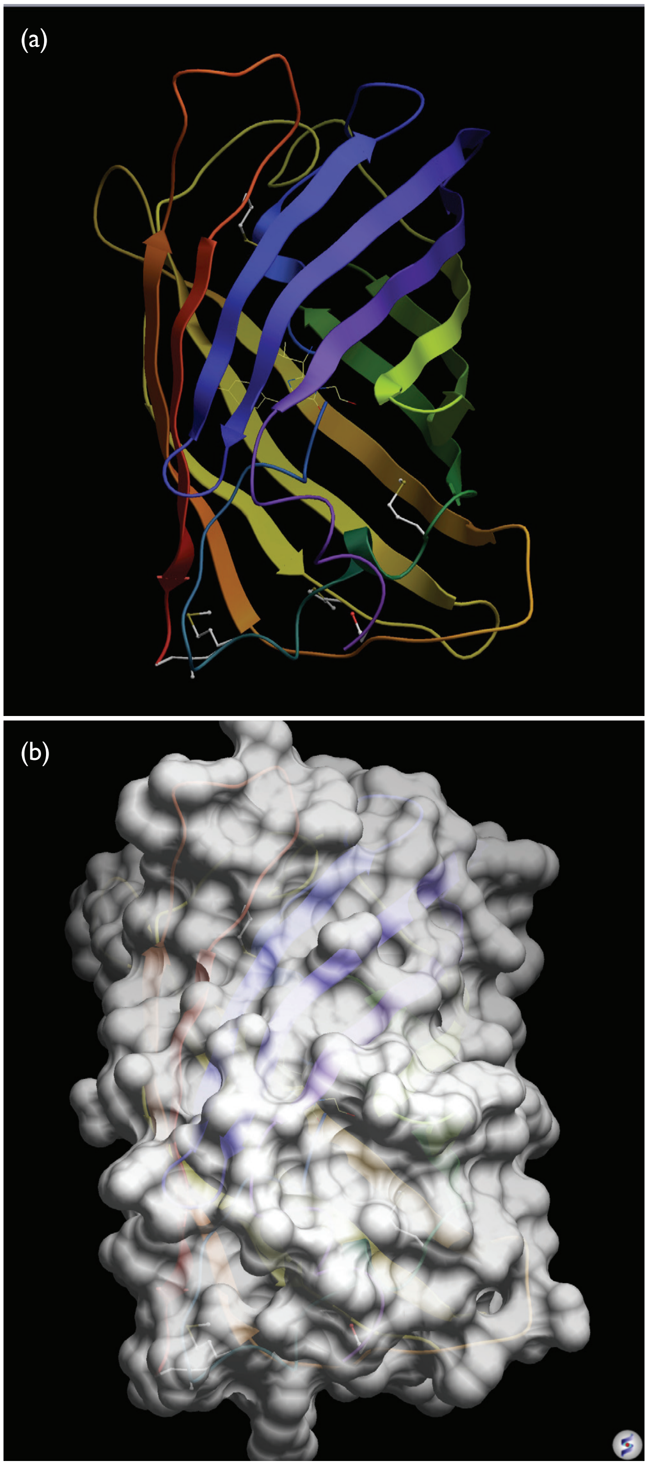

FIGURE 3. Green fluorescent protein (1EMA) (8) rendered with iMolview. (a) Visualized as a ribbon structure colored N to C. (b) Visualized with 3D surfaces (skin) drawn.

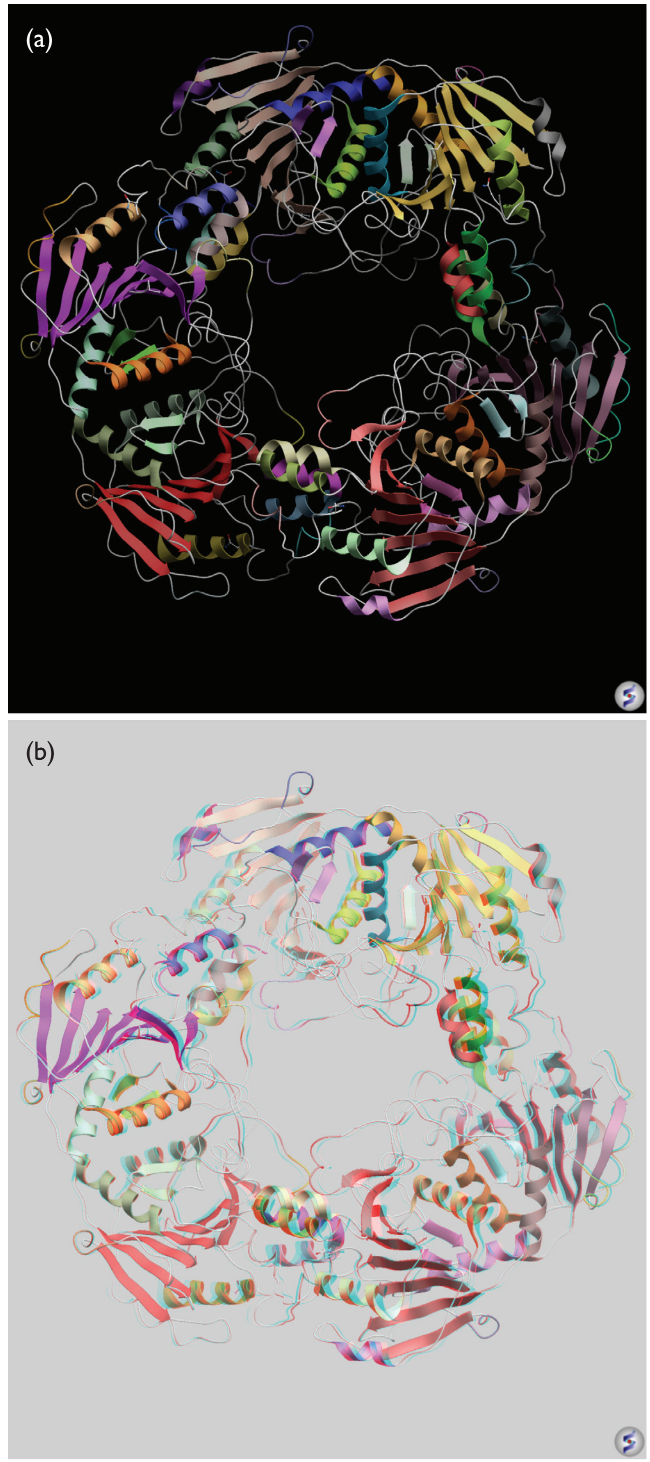

FIGURE 4. Cephalosporin hydroxylase from *Streptomyces clavuligerus* (2BM8) (9). Rendered with iMolview. (a) Protein structure. (b) Anaglyph structure.

Utilizing active learning to engage students in notions that are conceptually difficult to understand, such as protein folding and protein structure, can be performed hands-on at a series of price points and also with available mobile apps.

SUPPLEMENTAL MATERIALS

Appendix 1: Rationale and further information
Appendix 2: App instructions

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