The MIT Edgerton Center DNA/RNA, Protein and tRNA Sets

Teacher Guide Introduction:

An Innovation in molecular models

Today’s biology teachers need to teach about molecular function. This is hard to do. Students find it difficult to follow the many structural changes that molecules can undergo.

How can the MIT models help and what is the innovation?

From the start, the models were designed to be manipulated and are inviting to touch. The molecules’ functional groups are accentuated by attractive and colorful shapes. These features help students focus on the key aspects of the cell processes that they are re-enacting. The processes include DNA replication, mRNA transcription, and tRNA translation. After translation is completed, the chains of amino acid models are flexible enough that students can fold proteins into different shapes, illustrating all four levels of protein folding. The innovative models make it is possible demonstrate how a change in a single nucleotide can change a protein’s structure and function.

Our models’ capacity to reenact cell processes also increases student engagement. The hands-on experience brings a level of playfulness and also with it... a unique set of classroom challenges! To become familiar with best practices for teaching with these innovative tools, please be attentive to following essentials.

Four Essentials:
1) Practice with the hands-on models to become a skillful and confident leader.
2) Use the models at multiple levels to meet student needs.
3) Teach ‘Proteins before DNA’ to increase student understanding.
4) Prepare your kits with the “Team Kit Care Record Sheets” and follow maintenance instructions.

1. Practice with the hands-on models.

Before teaching, we strongly suggest taking out a kit and following the instructions in Booklet 1 very carefully. First you need to become familiar with how the student booklets are designed to work. Your class will be grouped in teams of two with each team sharing one kit and one booklet. A bold type sentence in the booklet indicates an action for the students to do with the models. The adjacent photos provide a visual for the action that is described in bold type. An underline in the text alerts the student to a new vocabulary word. A yellow highlighted question in the text is intended to have the students pause and reflect. The question functions as a periodic “check-in” for student understanding (answers in the back of book.)

During your practice time, please use the Teacher Guide online. (Camilla place URL here) Select the Demonstration Videos’ to see close-up views of exactly what to do with the models for each simulation. Mastering the modeling is important. Students will be acting out the cell processes with the models to learn the steps, so they need to physically --do it correctly--to learn it correctly. Luckily, most biomolecules are polymers! Students will get a lot of practice making and breaking bonds. For example, the two strands of the double helix are held together by weak hydrogen bonds. In the cell, the two DNA strands are easily separated and easily
rejoined. The models are designed to show this. With the right technique as demonstrated in the 'Demonstration Video' the DNA strands should pop apart!

2. **Use the models at multiple levels to meet students’ needs.**

The models are well suited for multiple levels of instruction: middle school, high school and the university/professional levels. For example, the model’s universal design supports an emphasis on nucleotide chemistry at the university level with the 3’ designation on the sugar models. However, the middle school teacher can fully use the models without ever referring to the 3’. In keeping with universal design, the booklets minimize the number of scientific terms so teachers can choose the scientific terms they will require students to learn. This gives teachers flexibility and autonomy. Instructors can elaborate on the chemistry that is represented and choose appropriate vocabulary.

The models provide an excellent means for teaching molecular biology to English language learners (ELL) because very little language is required. ELL students don’t often have opportunities to learn complex and interesting concepts, held back by their lack of vocabulary. But here, the concepts can be visually conveyed. Teachers in the USA have remarked how rewarding it is to see ELL students become engaged and eager to ask questions. Additionally, the models are ideal for tutoring. Overall, the models provide flexibility for many students with different learning needs. Instructors may wish to introduce their support staff in the use of the kits.

While a wide age-range is possible, we do not recommend the models for students under 11 years old. It is preferable for students have mature motor skills and a working knowledge of cells and molecules.

3. **Teach ‘Proteins before DNA’ to increase student understanding.**

High school and university instructors usually teach DNA first and then move on to teaching protein synthesis. This sequence mimics the central dogma sequence of molecular biology (DNA-> RNA-> Protein). This common practice makes things more difficult than necessary. First, proteins are unfamiliar molecules to most students who are learning protein synthesis. Thus, teachers are typically trying to teach about proteins at the same time as they are teaching about protein synthesis.

However, if teachers have already taught proteins with our models, the students will be able to focus on the process of synthesizing a protein from a gene. To be specific, if you teach proteins **before** the DNA and protein synthesis lesson, students can anticipate that the amino acids will be joined into a long chain. Furthermore, the students already recognize that the order of the amino acids determines a protein’s shape and function. So they understand how important it is to get the amino acid sequence right.

So try it! Teach our protein lessons first, even to middle school students! We know teaching about proteins is uncommon at this grade level. However, aren’t middle schoolers taught that DNA codes for something? So learning about proteins will give the students a much better understanding about DNA. Admittedly, teachers have had difficulty teaching about proteins in the past because they couldn’t find any suitable protein models. Our amino acids make the assembly and folding of protein chains into an understandable and satisfying hands-on activity.
4. **Prepare your kits well and follow these maintenance instructions.**

There are 14 kits in the DNA/ RNA Set and 14 kits in the Protein Set. Here is how it works: Kits #1-12 become the student kits; Kit #13 is placed aside for replacing parts as needed in the future; and kit #14 is kept as a teacher kit for demonstrations. (The tRNA Set is the exception. It has 4 kits. The tRNA set is used in a different classroom manner. See separate instructions.)

**Prepare all 14 kits before use**

For both the DNA/RNA kits and Protein kits see the adjacent figure and follow the instructions listed below the photo. You will number each kit (#1-14) on the side and on the top. You will place the folded ‘Team Kit Care Record’ paper inside the kit.

There is a small parts bag inside this kit that is not often used and could be easily lost. Remove the small bag in the lower right hand compartment. Only the 3 white tags inside are needed for DNA/ RNA Basic Booklet 1 lessons, so only replace the 3 white tags in the compartment. We recommend removing the rest of the bag from the kits for safe-keeping. Find a small box to be designated the “Lost & Found” for the whole class.

**Maintain kits with the following method**

At the beginning of each lesson, give teams about 3 minutes to fill out the “Team Kit Care Record.” Initially explain that you expect teams inspect kit pieces and confirm the piece counts. Students should report the kit status and not leave any blanks on the paper. The additional column on the paper labeled “teacher initials” is optional. Use this for teams that require your close supervision or for teacher notes/comments.

If you have removed DNA kits’ small parts bag as suggested in the “Prepare your kits” section above, amend the Team Kit Care Record paper to list 3 white tags in the compartment. This will speed up the kit check process. (When teaching the Advanced Topics DNA lessons in Booklet 2, you will need to return the small bag of parts.)

Why is this Team Kit Care system so effective? Teams keep the same kits. Checking is only done at the beginning of each class. Thus, each team checks the previous team’s use. Also the student kits were designed to minimize manual counting. Small quantities can be discerned by a glance. Lastly, remember to instruct the teams to place any extra pieces into a box designated as the Lost & Found Box. Lastly, the clear plastic box makes it possible the teacher to see the materials inside for quick visual confirmation.

This concludes the Essentials for Teaching. In summary: 1) practice with the models first yourself; 2) plan to use the models in multiple ways to meet diverse student needs; 3) ‘teach proteins before DNA’ to help your students learn the key concepts; and lastly, 4) prepare your kits and maintain your models well with the help of your students. Enjoy!