3-D Molecular Designs
...where molecules become real ™

Substrate Specificity Field Test Kit©

Teacher Notes

Activity Guide

This activity guide for the Substrate Specificity Field Test Kit© will help you to consider different ways you may use these materials. We encourage you to modify these lessons and activities to meet the learning objectives and needs of your specific students.

Objectives

Use the model pieces in the kit to:

- Construct a model of a substrate and examine its chemical properties.
- Engineer an enzyme active site specific to the substrate constructed.
- Explore different types of specificity including stereochemical specificity and absolute specificity.
- Discover how subtle changes in enzyme structure – either in the active site or elsewhere in the enzyme's structure – can potentially have a significant impact on substrate binding in the active site.

Materials:

- 1 3-foot mini toober
- 1 6-foot mini toober
- 1 blue functional group
- 1 red functional group
- 1 white functional group
- 2 yellow functional groups
- 1 4-hole sphere
- 1 2-hole sphere with post
- 5 metal clips
- 1 sheet of colored clip labels
- 2 sets of red and blue endcaps
- Amino Acid Side Chain Chart

Please note: when connecting or disconnecting the functional groups with the spheres, instruct students to align the pegs and holes straight into each other. Bending the pieces at an angle disfigures the pieces and permanently loosens the connection between the functional groups and the spheres.

Prior knowledge of protein structure and the rules of protein folding are necessary for the successful completion of this kit. We strongly suggest using 3D Molecular Designs' Amino Acid Starter Kit© with your students before using the Substrate Specificity Kit©. Students should be familiar with the basic principles of chemistry that govern protein folding in an aqueous environment, e.g. 1) hydrophobic side chains (color-coded yellow) will fold to the inside of the protein structure, 2) hydrophilic side chains (color-coded white) will fold to the outside of the protein structure, 3) negatively charged acidic side chains (color-coded red) will form a salt bridge with positively charged basic side chains (color coded blue) and 4) cysteines will pair to form a disulfide bridge. Students MUST be familiar with secondary structure (alpha helices and beta sheets) if you intend to use the 6-Foot Mini Toober Activity.

Teacher Notes Continued

Notes for 3-Foot Mini Toober Activity

If the learning objective for your students includes a basic focus on the properties of an enzyme's active site, you may want to consider following the instructions for the 3-foot mini toober. In order to avoid a misconception, be sure to tell your students that in this activity they are zeroing in on the active site of the enzyme. Students should be aware that there is much more to the overall structure of an enzyme than its active site, and that variations in enzyme structure at locations other than the active site may have an impact on enzyme function. We recommend that students work alone or in pairs for this version of the activity.

Question #2: If you would like to assess your students' understanding of the color scheme you may also have them indicate the color of each of the functional groups as they label the substrate.

Notes for 6-Foot Mini Toober Activity

If the learning objective for your students includes discussing the importance of protein secondary structure, we recommend you follow the instructions for the 6-foot mini toober. Using the 6-foot mini toober also encourages conversation about the overall structure of an enzyme, allowing students to realize that an enzyme is so much more than an active site. This activity works best if students work in groups of two or three.

Question #2: If you would like to assess your students' understanding of the color scheme you may also have them indicate the color of each of the groups as they label the substrate.

Question #8: Depending on available resources, you could have your students photograph and label their enzyme structures when finished with the activity. You could also have your students suggest possible atoms or functional groups for each of the colored parts of the substrate.

Question #18: You may choose to have your students explore other topics regarding specificity including bond specificity, group specificity, geometrical specificity or cofactor specificity.

Misconception Warning

"All models are wrong but some are useful." - George E.P. Box

Please be aware of a possible misconception that could develop when using this model. We do not want to give students the impression that a protein will fold around the substrate. The protein is prefolded into a precise structure with an active site in which the substrate fits. An enzyme is NOT a stiff structure locked into a given shape. As the substrate enters the active site, the enzyme (and the substrate for that matter) *slightly* change shape due to interactions between the chemical groups on the side chains of the amino acids that form the active site, and the chemical groups of the substrate.

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National Framework

Connections to: A Framework for K-12 Science Education Practices, Crosscutting Concepts, and Core Ideas*

Dimension 1: Scientific and Engineering Practices

1. Asking Questions (for Science) and Defining Problems (for Engineering)
2. Developing and Using Models
6. Constructing Explanations (for Science) and Designing Solutions (for Engineering)

Dimension 2: Scientific and Engineering Practices

1. Patterns
2. Cause and Effect: Mechanism and Explanation
6. Structure and Function
7. Stability and Change

Dimension 3: Disciplinary Core Ideas: Physical Science

Core Idea PS1: Matter and Its Interactions

PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions

Core Idea PS2: Motion and Stability: Forces and Interactions

PS2.B: Types of Interactions
PS2.C: Stability and Instability in Physical Systems

Dimension 3: Disciplinary Core Ideas: Life Sciences

Core Idea LS1: From Molecules to Organisms: Structures and Processes

LS1.A: Structure and Function

Dimension 3: Disciplinary Core Ideas: Engineering, Technology, and Applications of Science

Core Idea ETS1: Engineering Design

ETS1.A: Defining and Delimiting an Engineering Problem
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

*The NSTA Reader's Guide to A Framework for K-12 Science Education, National Research Council (NRC), 2011. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, D.C.: National Academies Press.