QUICK FIX

Seeing & Feeling How Enzymes Work Using Tangible Models

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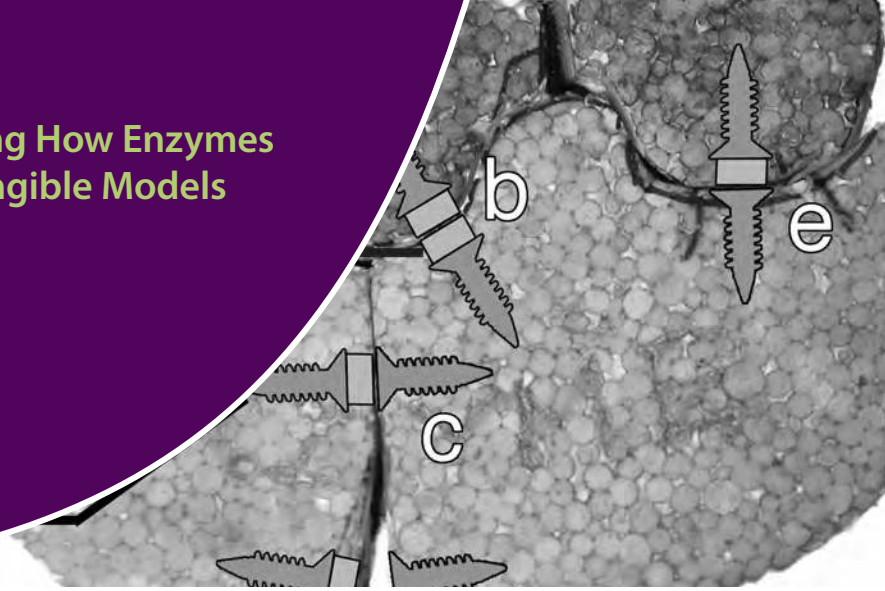

Abstract

This article presents a tangible model used to help students tackle some misconceptions about enzyme actions, particularly the induced-fit model, enzyme–substrate complementarity, and enzyme inhibition. The model can simulate how substrates induce a change in the shape of the active site and the role of attraction force during enzyme–substrate binding. It can also be used to show how noncompetitive inhibitors work differently from competitive inhibitors. In addition, the model allows students to visualize the random collisions between enzymes and substrates. For kinesthetic learners, this tangible model is likely to foster better comprehension of the unobservable enzyme concepts than computer animations. Uses of the model in the classroom are suggested. The model is readily made using simple materials that school teachers can easily acquire, and detailed production tips are provided.

Key Words: *Enzymes; biology teaching; induced-fit model.*

High school and college students were found holding some misconceptions about enzymes, including the induced-fit model, electrostatic complementarity, and noncompetitive inhibition (College Board, 2010; Bretz & Linenberger, 2012). Some of these concepts are essential for general biology learners, such as the induced-fit model, while the others are an important foundation for advanced learning in biological sciences (Bretz & Linenberger, 2012). Here, I present a tangible model that aims to help tackle these and other misconceptions about enzyme actions.

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The model is composed of an enzyme, two substrates, and a frame (Figure 1), which are all made of polystyrene foam. Magnets are used to create magnetic attractions between the enzyme and the substrates. When shaken inside the frame randomly, the substrates can bind to the active site according to their shapes and the magnetic forces (Figure 2). The model illustrates the geometric and electrostatic complementarity of enzyme–substrate interactions. Other enzyme models, such as the "nuts and bolts" model (Burton & Garling, 2012), tend to emphasize only the complementary shapes, such that students often neglect the role of electrostatic force in enzyme–substrate binding (Bretz & Linenberger, 2012).

The enzyme can change shape when bound by the substrate, which is triggered by the strong magnetic forces during binding. This change in shape aligns the two substrates in the positions in which they are connected by the hook-and-loop fastener (Figure 2). This simulation shows important features of the induced-fit model: substrate binding induces a change in the shape of the enzyme, which brings about the catalysis of the substrates into the product. This simulation helps tackle the misconceptions that the substrates bind with the enzyme in a lock-and-key manner and that it is the substrate, rather than the enzyme, that undergoes induced fit (College Board, 2010).

The model can be used further to illustrate enzyme inhibition. Competitive inhibition can be simulated by adding a polystyrene block whose shape allows it to bind the active site but not connect with the substrate next to it. To illustrate noncompetitive inhibition, staple the enzyme to prevent it from changing shape when bound by the substrates. The staple represents the noncompetitive inhibitor, which binds to an allosteric site of the enzyme to make its active site less fit to the substrates.

Computer animations about enzyme actions often portray that the substrate would invariably move toward the enzyme and bind to it successfully. However, the interactions between enzymes and substrates are random and probabilistic. This model is unique in its capability to demonstrate these features by randomly shaking the model enzyme and substrates within the frame. In addition, a tangible model is probably even better than animations for kinesthetic learners.

This model can be used in a variety of ways in the classroom. One good use is to support inquiry learning on enzyme actions. Students first observe an enzyme-catalyzed reaction – for instance, catalase in potato disks reacting with hydrogen peroxide. They are then asked to use the model to figure out how the enzymes work. Students can also use the model to work out the mechanisms of competitive and

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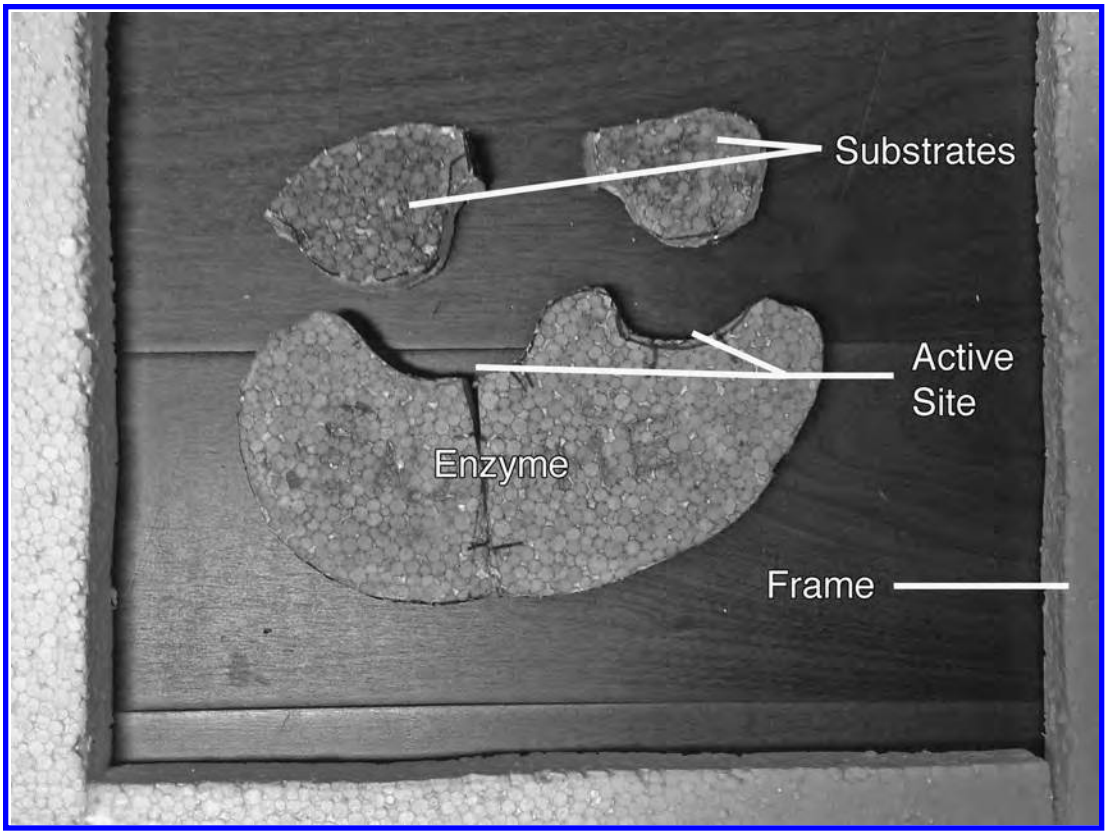

Figure 1. The model is composed of three polystyrene blocks representing the enzyme and two substrate molecules. These blocks are shaken within a frame to create random collisions among them. Note that the active site of this unbound enzyme does not fit perfectly to the substrates.

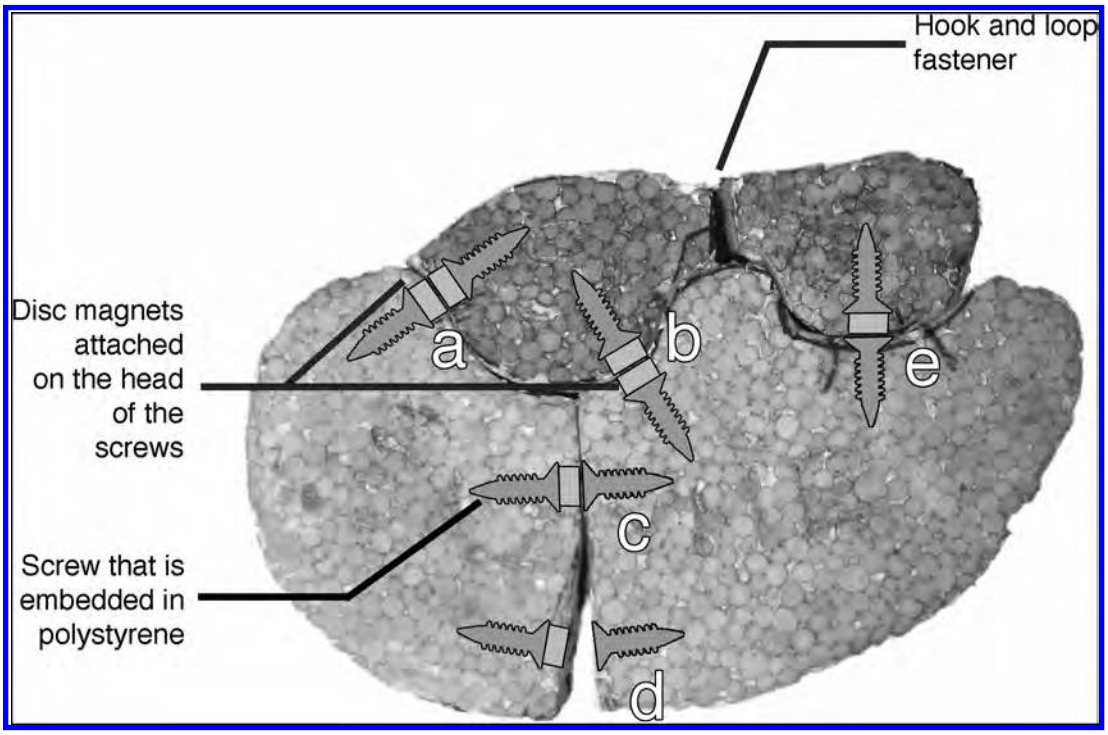

Figure 2. The two substrates bind with the enzyme and are joined by the hook-and-loop fastener. Note that the enzyme now has undergone an "induced" change in shape (notch at the bottom open). At positions a and b, there are two magnets with opposite poles facing each other to create strong magnetic force, but only one magnet is used at positions c, d, and e.

noncompetitive inhibition. On the other hand, the model provides a good opportunity for learning some aspects of the nature of science – in particular, scientific models and the evolutionary, tentative nature of science, which are shown by the progression from the lock-and-key model to the induced-fit model of enzyme actions.

Tips for Production

1. Cut the models out of a 2.5-cm-thick extruded polystyrene foam board.
2. Use neodymium disc magnets with a diameter of 0.8 cm. To fasten a disc magnet on the polystyrene foam, first turn a screw into the foam and then glue the disc magnet to the head of the screw.
3. The magnitude of the magnetic force is crucial to the working of the model. The force holding the shape of the enzyme should not be too strong, so as to make a change in shape possible. Therefore, a screw and a magnet are used instead of a pair of magnets. This also allows a fine adjustment of the magnitude of the force by turning the screw to change its distance from the magnet.

An online video is available that shows how this model works: http://www.youtube.com/watch?v=JknrDkoQF1E

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