

Protein Building Blocks (PBBs): Toys for teaching the principles of protein structure

Introduction. Natural proteins are made of 20 different amino acid building blocks, attached together in different sequences like beads on a string. These beads interact in different ways to cause the beads on a string to fold up into specific three-dimensional structures. The shapes of these structures allow the protein machinery to carry out functions as diverse as muscle contraction (actin and myosin) and transporting oxygen from your lungs to those muscles through your bloodstream (hemoglobin). The two fundamental lessons of protein folding that we wish to communicate are: 1) the order of amino acids in the linear chain (the primary sequence) dictates the three dimensional folded structure of the protein, and 2) complex, stable structures result from the sum of a large number of relatively simple interactions between the amino acids.

Protein Building Blocks (PBBs). To illustrate the principles of protein folding to, we have constructed educational toys that allow them to experience these interactions in a visceral, tactile fashion. Our protein building blocks are wooden blocks designed to represent the interactions of a reduced set of three types of amino acids with simple cubic shapes. These include positively (+) or negatively (-) charged amino acids and hydrophobic (■) amino acids. The interactions are introduced as follows: positive blocks have magnets embedded on four sides with all N sides facing out, negative blocks have magnets with all S sides facing out. Partially assembled blocks are shown in Figure 1. Thus, like charged particles repel each other, but unlike charges are attractive. Hydrophobic interactions are introduced through blocks covered with Velcro® on four sides such that any two hydrophobic blocks will stick to each other, but they will not stick to charged blocks, which have smooth sides. The protein building block interaction rules are illustrated in Figure 2. Finally, it is important that the blocks can be rapidly assembled and disassembled in different sequences to illustrate the effects of changes in block sequence on the folded structures.

Construction. The blocks are made from 1.5 inch wooden cubes. Charged blocks (1/2 of total) are made as follows: On 4 of 6 faces, a 0.25 inch deep, 0.75 inch diameter hole is drilled and a round magnet glued in place with all N or all S poles facing out for a given block. One magnet at a time must be glued to avoid ejection of the magnet due to repulsion. Once magnets are glued, small hooks are screwed into the other two faces. The blocks are painted black and the magnet faces labeled with stickers (+ for N or - for S). Hydrophobic blocks are made by painting the blocks black, then sticking four 0.6 inch square pieces of Velcro® on 4 of 6 faces. They should be arranged in an ABAB pattern as shown to maximize the chance that any hydrophobic face can stick to any other hydrophobic face. Once the Velcro® is attached, hooks should be screwed into the other two faces. Jewelry clasps are used to connect the blocks.



Figure 1. Protein building block construction

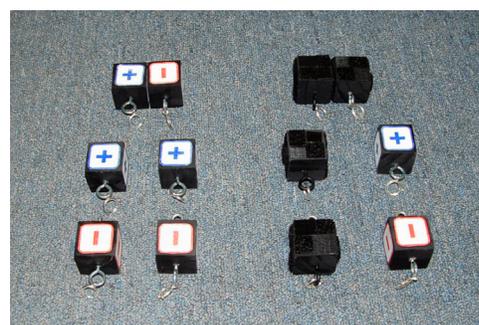


Figure 2. Building block interaction rules

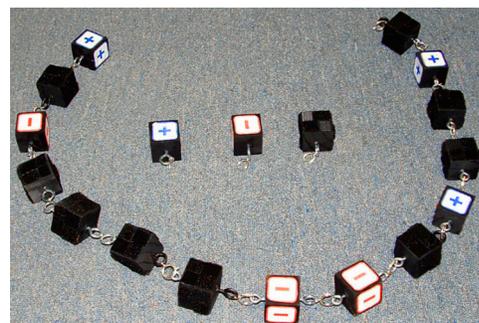


Figure 3. Example of protein sequence



Figure 4. Example of protein folded structure