

Action Potentials Are Child's Play

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Action potentials are difficult for most students to comprehend. Ion channels open and close in sequence. Sodium and potassium ions move across membranes in opposite directions. With all of these details to learn, students can easily lose sight of the overall concept of depolarization as electrical impulses travel down axons. This workshop showed how to build and use folk toys known as Jacob's ladders to demonstrate depolarization/repolarization both kinesthetically and visually.

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Introduction

Action potentials are difficult for most students to comprehend. Ion channels open and close in sequence. Sodium and potassium ions move across membranes in opposite directions. Chemically-gated and voltage gated-channels open and close in sequence. With all of the details to learn students can easily lose sight of the overall concept of depolarization as electrical impulses travel down neurons. Textbooks tend to show the process by showing pluses and minuses with arrows indicating movement (Marieb and Hoehn, 2010:403). This mini-workshop presented a way to demonstrate depolarization/repolarization both kinesthetically and visually using a simple folk toy that has amazed children and adults for over a century.

The Jacob's ladder is a folk toy that has been used for over 100 years. The basic concept was described in the October 12, 1889 edition of *Scientific American*. There are a variety of designs but in general it is a falling block device where blocks are loosely connected and flip in sequence after the first is inverted. Fig. 1 shows three ladders: two commercially made ones and one made in house located in the upper right. While there are multiple ways to make a Jacob's ladder, the method described in this paper are to construct ones as shown. The commercially made ones work nicely and are reasonably inexpensive, but the "homemade" ones allow for creating ones that better reflect the concept of depolarization/repolarization. The homemade one shown was painted with contrasting colors to represent positive and negative charges, whereas the purchased ones tend to be just brightly colored.

While traditionally the ladders have been constructed using wood, they can be made from a variety of materials. Due to a shipping problem, the material that was planned for use during the mini workshop arrived late. So pieces of

cardboard were substituted in place of the wood blocks. The resulting ladders were workable, although not durable. The ladder should have at least three blocks as a bare minimum but can be made as one wishes. The one shown in Fig. 1 has ten blocks and is a great length to use in classroom demonstrations.

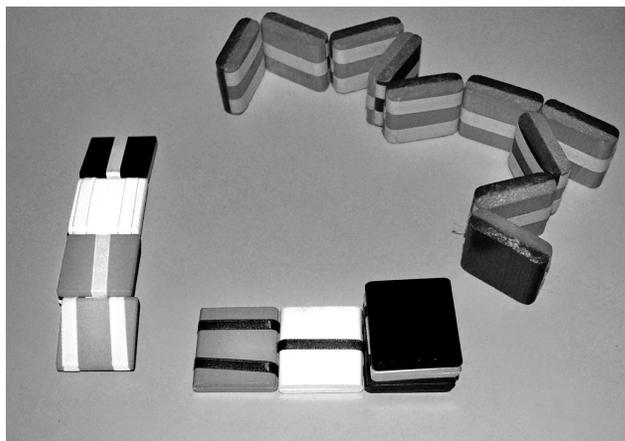


Figure 1. Three examples of Jacob's ladders. The ones on the left and bottom are commercially made and can easily be purchased. The one in the upper right was handmade in-house and is the example referenced in the instructions on how to construct a Jacob's ladder. Note the way the ribbons alternate in their over/under pattern.

Student Outline

Materials

The materials listed are those needed to complete a Jacob's ladder with 10 blocks like the one shown in the upper right in Fig. 1. Dimensions can be adjusted as needed.

- 20 pieces of wood: 1 cm X 5 cm X 5 cm
- Hot glue gun and glue sticks
- 4.5 m of 1 cm ribbon cut into three equal pieces
- Paint

Prior to constructing the Jacob's ladder, paint pieces of wood with desired colors and let dry completely. Painting half of the pieces one color and half a contrasting color will facilitate being able to see the charges reverse during the action potential. The surfaces that will be on the inside of the block need not be painted. For this example one side of the ladder will be green and the opposite side red.

Constructing a Jacob's Ladder.

Fig. 2 shows the side view of the ladder and traces the pathway of the ribbons through and around the blocks. Place the bottom row of red pieces of wood with the unpainted side up. Lay the green pieces of wood next to them. Starting at the block labeled A in Fig. 2, use a small amount of glue to secure one of the ribbon strips lengthwise down the middle of the to the unpainted side of the piece of wood, with the ribbon running toward the opposite end (labeled B). This ribbon is represented by the ++++++++ line in Fig. 2. Make sure the glue does not get on the painted (outer) surfaces of the blocks. Place another piece of ribbon on this same piece of wood next to the first piece but running the opposite direction (away from the opposite B end) and glue it in place. Repeat this with the third piece of ribbon on the opposite side of the center ribbon. These two outer ribbons are represented by the solid black line in Fig. 2. The green block should then be glued onto the red block. Glue should only be used on the inner block surfaces where the red and green pieces of wood fit together. Be careful that no glue gets on the other surfaces or the ribbon. The double ribbons should be then folded over the top of the green pieces of wood. Take the single middle ribbon and place it over the top of the second green piece of wood and then wrap it underneath as shown in Fig. 2. Take the double ribbons and run them under the second green piece. Move the second green piece up against the first one and pull the ribbons fairly tight. Glue the ribbons in place to the underside of the green piece of wood and glue the second green piece of wood to the second red piece. Continue running the ribbons as shown in Fig. 2. The blocks should fit fairly tightly together end to end. Fig. 3 shows what the assembled ladder should look like from above, however, the space between blocks has been exaggerated to match the spacing in Fig. 2.

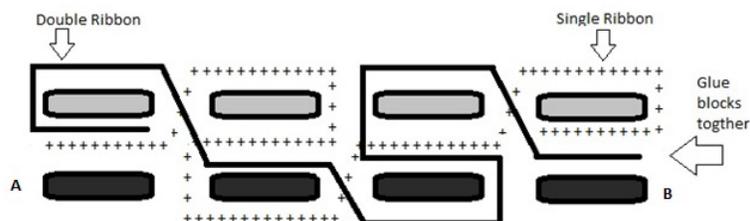


Figure 2. Side view diagram showing the pathway the ribbons follow. The solid line represents double ribbon pathway while the plus symbols the pathway of the single ribbon. The diagram shows a ladder that will have four blocks. To add more blocks simply continue the same pattern.

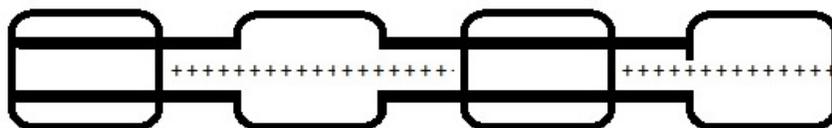


Figure 3. Top view of the completed Jacob's ladder using the ribbon pathways shown in Fig. 1. None of the surfaces shown in this view would be glued. The spaces between the blocks are exaggerated in order to match the spacing in Fig. 1. In the actual ladder, the blocks should fit loosely up against each other.

Notes for the Instructor

The Jacob's ladder can be used in multiple ways. Students can construct one as a lab activity and then have it to demonstrate the action of nerve impulses travelling along a neuron. They also make a great device to stress points during a lecture. Showing that there are two sides, one positive and one negative, demonstrates the polarized neuron. Flipping the blocks from green to red shows the action of depolarization and flipping back from red to green shows repolarization. The fact the blocks cannot physically "depolarize" prior to "repolarizing" mirrors the same actions in the neuron. Beyond depolarization/repolarization the Jacob's ladder can be used to demonstrate other concepts such as refractory period (one can only flip the blocks so fast), threshold (tilt the first block slowly until the next finally flips), and the one direction of impulse transmission (the block won't flip up, only down).

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Rick Wiedenmann received his M.S and B.S. in Biology and B.A. in Museum Studies from Baylor University. He is currently an Associate Professor of Biology at New Mexico State University-Carlsbad in Carlsbad, NM where he teaches *Natural History of Life, Cellular and Organismal Biology,* and *Human Anatomy and Physiology*.

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