TIPS, TRICKS & TECHNIQUES

Building Phylogenetic Trees with Drinking Straws

NABT BioClub RECOMMENDATION

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Abstract

Tree-thinking is a required skill for evolutionary literacy, but misconceptions are frequent in interpreting phylogenetic trees. Here, an easy, cheap way of building phylogenetic trees with drinking straws is suggested. It can be used to illustrate how to build phylogenetic trees from root to tips, to rotate nodes and to collapse branches.

Key Words: *evolution; phylogenetic trees; misconceptions; hands-on learning.*

Tree-thinking, the ability to conceptualize evolution in terms of phylogenetic trees (Baum & Offner, 2008), is a skill needed to increase evolutionary literacy. However, misconceptions about how to read and interpret phylogenetic trees are common (Meir et al., 2007; Gregory, 2008; Staton, 2015; Kummer et al., 2016). These misconceptions are usually addressed by means of activities that involve building phylogenetic trees with different kinds of data (Campo et al., 2009; Rau, 2012; David, 2018; Punyasettro & Yasri, 2021), and plotting phylogenetic trees by means of drawings (Bilardello & Valdés, 1998; Kozlowski, 2010; Dees & Momsen, 2016) or computers (Perry et al., 2008; Schneider et al., 2012; Zhang, 2012; Duffus, 2019). Here, a way of building phylogenetic trees by hand is suggested, using actual physical branches, a relatively little explored approach (Halverson, 2010). Physical phylogenetic trees facilitate the acquisition of topological skills—node rotation, branch regrafting—key to tree-thinking, that can be challenging when performed mentally or using drawings.

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Physical phylogenetic trees can be built in an easy, cheap way using drinking straws. All that is needed are straws of different colors, plasticine, and a folder made of hard plastic (Figure 1). Either plastic or carboard straws can be used, but the latter are more environmentally friendly. Tree branches are made with straws trimmed to a length of either 5 or 10 cm (Figure 1). Plasticine is plugged at each end of the straws (Figure 1) to help with fitting the connectors. Several kinds of connectors can be cut from the plastic folder, using scissors or a cutter, with a width that fits the diameter of the straws (Figure 1 and Figure S1 in Supplementary Material provided with the online version of this article). Rectangular trees are assembled by joining the straws using T or L connectors, while diagonal trees are assembled using Y connectors (Figure 2). I connectors allow students to expand the length of a branch (Figure 2). This basic design can be modified at will. Possibilities are almost endless; only a few are listed here. First, pieces of paper with drawings of different organisms (e.g., caminalcules: Sokal, 1983; Gendron, 2000) can be glued at the tips of the tree using "lollypop" connectors (Figure 1). Second, straws of different colors can be used to flag different clades in the tree. Third, straws can be combined with pipe cleaners (Halverson, 2010) or coated with sandpaper of different grit, such that visually impaired students can touch the trees and figure out not only the shape but also the different clades that branch along the tree.

Building physical phylogenetic trees can be included in the teaching of tree-thinking in at least five ways. First, these trees can be easily assembled by the teacher or the students during lectures to illustrate different topologies of trees, such as symmetric and asymmetric branching. Second, building physical phylogenetic trees can be easily included in hands-on activities designed to allow students getting familiar with establishing phylogenetic relationships between organisms, such as caminalcules (Gendron, 2000). These hands-on activities can reinforce tree-thinking and tree-building skills (Schramm et al., 2019).

Third, phylogenetic trees built with drinking straws can help students in dispelling several usual misconceptions (Gregory, 2008) (Figure 3 and Further Misconceptions in Supplementary Material provided with the online version of this article). For example, several misconceptions about phylogenetic trees identified by

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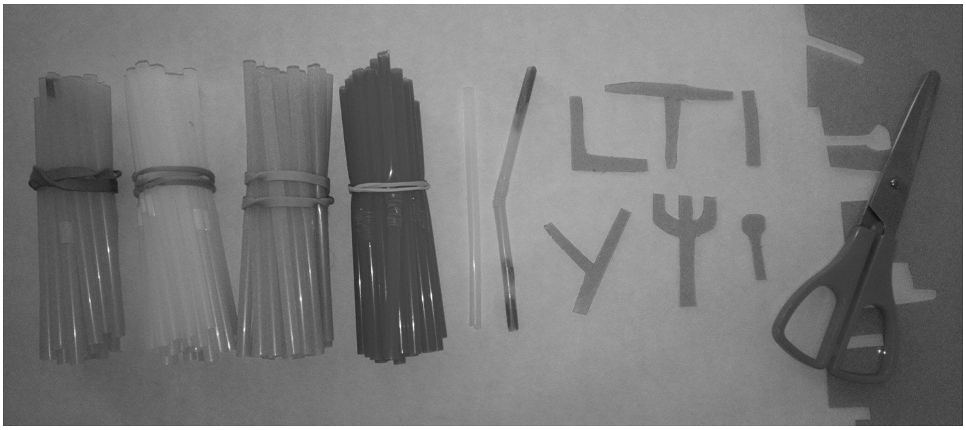

Figure 1. Materials needed to build phylogenetic trees with drinking straws. From left to right, drinking straws of different colors, trimmed to a length of 10 cm, straws with plugs of plasticine at the ends, one of them with a fold, and L, T, I, Y, psi, and lollypop connectors. Connectors are cut with scissors from a folder of hard plastic, visible at the right of the figure.

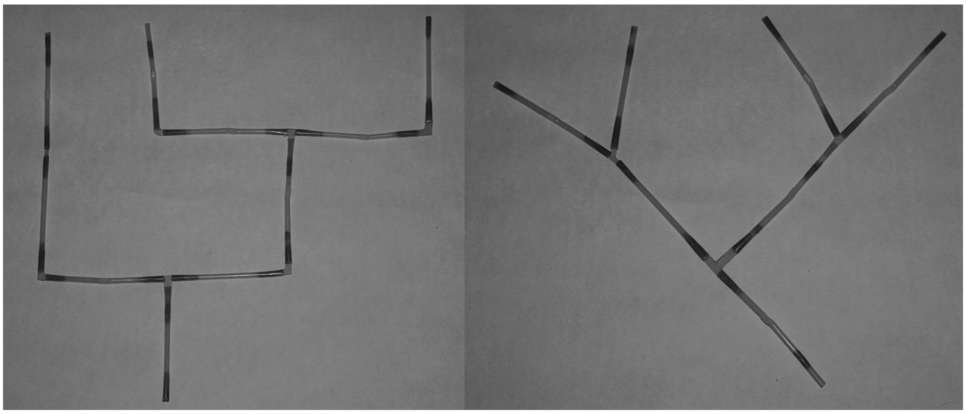

Figure 2. Left, a rectangular tree with three branches joined with T and L connectors; the leftmost branch is extended using an I connector. Right, a tree in diagonal version, using Y connectors.

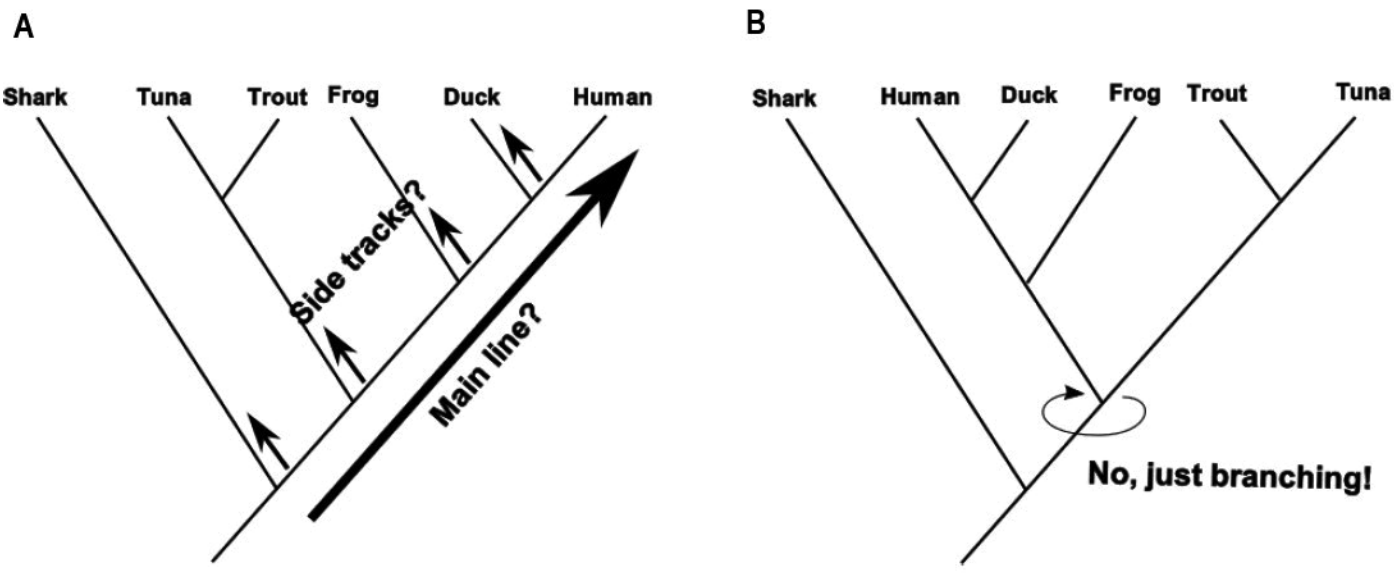

Figure 3. A: a tree showing the apparent main line of evolution toward a target, humans, while the rest of the tree is interpreted as side tracks away from that target. B: a simple rotation shows that this main line is only a product of the arrangement of the branches; actually, the tree is showing branching only from a common ancestor and no evolution toward a target.

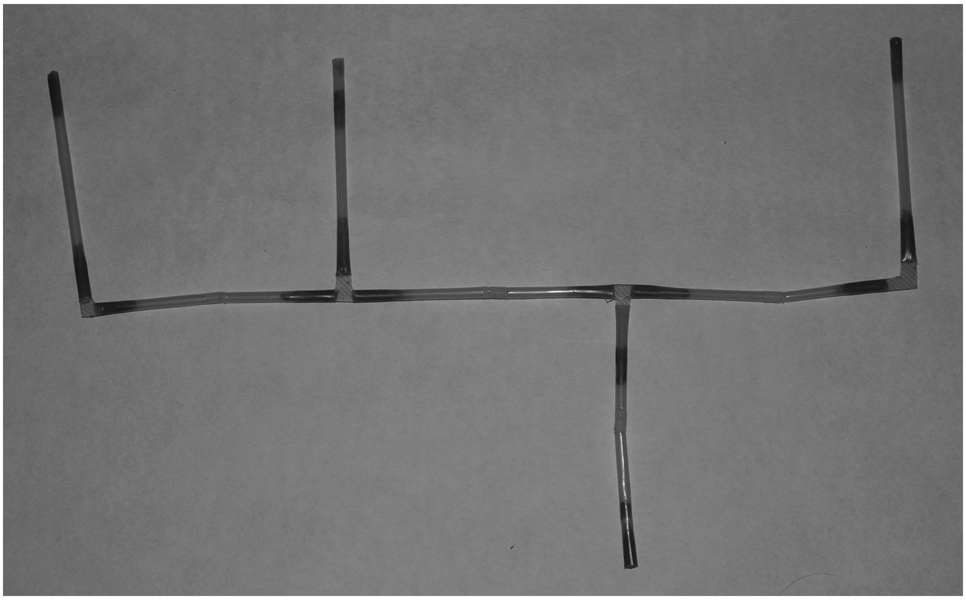

Figure 4. A tree with a polytomy, created with an inverted T connector.

Gregory (2008) can be dispelled by rotating branches around a node. Here, the misconception "main line and side tracks" is illustrated, as an on-class exercise. In asymmetrically branching trees, students tend to see one "main track," showing the "progress toward a target," while the rest of the branches are side tracks (Figure 3A). Rotation of nodes in a physical tree built with drinking straws graphically makes the point that such main track is only apparent, not real. The exercise has four steps. In step 1, show your students the phylogenetic tree on Figure 3A. In step 2, provide material to build trees with drinking straws and ask the students to build the tree, in which the misconception is apparent. In step 3, ask your students to rotate nodes of the tree so that they turn it into the tree in which the apparent track is not present. A potential solution is given in Figure 3B. In step 4, discuss how the apparent pattern in the left tree disappears without actually changing the tree, in other words, the phylogenetic relationships between species in the tree. This in-class exercise can be easily expanded to solve other misconceptions included in Gregory (2008) such as "reading across the tips" and "sibling vs. ancestor" (Further Misconceptions in Supplementary Material provided with the online version of this article).

Fourth, building physical trees helps realizing that trees are read from bottom to top, while drawing trees on a paper does not convey as easily the way in which a tree adds branches. Fifth, these trees support teaching how differences in topology involve branch regrafting, as well as how to collapse branches in order to create consensus trees with polytomies (Regrafting Branches in Supplementary Material provided with the online version of this article), both of which are more difficult with pipe cleaners. Trees with polytomies can be built simply using inverted T connectors (Figure 4), or by means of Ψ (psi) connectors (Figure 1). These suggestions can be easily developed by readers to fit their needs when teaching tree-thinking at primary, secondary, or college levels.

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