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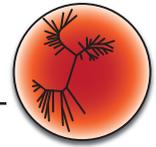


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Student Misconceptions about Plants – A First Step in Building a Teaching Resource †

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Plants are ubiquitous and found in virtually every ecosystem on Earth, but their biology is often poorly understood, and inaccurate ideas about how plants grow and function abound. Many articles have been published documenting student misconceptions about photosynthesis and respiration, but there are substantially fewer on such topics as plant cell structure and growth; plant genetics, evolution, and classification; plant physiology (beyond energy relations); and plant ecology. The available studies of misconceptions held on those topics show that many are formed at a very young age and persist throughout all educational levels. Our goal is to begin building a central resource of plant biology misconceptions that addresses these underrepresented topics, and here we provide a table of published misconceptions organized by topic. For greater utility, we report the age group(s) in which the misconceptions were found and then map them to the ASPB – BSA Core Concepts and Learning Objectives in Plant Biology for Undergraduates, developed jointly by the American Society of Plant Biologists and the Botanical Society of America.

INTRODUCTION

We depend on plants for food and for innumerable other uses including medicines, lumber, and landscaping, and yet their biology is foreign to many of us. Our own patterns of growth and life habits as animals are quite different from those of plants. As a result, when children attempt to make sense of the world they often generate very inaccurate ideas about plant structure and function (1, 2). Many of these incorrect ideas persist into adulthood and are seen in undergraduates, even in college students training to become science teachers (3–6).

Education researchers have called attention to the problem of misconceptions in science and the difficulty in eradicating misconceptions once established (7, 8). Investigators have suggested that instructors forewarned about common misconceptions would be more effective (9, 10). In a study of middle school physics teachers and

their students, Sadler et al. demonstrated that this is, in fact, true (11). They showed that learning gains were much larger when instructors were knowledgeable about both the scientific factual content and the common student misconceptions about that content, compared to learning gains when instructors were knowledgeable only about the factual content. The implication from their work is that knowing the inaccurate ideas students hold leads to more effective teaching.

To better understand what is known about the errors students make when thinking about plants, we extensively surveyed the available reports of plant misconceptions. We focused on topics that are commonly taught in undergraduate introductory plant biology courses with two exceptions: photosynthesis and respiration. These two subjects are by far the most frequently addressed in misconception studies to date. For example, Parker et al. recently reviewed photosynthesis misconceptions and developed diagnostic questions they used to understand what lies behind the errors in thinking, so we did not attempt to repeat their work and refer the interested reader to their paper (12). We did include misconceptions related to plant nutrition, which necessarily overlaps to some extent with photosynthesis. Finally, we also found numerous reports of inaccurate thinking about plant respiration, sufficient in number to warrant treatment in a separate article.

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We categorized the remaining collected misconceptions by major subject and organized them into a table (Appendix I) to make them readily accessible for other instructors. The table includes the incorrect ideas, the age groups from which they were collected, and citations of the original reporting papers. We also mapped each entry to the appropriate plant biology core concept as described in the document Core Concepts and Learning Objectives in Plant Biology for Undergraduates (developed jointly by representatives of the American Society of Plant Biologists and the Botanical Society of America and available at http://c.ymcdn.com/sites/aspb.site-ym.com/resource/resmgr/Education/Undergradplantbio_concepts.pdf).

An illustrative sampling from Appendix I shows the collected misconceptions range from the familiar to the less expected. For example, the belief that plants absorb their “food” from the soil is common and was reported in 28 separate articles, for elementary students through post-graduates and teachers in training. Less expected were beliefs that plant cells do not go through mitosis or meiosis (high school students), or that plants do not have genes or DNA (middle school, high school) and do not reproduce sexually (elementary through undergraduate students). Below we describe how we screened the literature and organized the collected misconceptions, and we discuss themes we see in the inaccurately held ideas.

METHODS

Identification of misconceptions

For the purpose of this study we defined “misconception” as any idea held by an individual that differs from the commonly accepted scientific understanding. We used Google Scholar, Web of Science (http://wokinfo.com/training_support/training/web-of-knowledge/), and the ERIC database (<https://eric.ed.gov/>) to create an initial set of articles reporting on plant misconceptions. We used Google Scholar’s “Cited by” feature to identify more recent articles. This feature returns articles that have cited a particular reference, allowing us to move forward in time from older articles. We set no limit in terms of publication date. In our searches we used a variety of search terms including “misconception,” “plants,” “plant biology,” “alternate conceptions,” “botany,” as well as terms from our Table I subheadings. To be included in our list, an article had to report on actual student-held conceptions. Review articles were included in the analysis, however, the original primary research articles were referenced in the analysis when possible. Age groups were recorded as reported by the original authors and combined into the following categories: elementary, middle school, high school, college, postgraduate, and pre-service teachers. Misconceptions collected from textbooks were not included, as a proper review of those would exceed the scope and length of a Perspectives article. In cases where similar misconceptions were found

in several references, they were combined into one clear misconception statement as determined by at least 2 authors of this paper. Occasionally an original misconception was rewritten to make it clearer.

Misconceptions were grouped into major categories typically found in plant biology textbooks: 1) Plant Cells, Plant Structure, Growth and Development, 2) Plant Physiology, 3) Genetics, Evolution, and Classification, and 4) Ecology. Each misconception was mapped onto the ASPB – BSA core concepts in plant biology (http://c.ymcdn.com/sites/aspb.site-ym.com/resource/resmgr/Education/Undergradplantbio_concepts.pdf) by agreement of at least 2 authors. When disagreements occurred additional authors were consulted in order to reach consensus.

Limitations of this study

In categorizing misconceptions and rewriting them for clarity or uniformity, an author’s interpretation may affect how a misconception is reported. Care was taken to minimize errors by having multiple authors examine misconceptions prior to their categorization or modification, and then engage in discussion until consensus was reached.

DISCUSSION

We screened the published literature for reports of student misconceptions about plants, and organized them into tabular form by topic for the convenience of readers. The table we developed should serve as a resource for instructors, although we note that student misconceptions for many important topics in plant biology have yet to be investigated. As a result, Appendix I is not exhaustive but should be considered a foundation on which to build a more complete collection. Instructors should find it useful to read the collected inaccurate ideas in preparation for teaching a course in plant biology.

There are at least two different types of thinking errors seen in Appendix I. The first type results simply from students that have insufficient knowledge: they are not familiar with the scientific vocabulary or the way plant scientists think about plants. Those kinds of errors are exactly the type meant to be eliminated by introductory plant biology courses. Confusion about what a monocotyledon is or what monoecious means can be corrected by basic instruction, as can uninformed ideas about what plant groups produce seeds or even what a seed is. But other inaccurate conceptions have deeper roots, and may persist despite exposure to established facts and scientifically accepted ideas.

The second type of thinking error may be connected to early perceptions of young children. Goldberg and Thompson-Schill (13) have argued that the early perceptions of children about living things form a foundation which later instruction does not erase, and which continues to influence how they think about plants as adults. For children, things

that are alive show movement, and things that are not alive do not (1). Rooted in place, plants do not move from one location in space to another under their own power, nor move their organs at observable time scales. As a result, young children perceive that since plants do not share these essential characteristics of animals, they are therefore not living (2). The idea that seeds are not alive conceivably arises from thinking influenced by such early perceptions. It is tempting to dismiss such naïve errors as not worth acknowledging in college level courses, but we point out that the misconception “Seeds are not alive” was reported from interviews of pre-service teachers (14).

Once children learn that *both* plants and animals are living things they may attempt to explain observations about plants by attributing to them the more familiar abilities of animals such as goal-directed behavior. Work by cognitive psychologists shows the importance of goal-directed movement to children as they develop their conceptions about living organisms (15, 16). A predator moves with purpose towards prey needed for food, so plants’ growth towards the light is interpreted as intentional behavior, occurring because plants need light. While it is true that plants require light, plants are not sentient beings and do not behave with a conscious intentionality. Biology instructors observe such teleological thinking in students with alarming frequency, and in some cases reinforce it themselves (17).

Drawing on the work of cognitive psychologists, Coley and Tanner described teleological thinking as a cognitive construal—a naïve, intuitive way of thinking that helps children make sense of the world (18). Kelemen and Rossett demonstrated that teleological thinking persists in adults, who continue to invoke causal explanations for what they observe in the natural world (19). Coley and Tanner suggested that the teleological cognitive construal is the origin of numerous biological misconceptions that may appear unrelated. For example, students attribute purposeful behavior to explain root growth, suggesting that roots grow into the ground to obtain water or to obtain food (20). Both of these ideas conflate the ultimate benefit (water and mineral nutrients) with the actual causative response, and indicate a lack of understanding of signal transduction pathways that govern plant growth.

We did not include textbook misconceptions in our analysis because our focus was on misconceptions held by students. Textbooks have been extensively examined for plant misconceptions by Hershey (21–24). For example, Hershey points out that not all plants are photosynthetic, as several hundred species lack chlorophyll (22). Hershey also notes that plant embryos are often represented as having one or two cotyledons, but many plants, particularly gymnosperms, have more than two cotyledons (22). Another misconception observed by Hershey is that all plants develop fruits through pollination and fertilization. This is inaccurate in that some fruits, such as seedless bananas and pineapples, develop by parthenocarpy (22). A recurring theme is that textbooks err by not acknowledging exceptions to the more

common states. Awareness of textbook misconceptions is important, and we encourage those interested in textbook errors to consult the Hershey reports.

Many of the articles we screened did not quantify the frequency with which a particular misconception was observed. Frequency data is desirable, as it enables us to determine which inaccurate ideas are truly pervasive and worth extra attention in the classroom. Seasoned instructors may know which concepts tend to be difficult and may know the kinds of errors students make with them, but documenting these in a systematic way will benefit newer instructors and better facilitate analysis of misconceptions’ root causes.

In conclusion, knowing what concepts are associated with deep-seated errors in thinking better positions instructors to select classroom activities that can help eradicate those errors. Collections of reported misconceptions help promote that knowledge. Our collection in Appendix I is a start, but there is much to be done before we have what might be considered a comprehensive set. For instance, it would be of great value to know what misconceptions accompany concepts that lie at the heart of plant distinctiveness, such as the nature of plant cell growth, the development of plant organs, meristems, primary growth, and woody growth. Conceptual errors associated with the characteristics of plant life cycles, such as alternating generations, would be very useful, as would misconceptions surrounding key features used to distinguish major plant taxa. A compilation of undergraduate misconceptions about all of those topics would be a great help to those who teach plant biology.

SUPPLEMENTAL MATERIALS

Appendix I: Table of plant misconceptions

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The authors declare that there are no conflicts of interest.

REFERENCES

1. Piaget J. 1929/1960. The child’s conception of the world. Littlefield, Adams and Company, Paterson, NJ.
2. Richards DD, Siegler RS. 1986. Children’s understandings of the attributes of life. *J Exp Child Psychol* 42:1–22.
3. Brown MH, Schwartz RS. 2009. Connecting photosynthesis and cellular respiration: preservice teachers’ conceptions. *J Res Sci Teach* 46:791–812.
4. Mak SY, Yip DY, Chung CM. 1999. Alternative conceptions in biology-related topics of integrated science teachers and implications for teacher education. *J Sci Educ Technol* 8:161–170.
5. Preece PF, Postlethwaite KC, Skinner NC, Simpson KA. 2004. Research report: investigating the “failure of further learning” effect in preservice science teacher education. *Int J Sci Educ* 26:805–820.

6. Yuruk N, Selvi M, Yakisan M. 2011. The effect of metaconceptual teaching activities on pre-service biology teachers' conceptual understanding about seed plants. *Educ Sci Theory Pract* 11:459–464.
7. McCloskey M. 1983. Naive theories of motion, p 299–324. *In* Gentner D, Stevens AL (ed), *Mental models*, Erlbaum, Hillsdale, NJ.
8. Taylor AK, Kowalski P. 2004. Naïve psychological science: the prevalence, strength, and sources of misconceptions. *Psychol Rec* 54:15.
9. Ausubel DP. 1978. In defense of advance organizers: a reply to the critics. *Rev Educ Res* 48:251–257. doi:10.2307/1170083.
10. Carlsen W. 1999. Domains of teacher knowledge, p 133–144. *In* Gess-Newsome J, Lederman NG (ed), *Examining pedagogical content knowledge*. Springer.
11. Sadler PM, Sonnert G, Coyle HP, Cook-Smith N, Miller JL. 2013. The influence of teachers' knowledge on student learning in middle school physical science classrooms. *Amer Educ Res J* 50:1020–1049. doi:10.3102/0002831213477680.
12. Parker JM, Anderson CW, Heidemann M, Merrill J, Merritt B, Richmond G, Urban-Lurain M. 2012. Exploring undergraduates' understanding of photosynthesis using diagnostic question clusters. *CBE Life Sci Educ* 11:47–57.
13. Goldberg RF, Thompson-Schill SL. 2009. Developmental “roots” in mature biological knowledge. *Psychol Sci* 20:480–487. doi:10.1111/j.1467-9280.2009.02320.
14. Sabel JL, Forbes CT, Zangori L. 2015. Promoting prospective elementary teachers' learning to use formative assessment for life science instruction. *J Sci Teach Educ* 26:419–445.
15. Keil FC. 1992. The origins of an autonomous biology, p 103–137. *In* Gunnar MR, Maratsos MP (ed), *Modularity and constraints in language and cognition*. The Minnesota symposia on child psychology, vol 25. Erlbaum, Hillsdale, NJ.
16. Opfer JE, Gelman SA. 2010. Development of the animate-inanimate distinction, p 213–238. *In* Goswami, U (ed), *The Wiley-Blackwell handbook of childhood cognitive development*, 2nd ed, Wiley-Blackwell.
17. Burmeister AR, Smith JJ. 2016. Evolution across the curriculum: microbiology. *J Microbiol Biol Educ* 17:252.
18. Coley JD, Tanner KD. 2012. Common origins of diverse misconceptions: cognitive principles and the development of biology thinking. *CBE Life Sci Educ* 11:209–215. doi:10.1187/cbe.12-06-0074.
19. Kelemen D, Rosset E. 2009. The human function compunction: teleological explanation in adults. *Cognition* 111:138–143.
20. Lin S. 2004. Development and application of a two-tier diagnostic test for high school students' understanding of flowering plant growth and development. *Int J Sci Math Educ* 2:175–199.
21. Hershey DR. 2005. More misconceptions to avoid when teaching about plants. *Actionbiosciences* 2017. <http://www.actionbioscience.org/education/hershey3.html?print=1>.
22. Hershey DR. 2004. Avoid misconceptions when teaching about plants. *Actionbiosciences* 2017. <http://www.actionbioscience.org/education/hershey.html>.
23. Hershey DR. 1995. Photosynthesis misconceptions. *Am Biol Teach* 57:198. doi:10.2307/4449969.
24. Hershey DR. 1994. Phototropism misconceptions. *Am Biol Teach* 56:6. doi:10.2307/4449733.