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Avoid Misconceptions When Teaching about Plants

By David R. Hershey

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articlehighlights

Hundreds of plant misconceptions occur in the teaching literature.

- *Fifty misconceptions are identified in this article.*
- *Some misconceptions are easier to identify because they are oversimplifications, overgeneralizations, or misidentifications.*
- *Others are more difficult to identify because they are obsolete concepts and terms or flawed research.*

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Avoid Misconceptions When Teaching about Plants

By David R. Hershey

One plant misconception can potentially mislead thousands of teachers and students.

The teaching literature contains hundreds of errors or misconceptions about plants, but this problem has not received enough attention to prevent its negative impacts. A plant misconception in a single textbook, educational web site, science project book, teaching journal article, or curriculum guide can potentially mislead thousands of teachers and students. Teachers often cannot detect even glaring errors because "new teachers coming out of our universities and colleges are very poorly trained in basic botany." [1]

Once learned, misinformation may be difficult to correct.

Many research studies have examined student misconceptions about plants. [2–5] Not surprisingly, some misconceptions about plants also appear in the teaching literature, misleading students and teachers. Student misconceptions are difficult to correct even when teachers specifically attempt to correct them.[3–5] Here I identify 50 plant misconceptions and five categories of misconceptions:

- Oversimplifications
- Overgeneralizations
- Obsolete concepts and terms
- Misidentifications
- Flawed research

Oversimplifications

Oversimplification is prevalent at

Many misconceptions involve oversimplification of concepts, particularly at the precollege level. Such an "extreme of simplification" in plant

the precollege level.

teaching is not new.[6] The following summary equation for plant photosynthesis is an oversimplification that contains several misconceptions:

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{sunlight, chlorophyll}} 6\ O_2 + C_6H_{12}O_6 \text{ (glucose)}$$

- Chlorophyll alone is insufficient for plant photosynthesis. Many other enzymes and organic compounds are required. “Chloroplasts” is a better requirement.
- Glucose is not the major photosynthetic product. There is virtually no free glucose produced in photosynthesis.[7] The most common product is starch or sucrose, and students often test leaves for starch. Starch is approximated as $(C_6H_{10}O_5)_n$, where n is in the thousands.[8]
- The six water molecules consumed per glucose molecule generated underestimates the water required. Much larger amounts are transpired to keep the stomata open. Without open stomata, photosynthesis is limited by lack of carbon dioxide. Submerged aquatic plants require large amounts of water for their aquatic environment.
- Drawing a single arrow wrongly implies that photosynthesis occurs in one step. Many small arrows should be used.
- Some of the energy captured in the light reactions of photosynthesis is used in the chloroplast to synthesize fatty acids and proteins.[7] Thus, there are other types of “photosynthesis.”
- The biology teaching literature contains much information on photosynthesis, yet it often has minimal discussion of mineral nutrient uptake by plants.[9] To counter this problem, “mineral nutrients” should be added to the equation. Most essential mineral nutrients play a role in photosynthesis.

The explanation of photosynthesis is a particularly good example.

Taking these misconceptions into account gives the following summary equation for photosynthetic carbon fixation in plants:

chloroplasts, light, mineral nutrients

$H_2O + CO_2$-->-->-->-->-->-->-->-->-->-->$O_2 + (C_6H_{10}O_5)_n$ [starch]

water for transpiration or an aquatic environment

Overgeneralizations

A major theme of biology is the great biodiversity of life. Overgeneralizations inaccurately minimize biodiversity.

The scope of plant biodiversity is sometimes minimized.

- Teaching publications sometimes state that all plants are photosynthetic. Although they constitute less than 1% of plant species, a few hundred parasitic species lack chlorophyll, including the world’s largest flower, *Rafflesia arnoldii*.[10]
- Biology textbooks often portray plants as land organisms. They rarely mention seagrasses, flowering plants that live submerged in shallow ocean waters.
- Books sometimes state that all seeds have one or two cotyledons. This is one of several examples of focusing on angiosperms or

flowering plants and ignoring gymnosperms, the nonflowering seed plants. Gymnosperm seeds often have more than two cotyledons.

Obsolete Concepts and Terms

Some terms are now obsolete because the Plant Kingdom has been restructured.

- A *saprophyte* is defined as a plant that obtains its energy from dead organic matter. Plants once thought to be saprophytes, such as Indian pipe (*Monotropa uniflora*), are now known to be indirectly parasitic on trees.[10] They are *myco-heterophytes* because a mycorrhizal fungus connects the nonphotosynthetic parasitic plant to the photosynthetic host plant. The mycorrhizal fungus transfers nutrients from the host to the parasite. “Saprophyte” is an obsolete term because organisms that get energy from dead organic matter, such as some fungi, are no longer in the Plant Kingdom. Such fungi can correctly be termed “saprobes” or “saprotrophs.”
- Knops solution was developed in the 1860s to grow terrestrial plants without soil. Its use in teaching today is misleading because it contains just 6 mineral nutrients.[11] Today there are 14 mineral nutrients considered essential for plants.
- “Geotropism” is misleading because the stimulus is gravity, not the Earth. The correct term is “gravitropism.”

Misidentifications

- A celery stalk is often misidentified as a stem. “Stalk” is short for “leafstalk,” so a celery stalk is a leaf part. This should be obvious because stems are circular to square in cross section. A celery stalk is crescent shaped in cross section. If all the stalks are removed from a bunch of celery, a short conical stem remains.
- Carrot storage root tissues are sometimes misidentified. The storage root lacks the epidermis and cortex found in young roots. Most of the storage root consists of secondary phloem.[12]

Angiosperms and gymnosperms are still sometimes confused.

- Terms that only apply to angiosperms are frequently applied to gymnosperms, for example, pine nuts, ginkgo nuts, juniper berries, and yew berries. Nuts and berries are specific types of fruits. Gymnosperms do not produce fruits.

Flawed Research

The most difficult misconceptions for teachers to catch are those caused by flawed research.

Hypotheses about animal and plant relationships require sufficient evidence.

- Many textbooks state that seeds of the tambalacoque, or calvaria, tree have to pass through the digestive system of the dodo bird before they will germinate. Supposedly, no endangered tambalacoques had germinated since the dodo became extinct in the 1680s. The only experimental data in support of this hypothesis was germination of 3 of 17 seeds in tambalacoque fruits force-fed to turkeys.[13] However, there were no control fruits not fed to turkeys. Several authors disputed this hypothesis.[14,15] Young tambalacoques exist in the wild. Widespread deforestation and introduced plant and animal species endangered the tambalacoques.
- A widespread misconception involves *allelopathy*, defined as a plant

excreting chemicals that inhibit growth of neighboring plants. A zone of bare soil around a California shrub was assumed to be caused by the shrub's allelochemicals.[16] Fencing the shrubs caused the bare zones to disappear, so the bare zone was in fact caused by rodents and birds that hid in the shrubs.[17]

Allelopathy lab experiments are artificial.

- Allelopathy lab experiments are artificial because they use unrealistically high doses of allelochemicals and lack soil.[18] In nature, allelochemicals are often inactivated by soil or soil microbes. Even in nature, it is very difficult to determine if growth inhibition of neighboring plants is caused by allelochemicals or competition among plants for light, water, and mineral nutrients.

Common Misconceptions by Topic

Pollination

Not only the definition but the methods of pollination are incorrectly explained.

- *Pollination* is often defined as transfer of pollen from anther to stigma. That definition inaccurately excludes gymnosperms, which have pollination but lack anthers and stigmas. In gymnosperms, pollination is the transfer of pollen from a microsporangiate, or "male," cone to the micropyle of a megasporangiate, or "female," cone.
- The importance of animal pollination is often overestimated for crop production. While about 90% of plant species are animal pollinated, our most important food crops are wind pollinated, including corn, wheat, and rice.[19] Other major crops are asexually propagated and have vegetative edible parts, such as potatoes, sweet potatoes, and cassavas. Still other major crops are primarily self-pollinated, such as peanuts, soybeans, and beans.
- *Self-pollination* is often defined as pollination with pollen from the same plant. However, self-pollination also occurs with pollen from another plant of the same clone. Plant clones are extremely important in agriculture and in many wild species.[20]
- Plants that are considered self-pollinated may depend on animal pollination. Tomatoes are self-fertilizing but pollinated by bumblebees that vibrate the flowers.[19] Greenhouse tomato flowers may need to be vibrated manually to obtain pollination.
- Pollination is not the same as fertilization nor does pollination ensure fertilization.
- Texts sometimes say animal pollination is an advance found only in angiosperms. Cycads are gymnosperms pollinated by beetles.[21]

Photosynthesis

Students may think that cellular respiration occurs only at night.

- A widespread misconception states that leaves reflect all green light and do not use green light in photosynthesis. Leaves often absorb more than 50% of the green light and use it efficiently in photosynthesis.[8,22] The origin of this misconception is probably the chlorophyll absorption spectrum in textbooks. The chlorophyll absorption spectrum is a graph of light absorption versus light color. It shows that chlorophyll absorbs much red and blue light but little green light. However, accessory pigments absorb green light and pass that energy on to chlorophyll.

- A common student misconception is that plants photosynthesize during the day and conduct cellular respiration only at night. Some teaching literature even states this. Cellular respiration occurs continuously in plants, not just at night.
- The "dark reactions" of photosynthesis are a misnomer that often leads students to believe that photosynthetic carbon fixation occurs at night.[23] It is preferable to use the term "Calvin cycle" instead of dark reactions.
- Bubble formation on leaves submerged in water is not always caused by photosynthesis. If the water is cold, bubbles form on leaves as the water warms and gases become less soluble.[6]
- The aquatic plant *Elodea* is often used to visualize gas formation in photosynthesis. The gas produced is not pure oxygen, as often claimed.[6] As photosynthetic oxygen dissolves, some of the nitrogen comes out of solution.

Tropisms

- Texts often state that shoots are only positively phototropic. However, shoot tips of some vines, such as English ivy, are negatively phototropic. If vine shoot tips were positively phototropic, they would grow away from walls or tree trunks, rather than climb them.
- Several simple classroom activities that supposedly demonstrate hydrotropism merely show that roots require water to grow.[24] Most hydrotropism research is artificial because it studies roots grown in air, not soil. Hydrotropism is unlikely under natural conditions because the sharp relative humidity gradients required for hydrotropism rarely occur in soils. Relative humidity in soil pores is above 98% even when the soil is so dry that plants remain permanently wilted unless more water is added.[8]

Some classroom experiments can produce flawed conclusions.

Physiology

- Texts usually state that phloem transports organic compounds. However, phloem normally contains high concentrations of potassium. It also transports phosphate, potassium, and magnesium from dying leaves and from old to young parts when those mineral nutrients are deficient.
- Boron was long considered immobile in phloem. However, some species, such as celery, grape, apple, and peach, are able to transport boron in phloem.[25]
- Stomata do not open because a pair of guard cells have thicker cell walls on their adjoining side. Rather the radial arrangement of cellulose microfibrils in the cell walls cause the guard cells to bend apart when they swell.[8]
- Capillarity is not a factor in upward water movement in stems. Capillarity occurs in tubes of small diameter that are initially empty. Water spontaneously moves up such tubes. Functional xylem comprises small diameter tubes that are not empty to begin with.[8]
- Most cultivated flower, vegetable, and lawn grass seeds are not dormant because they will germinate promptly when given

Water spontaneously moves up stems; capillarity is not a factor.

environmental conditions required for germination. Such seeds are *quiescent*.[26] Dormant seeds will not germinate even when given environmental conditions needed for germination.

Reproduction

- The generalization that angiosperm seeds have abundant endosperm or cotyledons packed with stored nutrients is misleading. The largest plant family, Orchidaceae, has tiny seeds with rudimentary embryos and virtually no nutritive tissue. In nature, orchid seedlings depend on fungi for their early nutritional needs.
- The angiosperm life cycle is often overgeneralized to show just sexual seeds. In some species, such as dandelion, most seeds are asexual. Asexual seed production is termed apomixis.

The angiosperm life cycle is often overgeneralized.

- Contrary to textbook life cycle diagrams, fruits sometimes develop without pollination and fertilization, termed *parthenocarpy*. It is of substantial economic importance because of the popularity of seedless fruits such as bananas and pineapples.
- Contrary to some texts, production of seedless fruit may provide an advantage to certain plant species. If pollination or fertilization fails one year and no fruit are produced, seed-dispersing animals that rely on the fruit may starve or leave the area. Seedless fruit can feed the seed-dispersing animals. The leafy top of a seedless pineapple can form a new plant. Seedless fruit of wild parsnip are preferred by herbivorous insects thus reducing damage to seeded fruit.[27]

Some grapes are seedless because of genetics not manipulation.

- Seedless grapes in supermarkets are not seedless because they are sprayed with the plant hormone gibberellic acid. They are genetically seedless. Gibberellic acid is applied to increase the size of the seedless grapes.
- Most seedless grapes are not parthenocarpic, because they require pollination and fertilization to set fruit. The grape seeds abort early in development, termed *stenospermocarpy*.
- Seedless fruit crops are not always vegetatively propagated. Seedless tomatoes, seedless cucumbers, and seedless watermelons are grown from seed.

History

Books can present half-truths about historical events.

- Johann van Helmont (1580–1644) was not the first to conclude that plants did not "eat" soil. Van Helmont got the idea for his 1648 potted willow experiment from a nearly identical experiment described in a 1450 book by Nicolaus of Cusa.[28] In 1627, Sir Francis Bacon published experiments with terrestrial plants grown in water and concluded that plants got their nutrition from water rather than soil.[28]
- George Washington Carver (1864–1943) is often credited with revolutionizing agriculture in the southern United States with his more than 300 peanut inventions. However, none of Carver's peanut inventions was ever a commercial success, nor did Carver invent peanut butter as is often claimed.[14] Carver's main contribution to the peanut industry was his testimony before a congressional committee on peanut tariffs in 1921.

Miscellaneous

- An *epiphyte* is usually defined as a plant that lives on another plant without causing it any harm. This definition is often unrealistic because epiphytes are "nutritional pirates" that can intercept as much as half of the mineral nutrients that the host plant would otherwise receive.[29] The weight of large numbers of epiphytes often causes limb breakage on the host tree. The strangler figs (*Ficus spp*.) start out as epiphytes but eventually kill their host trees.
- The so-called knees of bald cypress are often said to function in obtaining oxygen for the roots or in supporting the tree. However, their function is not known for certain. Several possible functions have been hypothesized.[30]

Some misconceptions are based on popular beliefs.

- Poinsettia is not poisonous, as is often stated.[31] Its poisonous reputation was due to an erroneous report in the early 1900s that a child died after eating poinsettia leaves.
- Not all deciduous temperate trees are angiosperms. Deciduous gymnosperms include bald cypress, ginkgo, larch, and dawn redwood.
- Plant "food" is a misnomer because mineral nutrients are not really food for plants. "Fertilizer" is the correct term.

Conclusion

Teaching botany requires diligence.

Science teachers, particularly precollege teachers, should be aware of numerous plant misconceptions in the teaching literature. Teachers can sometimes identify literature misconceptions because many are oversimplifications, overgeneralizations, or misidentifications. Others are more difficult to identify because they are obsolete concepts or flawed research.

About the author: David R. Hershey, Ph.D., is a biology education consultant and author of *Plant Biology Science Projects* (1995, Wiley). He has published over three dozen teaching articles in journals such as *Science Teacher*, *Science Activities*, *Plant Science Bulletin*, *American Biology Teacher*, and *BioScience*. He answers botany questions for madsci.org and often contributes to the bionet.plants.education newsgroup. Hershey received his Ph.D. in plant physiology from University of California at Davis.
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1) Carter, J. L. 2004. Developing a curriculum for the teaching of botany. Plant Science Bulletin 50: 42–47. http://www.botany.org/bsa/psb/2004/psb50-2.pdf
2) Amir, R., and P. Tamir. 1994. In-depth analysis of misconceptions as a basis for developing research-based remedial instruction: The case of photosynthesis. American Biology Teacher 56: 94–100.
3) Canal, P. 1999. Photosynthesis and “inverse respiration” in plants: An inevitable misconception? International Journal of Science Education 21: 363–371.
4) Ozay, E., and H. Oztas. 2003. Secondary students’ interpretations of photosynthesis and plant nutrition. Journal of Biological Education 37: 68–70.
5) Wood-Robinson, C. 1991. Young people’s ideas about plants. Studies in Science Education 19: 119–135.
6) Ganong, W. F. 1906. The erroneous physiology of the elementary botanical text-books. School Science and Mathematics 6: 297–302.
7) Storey, R. D. 1989. Textbook errors and misconceptions in biology: Photosynthesis. American Biology Teacher 51: 271–274.
8) Salisbury, F. B., and C. W. Ross. 1985. Plant Physiology. Belmont, CA: Wadsworth.
9) Epstein, E. 1972. A blind spot in biology. Science 176: 235.
10) Hershey, D. R. 1999. Myco-heterophytes and parasitic plants in food chains. American Biology Teacher 61: 575–578.
11) Hershey, D. R. 2001. Knop’s solution is not what it seems. Science Activities 38(3): 17–20.
12) McMenamin, J. P. 1948. Teaching the carrot root correctly. School Science and Mathematics 48: 47–48.
13) Temple, S. A. 1977. Plant-animal mutualism: Coevolution with dodo leads to near extinction of plant. Science 197: 885–886.
14) Hershey, D. R. 2000. The truth behind some great plant stories. American Biology Teacher 62: 408–413.
15) Witmer, M. C., and A. S. Cheke. 1991. The dodo and the tambalacoque tree: An obligate mutualism reconsidered. Oikos 61: 133–137.
16) Muller, C. H. 1965. Inhibitory terpenes volatilized from Salvia shrubs. Bulletin of the Torrey Botanical Club 92: 38–45.
17) Bartholomew, B. 1970. Bare zone between the California shrub and grassland community: The role of animals. Science 170: 1210–1212.
18) Hershey, D. R. 1996. Allelopathy experiment pitfalls. Journal of Biological Education 30: 13–14.
19) McGregor, S. E. 1976. Insect Pollination of Cultivated Crop Plants. USDA Agriculture Handbook No. 496. Washington (DC): GPO. http://gears.tucson.ars.ag.gov/book/index.html
20) Cook, R. E. 1983. Clonal plant populations. American Scientist 71: 244–253
21) Norstag, K. 1987. Cycads and the origin of insect pollination. American Scientist 75: 270–279.
22) Hershey, D. R. 1995. Photosynthesis misconceptions. American Biology Teacher 57: 198.
23) Lonergan, T. A. 2000. The photosynthetic dark reactions do not operate in the dark. American Biology

Teacher 62: 166–170.
24) Hershey, D. R. 1992. Is hydrotropism all wet? Science Activities 29(2): 20–24.
25) Brown, P. H., and H. Hening. 1998. Boron mobility and consequent management in different crops. Better Crops with Plant Food 82: 28–31. http://www.back-to-basics.net/fertilityfacts/pdf_files/boron_mobility.pdf
26) Hartmann, H. T., and D. E. Kester. 1983. Plant Propagation: Principles and Practices. 4th ed. Englewood Cliffs (NJ): Prentice-Hall.
27) Zangerl, A. R., M.R. Berenbaum, and J. K. Nitao. 1991. Parthenocarpic fruits in wild parsnip: Decoy defense against a specialist herbivore. Evolutionary Ecology 5: 136–145.
http://www.life.uiuc.edu/berenbaum/newpage11.htm
28) Hershey, D. R. 2003. Misconceptions about Helmont's willow experiment. Plant Science Bulletin 49: 78–84.
http://www.botany.org/bsa/psb/2003/psb49-3.html
29) Benzing, D. H. 1980. The Biology of the Bromeliads. Eureka, CA: Mad River Press.
30) Briand, C. H. 2000. Cypress knees: An enduring enigma. Arnoldia 60(4): 19–25.
31) Lampe, K. F., and M. A. McCann. 1985. AMA Handbook of Poisonous and Injurious Plants. Chicago: American Medical Association.