More Misconceptions to Avoid When Teaching about Plants

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articlehighlights

The teaching literature contains hundreds of plant misconceptions. Note: This article is a sequel to Avoid Misconceptions When Teaching about Plants.

- *Fifty more misconceptions are identified in this article.*
- *Undergeneralizations are added to the list of oversimplifications, overgeneralizations, obsolete concepts and terms, misidentifications, and flawed research.*
- *A glossary at the end of the article compares words used in botany with their popular usage.*

Misconceptions can be a useful educational tool.

Plant misconceptions are common in textbooks, science project books, dictionaries, encyclopedias, science education journals, and educational websites. Published misconceptions may misinform large numbers of students and teachers, but when they are known, misconceptions can be useful indicators of concepts that are potentially confusing to students. In an earlier article, I identified 50 published misconceptions that were classified into five categories: oversimplifications, overgeneralizations, obsolete concepts and terms, misidentifications, and flawed research.[1] In this article I will present an additional category, undergeneralizations, and 50 more misconceptions about plants.

Undergeneralizations

Undergeneralizations are concepts that are applied too narrowly,

such as concepts that are restricted to angiosperms when they also apply to gymnosperms or seedless plants.

Problems stem from limiting concepts to angiosperms.

- Dioecious species are often defined as having staminate ("male" or pollen producing) and carpellate ("female" or ovule bearing) flowers on separate plants. About 40 percent of gymnosperm species are dioecious, with pollen and seeds produced on separate plants.

- Monoecious species are often defined as having staminate and carpellate flowers on the same plant. This excludes monoecious gymnosperms that have pollen cones and seed cones on the same plant.

- "Perennial" is often used to describe plants that live more than two years and usually flower every year, and yet most nonflowering plants are also perennial.

- Texts often imply that only woody plants have secondary growth. Many nonwoody plants have secondary growth; for example, carrot storage roots are mainly secondary tissues.

Obsolete concepts

- Texts usually say photorespiration lowers the efficiency of photosynthesis in C3 plants and has no purpose. Recent research reveals that normal nitrate metabolism requires photorespiration.[2]

- The plant hormone, abscisic acid, was misnamed. Ethylene is now considered to be the hormone that triggers abscission.[3]

Some obsolete concepts are still being taught.

- Nickel is often omitted as an essential element for plants, yet research published in 1987 showed nickel is essential for plants.[4]

- Florigen was long considered to be merely a hypothetical flowering hormone, but it now appears to be a messenger RNA, according to recent research.[5]

- Phloem is sometimes said to carry organic "wastes," when the

roles of these organic compounds are unknown in plants. Secondary organic compounds are assumed to function in defense if they have no other obvious role.[3] Direct evidence for this is often lacking, although it may be forthcoming in future studies. For example, when tobacco was genetically engineered not to produce nicotine, insects attacked plants without nicotine more severely than plants with normal nicotine levels.[6]

- The oldest living seeds were thought to be those from a 1300-year-old lotus (*Nelumbo nucifera*).[7] Recently, carbon-dating of a germinated seed of date palm (*Phoenix dactylifera*) showed it was 2000 years old.[8]

- A dictionary definition of intelligence can be applied to plants, even though they lack nervous systems, because of their adaptively variable behavior.[9-11]

Oversimplifications

Gymnosperms are much more than "naked seeds."

- A science project book claimed chlorophyll and hemoglobin each contain 137 atoms and replacing one atom changes hemoglobin into chlorophyll. That is not possible because chlorophyll a has a molecular weight of under 900 daltons, whereas one subunit of human hemoglobin has a molecular weight of 16,000 daltons. The grain of truth is that chlorophyll and hemoglobin both contain a similar ring structure with a different central ion: magnesium in chlorophyll and iron in hemoglobin.

- Stating that gymnosperm means "naked seed" can mislead students because the degree of "nakedness" varies among the four phyla of gymnosperms. Ginkgo seeds are naked from an early stage in their development, but yew seeds are partly surrounded by a fleshy aril, or covering, that is often mistaken for a fruit. Pine seeds are usually hidden by cone scales until maturity, but cones of five *Pinus* species (*Pinus albicaulis* and four others) are indehiscent; that is, they remain closed until they decay or are opened by animals. Emphasize that gymnosperms lack flowers and fruits rather than emphasizing their naked seeds.

- Cycads are extinct according to one biology dictionary. It's true

that many are endangered, but there are about 100 living species of cycads, including sago palm (*Cycas revoluta*), a common houseplant.[12]

Overgeneralizations

- Texts often say that seeds require oxygen to germinate. Most do, but there are some seeds, such as *Echinochloa oryzicola*, that germinate using anaerobic respiration.[13]

- Light is often omitted as a requirement for seed germination, yet some types of seed do require light to germinate, such as the princess tree (*Paulownia tomentosa*).[14]

Some exceptions are important.

- Texts often emphasize the cuticle as an important adaptation for plant survival on land, but that is not true for all plants. Bryophytes that lack a cuticle have adapted to withstand dehydration by rapidly equilibrating with their environment, a mechanism termed *poikilohydry*.[15]

- Red beets are sometimes said to be colored by anthocyanins. Beets (*Beta vulgaris*) are among over 11,000 species that have pigments called betalains instead of anthocyanins.[16]

- Perennials are often said to sexually reproduce every year, but many perennials do not. Some sexually reproduce only once, such as bamboo; some may not sexually reproduce at all if they just reproduce asexually.

Misidentifications

Botanical terms differ from gardening terms.

The first misconception listed here is an example of a wider problem of botanical terms that have different popular or gardening definitions. Such problem terms include berry, bulb, fertilization, flower, fruit, herb, nut, petal, root, thorn, and variety. A glossary is provided at the end of the article to help illustrate the differences between botanical and popular definitions for these terms (see Author Glossary).

- Petunia, tomato, geranium (*Pelargonium* spp.), wax begonia,

coleus, impatiens, snapdragon, and many other nonwoody plants are often called annuals. They are all perennials, but gardeners call them annuals when they are grown for one season before they die from winter cold. Examples of true annuals are corn and zinnia.

- One science project book lists celery as a monocot. Celery is a dicot or eudicot. The author probably misidentified the edible celery petiole as a leaf blade and believed it had parallel veins characteristic of monocots.

- An educational website misstated that the Amazon water lily (Victoria spp.), with leaves more than 2 meters in diameter, has the largest leaves of any plant. The *Guinness Book of World Records* lists a tie between raffia palm (*Raphia farinifera*) and Amazonian bamboo palm (*Raphia taedigera*), both with leaves up to 20 meters long.

Other misconceptions

Plant reproduction

- Many websites say the plant equivalent of animal parthenogenesis, or reproduction without fertilization, is *parthenocarpy*, the production of seedless fruit. Parthenocarpy rarely functions in reproduction, however. (Seedless pineapple fruit is an exception because the leafy crown of the fruit can root and form a new plant.) The equivalent of parthenogenesis in plants is *apomixis*, the production of asexual seeds. Apomictic seeds rarely develop from unfertilized haploid eggs, as in parthenogenesis. Most apomictic seeds develop from diploid eggs that don't undergo meiosis, or from diploid cells in the surrounding nucellus.[17]

- *Asexual reproduction* and *vegetative reproduction* are not synonymous. Vegetative reproduction involves plant parts—stems, leaves, or roots—not involved in sexual reproduction. Apomixis is a method of asexual reproduction but not of vegetative reproduction.

Asexual and vegetative reproduction are not the

- Vegetative propagation does not always produce offspring that are identical to the parent plant. Plants with variegated leaves are chimeras, meaning they have more than one tissue type, green and nongreen. When a variegated snake plant is propagated from leaf cuttings, plants with nonvariegated leaves are produced. The adventitious shoot that develops from the leaf cutting originates from a single cell of one tissue type. To retain the leaf variegation, the snake plant must be propagated by dividing the parent into two or more plants.[17]

- A plant clone is not always produced from a single cell, although it can be. Plant clones are usually grown from shoots, roots, or leaves.

- Pollen is not the male gamete, as stated in a science project book. Pollen is the multicellular male gametophyte, which contains male gametes.

- An educational website states that endosperm (embryonic food tissue) is located inside cotyledons (embryonic leaves). Cotyledons may digest and absorb the endosperm during development, but it is no longer endosperm after digestion. When present in a mature seed, endosperm always occurs outside the cotyledon(s).

Plant taxonomy

Know your nomenclature.

- In a binomial, such as *Quercus alba*, *Quercus* is the genus but *alba* is not the species. *Quercus alba* is the species, and *alba* is the specific epithet.
- Some publications italicize cultivar names. Cultivar names are not italicized. They are enclosed by single quotes, for example, ‘Red Delicious’ apple.
- It was once true that plant taxonomists used divisions, which are equivalent to phyla used by animal taxonomists. Plant taxonomists can now use phyla and often do; teachers may want to use phyla for both animals and plants.

Plant anatomy

- The term “phloem vessels” appears on many educational websites. This is a misnomer because vessels are structures characteristic of xylem. The correct term is “phloem sieve tubes.”

- Drawings of root cross sections often do not show mycorrhizal fungi. This is atypical because about 90 percent of plant species have mycorrhizae, which means “fungus root.”

- The food storage tissue of angiosperm seeds is not always endosperm. Some angiosperm seeds have a diploid perisperm as their food storage tissue instead of endosperm. The perisperm develops from ovule cells. Example of seeds with perisperm are pepper (*Piper nigrum*) and beet (*Beta vulgaris*).

- An educational website states that dead xylem cells, which transport water, are impermeable. Dead xylem cells, both vessel elements and tracheids, could not transport water if they were impermeable.

Plant morphology

- “Staminate cones” is a widely used term, but it is a misnomer because gymnosperm cones lack stamens. The correct term is “pollen cone.”

Terms are commonly misused.

- An encyclopedia states that “suckers” are specialized roots of parasitic plants that steal nutrients from their host plant. The specialized roots of parasitic plants are called “haustoria.”[18] Suckers are adventitious shoots that arise from underground roots.

- An encyclopedia relates that stems of a strangler fig “strangle” its tree host. Strangler fig (*Ficus* spp.) usually starts as an epiphyte high in the host tree, and its aerial roots encircle the host trunk and do the “strangling.”[19]

- An educational website claims that dandelion seeds have “parachutes” for wind dispersal, attributing what is often a fruit function to seeds. The dandelion fruit serves as the “parachute.”

Plant physiology

Tropism is a directed response.

- "Tropism" may easily be the most misdefined term in plant biology. Defining tropism as a growth response to an environmental factor is far too vague. Tropism refers to the direction of plant growth being determined by the direction of an environmental factor, such as light, gravity, or touch.

- The caption for a photo of a single-rooted philodendron cutting claimed that auxins were applied to promote rooting. Philodendrons have aerial roots, so no auxin application is needed to elongate those preformed roots. (Another generic error is illustrated here: The appropriate control treatment isn't pictured to make the treatment effect clear.)

- A text claimed that a *nastic movement*, a plant response to certain stimuli, is not caused by an external stimulus. Some nastic movements are caused by an external stimulus, such as rapid closure of a Venus flytrap leaf, but the direction of movement does not depend on the direction of the stimulus, as in a tropism.[20]

- A text stated that the circling of a twining stem before it contacts a support is a nastic movement. That phenomenon is termed *circumnutation*.[21]

- "Photoperiodism" is often defined as the effect of day length on flowering. This understates the scope of photoperiodism, which also affects seed germination, tuber and bulb formation, leaf abscission, dormancy, adventitious plantlet formation on leaves, and sexual reproduction in some nonflowering plants.[22]

- A text stated that houseplants have little phototropism, which is why they were selected as houseplants. Houseplants do exhibit phototropism and are not selected for their response to light (or lack thereof) but for their ease of production and ability to survive and remain attractive in a home environment.

Plant mineral nutrition

- Squanto is often credited with showing Pilgrims how Native Americans used fish as fertilizer. Squanto did show them this, but it was not a Native American practice where he lived.[23] Squanto had been to Europe and learned of fish fertilizer from European farmers. Native Americans practiced shifting agriculture and had no need for fertilizer. They moved on to new land when the soil fertility of a place was depleted.

Sources may be incorrect about mineral nutrients.

- Texts often say soil pH determines hydrangea flower color. Actually, the aluminum concentration in the flower tissue determines its color.[24] Hydrangeas in acidic organic soil form pink flowers because there is often little aluminum in organic soils. Commercial growers who want blue hydrangeas add aluminum sulfate to the soil. This provides sufficient aluminum as well as a low enough pH for the aluminum to be available for plant uptake.

- The available form of boron for plants is not H_2BO_{3-}. Plants absorb boron mainly as uncharged boric acid, $B(OH)_{23}$. [It is structurally more accurate to write $B(OH)_3$ than H_3BO_3.] As a Lewis acid $B(OH)_3$ combines with H_2O to produce $B(OH)_4^-$ and H^+.

- Sulfates do not lower soil pH. The cation part of the molecule does. Calcium sulfate and potassium sulfate are not used to acidify soil. Aluminum sulfate [$Al_2(SO_4)_3$] and iron sulfate ($FeSO_4$) are used to acidify soil. Both Al and Fe combine with hydroxyl ions (OH^-) to form insoluble hydroxides, $Fe(OH)_3$ and $Al(OH)_3$. Elemental sulfur can acidify soil when *Thiobacillus* bacteria convert it to sulfuric acid.

- The calcium in liming materials does not raise soil pH. The anion part of the liming molecule, such as carbonate or hydroxyl, neutralizes hydrogen ions. Other hydroxides or carbonates, such as magnesium and potassium, also function as liming materials.

Conclusion

Be skeptical

Given the frequency of published plant misconceptions, teachers must inform students about the problem. Students and teachers need to maintain a healthy skepticism about plant facts. The

plant facts.

bionet.plants.education newsgroup is a good place for teachers to pose questions on suspected plant misconceptions.

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http://www.fortunecity.com/greenfield/clearstreets/84/bio.htm

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» Avoid Misconceptions When Teaching about Plants
Fifty more plant misconceptions are identified, with several plant education links.
http://www.actionbioscience.org/education/hershey.html

» Plant Content in the National Science Education Standards.
Shortcomings and misconceptions of plant content in the National Science Education Standards are described along with suggestions for successful teaching about plants.
http://www.actionbioscience.org/education/hershey2.html

Scott's Botanical Link of the Day

University of Oklahoma botany professor Scott Russell provides a link to an informative botany website every day. Over 1700 links.
http://www.ou.edu/cas/botany-micro/bot-linx/

Royal Botanic Gardens, Kew, information sheets

Links to a wide variety of plant topics include economic plants, invasive plants, plant diversity, and plant structure.
http://www.rbgkew.org.uk/ksheets/

Plant Explorers
Read articles on famous plant explorers—the Indiana Joneses of botany—and on botanical artists, Linnaeus, and Nathaniel Ward, the inventor of the terrarium.
http://www.plantexplorers.com/

Guinness World Records
Search for plant world records on trees, flowers, seeds, plants, weeds, and more.
http://www.guinnessworldrecords.com/

Images and art of plants

» University of British Columbia's botany photo of the day
http://www.ubcbotanicalgarden.org/potd/
» Harvard University's Ware Collection of Blaschka Glass Models of Plants,
http://www.hmnh.harvard.edu/on_exhibit/the_glass_flowers.html
» HMS Endeavour botanical illustrations from the Natural History Museum, London
http://internt.nhm.ac.uk/jdsml/nature-online/endeavour-botanical/
» Curtis's Botanical Magazine
http://www.nal.usda.gov/curtis/
» Purdue University's image collection
http://www.hort.purdue.edu/newcrop/history/lecture39/images.html

Focus on specific plants

» The "exploding" flowers of bunchberry dogwood (*Cornus canadensis*)
http://www.williams.edu/biology/explodingflower/plant.html
» Introduction to the cycads: Legacy of the Mesozoic
http://www.ucmp.berkeley.edu/seedplants/cycadophyta/cycads.html
» Wollemi Pine, the living fossil conifer
http://www.wollemipine.com/
http://www.rbgsyd.nsw.gov.au/information_about_plants/wollemi_pine
» The Ginkgo Pages, about this living fossil gymnosperm
http://www.xs4all.nl/~kwanten/
» The Lotus-Effect
A scientific study of plant surfaces by W. Barthlott and C. Neinhuis (1997, Planta 202: 1–8) founded a new concept in physics, the Lotus-Effect, and provided the idea and trademark for a dirt-repelling paint.
http://lotus-shower.isunet.edu/the_lotus_effect.htm

For educators and students: Textbooks

» Introductory Plant Biology, 9th edition

A college botany text by Kingsley Stern, with an online learning center and free content.
http://highered.mcgraw-hill.com/sites/0072909412/student_view0/

» Botany Online: The Internet Hypertextbook
A Web-based botany textbook, under construction but with many worthwhile sections.
http://www.biologie.uni-hamburg.de/b-online/e00/contents.htm

» Farabee's Online Biology Textbook
A free college biology text with several plant chapters.
http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookTOC.html

» Kimball's Biology Pages
Free online college biology text with a dozens of pages on plant biology topics.
http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/

getinvolved links

Scientific Inquiry through Plants
In this project of the Botanical Society of America, plant biologists mentor public school teachers and students in research projects.
http://www.plantbiology.org/

Partnership for Plant-Based Education
This partnership of nonprofits promotes the use of plants for standards-based learning in K–12 classrooms.
http://ppbe.org/

School Garden Wizard
Create a school garden using this guide by the United States Botanic Garden and Chicago Botanic Garden.
http://www.schoolgardenwizard.org/

Center for Plant Conservation: Plants in Peril
Explore biodiversity and conservation with this guide for middle school educators.
http://www.centerforplantconservation.org/peril/perilmnu.html

New York Botanical Garden's Children's Education
Programs for K–8 students and teachers include self-guided tours and curriculum units.
http://www.nybg.org/chil_edu/

Jurassic gardens

Gardens with nonflowering plants, such as cycads, mosses, and conifers, can recreate the environment of the Jurassic Period, or the age of dinosaurs.
http://leon.ifas.ufl.edu/News_Columns/2003/011903.pdf
http://www.earthmuseum.segs.uwa.edu.au/the_eocene_and_jurassic_gardens
http://www.st-andrews.ac.uk/~www_sgg/html/jurassicgdn.html

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author glossary

Berry — *In botany,* “berry” is a fruit with all fruit layers fleshy, usually with multiple seeds, such as grape, banana, blueberry, pepper (*Capsicum* spp.), and tomato. *In popular use,* “berry” is applied to several types of small, at least partly fleshy botanical fruits, including drupes (bayberry, holly), pomes (chokeberry, pyracantha), multiple fruits (mulberry), and aggregate fruits (blackberry, raspberry, strawberry). *In popular use,* “berry” is also applied to gymnosperm seeds with fleshy seed coats (juniper) or fleshy seed arils (yew).

Bulb — *In botany,* “bulb” is usually an underground structure consisting of a short, vertical stem with fleshy storage leaves attached, as in daffodil, tulip, and lily. *In gardening,* “bulb” can be any specialized underground structure that is used to propagate plants, including true bulbs, corms, tubers, tuberous roots, and rhizomes.

Fertilization — *In botany,* “fertilization” is the union of two gametes to form a zygote. “Syngamy” is a synonym. *In plant agriculture and gardening*, “fertilization” is the application of essential mineral nutrients to plants.

Flower — *In botany,* the characteristic sexual reproductive organ of angiosperms consists of stamens, carpels, petals, and sepals. *In popular use,* some plant field guides and plant identification manuals use “flower” to refer to gymnosperm cones. The official state flower of Maine is the white pine cone and tassel; the pine tassel is apparently the leaves. “Flower” often is used by nonbotanists to refer to an inflorescence or cluster of flowers, as in daisy and lilac.

Fruit — *In botany,* “fruit” is a ripened ovary, sometimes with accessory parts. *In popular use,* “fruit” is a sweet, fleshy botanical product usually eaten as a dessert, snack, or juice. Fruits in the popular sense include apple, grape, peach, pear, and strawberry. *In popular use,* “fruit” does not include other edible botanical fruits such as tomato, pepper (*Capsicum* spp.), eggplant, squash, and green beans; they are termed “vegetables” instead.

Herb — *In botany,* “herb” is a nonwoody plant. *In popular use,* “herb” is one of the following: (1) a plant used as a flavoring in cooking, such as sage, rosemary, and thyme; (2) a plant valued for fragrance, such as lavender in herbal shampoos; (3) a plant with supposed medicinal properties, such as an herbal supplement or herbal remedy.

Nut — *In botany,* “nut” is a dry, indehiscent, one-seeded fruit with a hard shell, as in oak and chestnut. *In popular use,* “nut” includes certain edible seeds, such as peanut, Brazil nut, pine nut, ginkgo nut, and some types of hard botanical fruits, such as walnut, which is actually a drupe.

Petal — *In botany,* “petal” is usually a colored flower part in the next-to-outermost whorl. *In popular use,* “petal” is also applied to colored leaves, termed bracts, associated with some flowers, as in dogwood, poinsettia, and bougainvillea.

Prickle — *In botany,* “prickle” is a sharp outgrowth of bark or epidermis on a stem that functions as a mechanical defense, as in rose. *In popular use,* the term often used is “thorn.”

Root — *In botany,* “root” is usually an underground, cylindrical structure of vascular plants that functions in anchorage and absorption of water and mineral nutrients. *In popular use,* “root” also refers to underground stems. The ginger root sold in supermarkets is botanically an underground

stem, termed a “rhizome.”

Spine — *In botany,* “spine” is a sharp, modified leaf or leaf part that functions as a mechanical defense, as in cactus and barberry. *In popular use,* the term often used is “thorn.”

Thorn — *In botany,* “thorn” is a short, sharp modified branch functioning as a mechanical defense, as in honeylocust. *In popular use,* “thorn” is also applied to prickles and spines.

Variety — *In botany,* “variety” is a subpopulation of a species that differs in some minor characteristic from most members of the species. For example, *Cornus florida* var. *rubra* is a subpopulation of the species in which all individuals have pink to red bracts rather than the normal white. *In popular use,* “variety” is a cultivar, a portmanteau of cultivated plants. *The International Code of Nomenclature for Cultivated Plants* defines “cultivar” as “an assemblage of cultivated plants which is clearly distinguished by any characters (morphological, physiological, cytological, chemical or others) and which, when reproduced, sexually or asexually, retains its distinguishing characters.” For example, *Cornus florida* ‘Cherokee Chief’ is a specific genotype, or clone, with red bracts.
