A Historical Perspective on Problems in Botany Teaching

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Bozniak (1994) and Uno (1994) have recently called attention to some of the many problems facing botany teaching, but their analyses lacked a historical perspective. This article discusses how the many problems in botany teaching are interrelated, and most have existed since at least the early 1900s. In this article, botany is defined as the whole field of plant biology encompassing any discipline with a major focus on the plant kingdom, including horticulture, agronomy, forestry, plant pathology, weed science, plant physiology, plant morphology, plant genetics, plant ecology, plant taxonomy, etc. Botany teaching at both the precollege and introductory college levels will be considered.

Botany Neglect in Biology Teaching

The neglect of botany in biology teaching appears to be a longstanding problem (Nichols 1919; Whitney 1930; Kurtz 1958; Taylor 1965; Walch 1975) that has gotten worse over time. The National Research Council (1992) has identified this declining spiral in plant biology training and research. There has been much recent evidence of botany neglect (Flannery 1991; Honey 1987; Moehlmann 1993; Stern 1991; Uno 1994). A very striking example of botany neglect was a 26 × 73 cm color poster promoting Science and Technology Week by the National Science Foundation (1993) that featured six animals and one flower. The text on the back of the poster recommended that teachers invite students "to ask questions about the animals they see" but the plant was not mentioned. A field trip to a "local science museum, aquarium or zoo" was recommended but not to an arboretum or botanic garden. The neglect of plants in biology teaching is mentioned so often that it seems to be accepted as the *status quo*, but has botany always been neglected in biology teaching?

Biology teachers might be surprised to learn that in the early 1900s, botany was offered as a one-year or half-year course in the majority of American high schools (Coulter & Caldwell 1911). During this "Golden Age of Botany Teaching" dozens of botany textbooks were published by the leading botanical scientists of the day including Asa Gray, Francis Darwin, Charles Bessey, John Coulter and Liberty Hyde Bailey. The last three were Presidents of the American Association for the Advancement of Science. There was even a complaint that there were too many botany textbooks (Beal 1907). Botany teaching articles appeared in leading research journals like *Science* and the *Botanical Gazette*, there were manuals on high school botany teaching (Ganong 1910, Lloyd 1907), there was a botany science project book for students (Osterhout 1905), and numerous botany education articles appeared in *School Science and Mathematics* and other education journals. Botany was also a major part of the nature study and school gardening movements (Bigelow 1911). There was a standard college entrance examination in botany, and a standard unit course in botany (Ganong 1910). High school botany teachers were expected to have two years of college botany including general morphology of higher and lower plants, elementary plant physiology and ecology, zoology, physiography, and general bacteriology (Ganong 1910).

In 1910, the first year that national statistics were kept, 16.8% of American high school students took a botany course (Brownell 1926). However, high school botany enrollments steadily dropped to 9.1% in 1915, to 3.8% in 1922, and to 1.6% in 1928 (Monahan 1930). Botany courses were replaced by biology courses, which rose from 6.9% enrollment in 1915 to 13.6% in 1928 (Monahan 1930). What caused the sudden decline in high school botany?

Reasons for the decline include most of the problems discussed in this article. Failure to resolve disagreements about course content and teaching methods seemed to prevent needed reforms. Boney (1991) detailed the heated debate over elementary college botany teaching in Britain from 1917 to 1919. There also seemed to be a lack of qualified botany teachers, irrelevance of botany for high school students and parents (Suydam 1902), competition from a range of new science courses (Downing 1924), and a return to the teaching of a single course in biology instead of separate courses in botany and zoology. The latter seems to have represented a return of the "zoological

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submergence" from which botany teaching had briefly emerged (Coulter & Caldwell 1911).

Nichols (1919) credited noted British zoologist Thomas Henry Huxley with the introduction, in about 1870, of the general biology course that replaced separate botany and zoology courses. The influence of Huxley's student, H. Newall Martin, led to the establishment of general biology in many American high schools and colleges. However, such courses were generally considered a failure, and most institutions returned to separate botany and zoology courses. Even Huxley's university returned to separate courses after his retirement. Nichols (1919) found the major reason for the failure of the general biology course was that it could not help but become one-sided because most teachers were trained as either botanists or zoologists. He also noted that most such courses were taught by the more numerous zoologists whose "familiarity with plants is little more than skin-deep" so biology was generally "botany taught by a zoologist." Given the early failure of general biology courses, the current plant neglect in biology teaching is not surprising.

The remainder of this article will consider other problems related to teaching botany, try to determine if they are causes or just symptoms of botany neglect, and offer some potential solutions.

Botanical Illiteracy

As a result of plant neglect, the general public, most precollege teachers, and many college-level biology teachers are generally illiterate about botany (Firn 1990; Storey 1989; Wood-Robinson 1991). Such botanical illiteracy encourages teachers to minimize class time spent on botany and ensures that much of the botanical knowledge that is transferred to students is inaccurate. Again this is not a new problem (Ganong 1906). Blame for lack of botany training has to be shared by colleges of education who require far too few content courses, by biology courses that contain little botany, and by college botany teachers who seldom offer botany courses that provide precollege teachers with the knowledge and hands-on experience to teach precollege students.

Botanical illiteracy is widespread so even prestigious publications often have glaring botanical errors. For example, *Science* stated that *Ginkgo* produces berries, which contain nuts (Amato 1993). *Ginkgo* is a gymnosperm, which has naked seeds and no fruits. Berries and nuts are two distinct types of fruit, so a single plant species does not produce both berries and nuts. A simple check of a standard dictionary would have revealed that *Ginkgo* is a gymnosperm, that gymnosperms lack fruits, and that berries and nuts are distinct types of fruits.

Uninteresting or Irrelevant Botany Teaching

The cause of botany neglect has often been attributed to botany being uninteresting (Flannery 1987; Uno 1994). The view of Flannery (1987) is that "... I am not alone in my prejudice; to many, botany is synonymous with what is dry, complicated, and uninteresting in biology." However, this is a misconception. Plants are less complicated than animals, and botany as a subject is not dry or uninteresting, but botany teaching is often uninspiring. This may be due to the teacher's lack of interest in botany, the teacher's botanical illiteracy, or the teaching methods. Uninteresting botany teaching is an old problem, e.g. Pool (1919) complained about the overuse of "botanical cadavers," i.e. preserved plants. Relying only on preserved plants misses one of the great strengths of botany in biology teaching: Many fascinating plants are easily grown and experimented with in the classroom without offending animal rights advocates.

Students are fascinated by movement so they often have a greater interest in mobile animals than in comparatively immobile plants. Botany teachers should take advantage of this fascination with movement by having students investigate plant movements, such as phototropism and gravitropism, and by growing and experimenting with plants famous for their conspicuous movements, e.g. sensitive plant (*Mimosa pudica*), Venus flytrap (*Dionaea muscipula*), telegraph plant (*Desmodium motorium*), prayer plant (*Maranta leuconeura*), resurrection plant (*Selaginella lepidophylla*), and life plant (*Biophytum sensitivum*).

The science teaching literature is filled with success stories of teachers who have excited their students about botany. For example, at the college level: a service course in Indoor Plants with an annual enrollment of 450 despite a $25 lab fee (Lyons 1992), a radio talk show in an introductory botany course (Melaragno 1975), a spectacular light and music show (Jensen 1970), and a nonmajors general science elective emphasizing horticulture (Bouthyette 1991). At the precollege level, successful approaches have included apple day (Cruttenden 1914), hydroponics in a simulated space module (Silberstein & Brooke 1994), a botanical learning center (Hollingshead & McDowell 1992), terrariums (Clark 1978), Wisconsin Fast Plants (Williams 1989), and blindfold botanists (Walch 1975).

A common characteristic of such successful approaches is that the teachers went beyond the textbook and devoted extra effort to excite their students about botany. Botany courses are often uninteresting because of too little use of living plants, too few hands-on activities, and a lack of excitement about plants communicated to the students. Interesting students in botany often involves making botany relevant. Unfortunately, relevance of botany is often

Table 1. Common plant biology teaching topics and examples of their relevance.

Topic	Relevance
Photosynthesis	Directly or indirectly produces virtually all of our food, clothing, oxygen gas, wood, spices, and fossil fuel and much of our shelter, medicine, paint, film, perfumes, etc.
Plant taxonomy	Keying out unknown plants at Poison Control Center to determine if children or pets have been poisoned. Plant identification used in murder trials, e.g. Lindbergh baby kidnapping/murder case. Binomial nomenclature is a rare example of international cooperation as it is the same in all languages.
Monocot *vs.* dicot stem anatomy	Monocots rarely grafted, dicots frequently grafted, e.g. most fruit and nut trees grafted, many landscape trees and shrubs grafted. Some nonwoody plants grafted.
Dioecious plants	Must have male and female plants to get fruits, e.g. holly (*Ilex* species). The development of messy or stinky seeds or fruits is prevented by planting only male trees, e.g. ginkgo (*Ginkgo biloba*) and mulberry (*Morus species*).
Plant genetics	Breed plants with greater yield, more disease and pest resistance, more tolerance of environmental stress, more fragrant flowers, greater postharvest life, and more nutritious or flavorful.
Apical dominance	The practice of pruning encourages branching in most plants because it eliminates apical dominance by removing shoot or root tips.
Gravitropism	Certain types of cut flowers bend upright (negative gravitropism) and become permanently crooked when laid flat so they must be shipped and stored upright. Researchers are looking for methods to grow plants without gravity so plants can be grown successfully in the space station.
Phototropism	Negative phototropism essential for stems of certain vine species to climb walls. Houseplants on windowsills become crooked because of positive phototropism.
Photoperiodism	Streetlights harm certain plants because the plant perceives that it is summer when the daylength is long and does not go dormant at the proper time. Daylength is varied artificially so plants that need a particular photoperiod to flower, like chrysanthemum, can be made to bloom throughout the year.
Transpiration	Cools environment because heat is used to evaporate water. Key part of hydrologic cycle so removal of vegetation from large areas may cause changes in rainfall patterns.
Mineral nutrition	Environmentally responsible use of fertilizers to prevent eutrophication and groundwater pollution. Use of accumulator plants as an environmentally responsible way to mine for metals. Identification of nutrient deficiency or toxicity symptoms.
Hydroponics	Used for plant growth in space station to provide oxygen gas and food for astronauts. Popular exhibit at Walt Disney World EPCOT Center. Used for year-round production of pesticide-free lettuce.
Plant propagation	Important to assure survival of endangered plant species via cultivation. Essential in crop production. Allows clonal reproduction of superior individual plants.
Plant tissue culture	Method to free plants from virus diseases, to clone plants, and to produce new types of plants.
Plant hormones and chemical growth regulators	Used commercially in dozens of ways: to stimulate rooting of cuttings, to thin fruit, to dwarf plants, to increase plant height, to stimulate flowering, to increase stem length, and to increase fruit size in seedless grapes.
Terrarium	When introduced in the 1830s, the terrarium greatly increased the efficiency of sea transport of plants and accelerated the introduction of new plants into cultivation.

missing in biology and botany classes and textbooks (Hershey 1992). This lack of relevance seemed to be a major reason for the disappearance of high school botany courses (Clute 1908; Ewers 1912; Kauffman 1917; Kirkwood 1918; Suydam 1902; Works 1912). A major reason for the lack of relevance in botany teaching is the old prejudice that science is classified as either applied or basic (pure). Liberty Hyde Bailey (1904) summarized the situation:

> *Botany has not been alone in holding itself aloof from subjects that are made unclean by serving a direct purpose in the lives of men. All academic subjects have considered themselves worthy in proportion as they serve no concrete purpose.*

Too often botany research involves obscure species with no economic value, and some botanists do not even realize that their research has relevance. For example, Firn (1990) noted that phototropism was of little practical interest, yet phototropism is a very common problem in houseplants. It is essential for many climbing vines, which have negatively phototropic stems.

Adding relevance to botany teaching is not difficult because most botanical concepts have practical significance (Table 1). At the college level, two of the most popular plant courses are Plant Propagation, in which students can take home the plants they propagate, and Tree Identification, in which students learn to identify the trees on campus and their characteristics. Both courses provide knowledge that is both useful and intellectually satisfying.

Teaching that science can or should be classified as applied or basic is silly because all research produces new knowledge, so it could be considered to be of basic or fundamental value. Most science can be of applied value as well. As Louis Pasteur said, "There are no such things as applied sciences, only applications of science."

Zoochauvinism

Considering plants inferior to animals as objects of study has been termed zoochauvinism (Bozniak 1994) or animal chauvinism (Darley 1990). Flannery (1991) unintentionally but succinctly defined zoochauvinism as, "We are all more interested in animals." Zoochauvinism is widespread in society e.g. most people only think of animals when they hear the word wildlife, and plants are typically considered as simply part of the habitat of animals. These perceptions are reinforced by the paucity of plant coverage on television nature programs, which nearly always focus on animals instead of plants. Two of the few television episodes examining plants, *Deathtrap* on carnivorous plants and *Sexual Encounters of the Floral Kind* on pollination, illustrate that it is possible to create fascinating nature programs about plants. Popular nature and science magazines, such as *International Wildlife, Discover* and *Natural History*, also deal mainly with animals. In addition, children (and many adults) are almost indoctrinated into zoochauvinism by thousands of cute, anthropomorphic animal characters in toys, books, cartoons, television shows, and movies, e.g. Winnie the Pooh, Lion King, Bugs Bunny, Mickey Mouse, Bambi, Flipper, Lassie and Benji.

Zoochauvinism seems to be a major cause of plant neglect, and it is really an embarrassing situation for biology teaching because zoochauvinism is so antiscientific. Plants are absolutely essential to animal life, so to consider plant study less important is prejudice that has no scientific basis. Too, plant study has resulted in many major scientific advances as indicated by a brief list of botanists: Jean-Baptiste van Helmont, Carl Linnaeus, Charles Darwin, Gregor Mendel, and Barbara McClintock. The National Research Council (1992) stated that:

> "Our knowledge about the world around us is incomplete if we do not include plants in our discoveries, and it is distorted if we do not place sufficient emphasis on plant life."

Too many biology classes present such a distorted view of biology because they neglect plants. Unfortunately, zoochauvinism is self-perpetuating because biologists who are prejudiced against plants and who ignore plants in their teaching produce future teachers who are at least ignorant in botany, if not prejudiced against it. Thus, zoochauvinism seems to be an underlying cause for all the other problems.

Research Chauvinism

Research chauvinism is the widespread policy of many colleges and universities that gives more prestige and rewards to faculty who excel in research compared to faculty who excel in teaching. Research chauvinism discourages faculty from spending a great deal of time and effort on teaching. Again, this was not always so. In the early 1900s, university botany faculty published numerous botany texts, lab manuals, and botany teaching articles even in major science journals like *Science* and *Botanical Gazette*. Ganong (1910) noted the rise of research chauvinism: "at the present time the universities are giving to investigation a prominence which . . . is inappropriate or even injurious to the work of those who engage in college or high school teaching."

Research chauvinism is also the norm in most plant science societies. A few years ago, I asked why the American Society of Plant Physiologists (ASPP) did not publish teaching articles in its journal, *Plant Physiology*, despite Instructions for Contributors that it published papers "in all phases of plant physiology." In response, the Instructions to Contributors were changed to "all phases of experimental plant biology," and short teaching items were relegated to a low-status "Teaching Corner" in the society newsletter, which is available in few libraries. It is really not part of the botany teaching literature. To ASPP's credit, they have recently invited precollege teachers to visit a Teaching Booth at their annual meeting. They also have started a triennial teaching award, although the several research awards are biennial. The American Society for Horticultural Science (ASHS) has a teaching working group but only publishes teaching articles in the less prestigious of its three journals. ASHS gives four annual awards for outstanding research articles in its journals but refused to establish an award for an outstanding teaching article.

Such second-class status for teaching is common in botanical societies, but does not seem as severe in some other disciplines. The American Chemical Society publishes the monthly *Journal of Chemical Education* with a distribution about 50% greater than that of *The American Biology Teacher*. The American Chemical Society also has major programs to market chemistry.

Botanical societies could have a major impact in improving botanical teaching by more strongly supporting teachers. This could come by publishing teaching articles in their journals, funding symposia on botany teaching at their national meetings, producing curriculum guides for precollege teachers, and giving annual awards for outstanding teaching articles. The dozen-plus major botanical societies could even join together and finance an extra annual plant science issue of *The American Biology Teacher*. To encourage accurate botanical coverage, botany societies could review biology textbooks for quantity and accuracy of botanical coverage and widely publicize the ratings. Also, science teaching societies, like NABT, could take some special actions to address the many problems in botany teaching, e.g. a policy statement recognizing the problem of plant neglect in biology teaching and a guide for botanically illiterate biology teachers containing plant examples for basic biological concepts.

The ultimate solution is for scientists and college administrators to think ecologically and realize that teaching and research are intimately connected. Excellent botany teaching trains excellent botany researchers and gives citizens a respect for botany, so they will use public funds for botanical research. Thus, strong teaching leads to strong research.

Weaknesses of Botany Teaching Literature

The botany teaching literature, consisting of many thousands of articles, books, and curriculum materials, is underutilized, difficult to access, filled with errors, and not strongly supported by education granting agencies. These weaknesses greatly undermine the quality of botany teaching.

Relatively few authors of new botanical teaching publications make good use of the botany teaching literature, which results in articles, textbooks and curricula containing errors that have been pointed out previously as well as the creation of new errors or misconceptions. An excellent example is Hardy and Tolman (1993) which cited no literature and thus incorrectly described the construction and use of a plant clinostat. They also incorrectly concluded that a plant stem turned from its vertical position will bend upright again solely due to phototropism. They did not even mention gravitropism, which alone can account for the bending.

A major reason why the botany teaching literature is underutilized is that it is not accessible to most biology teachers, especially precollege teachers, because it is scattered in hundreds of books and journals available only in larger university libraries. Unlike the research literature, which is well-indexed and abstracted, the botanical teaching literature is poorly indexed and abstracted. The ERIC database contains less than 50% of the post-1966 botanical teaching literature and virtually none of the pre-1966 literature. Thus, it misses all the literature from the "Golden Age of Botany Teaching." Possible solutions to the underutilization and accessibility problems include:

1. Requiring that authors in science education journals provide appropriate literature citations
2. Making the ERIC database more comprehensive, especially in terms of pre-1966 literature
3. Publishing an annual review of the botanical

teaching literature that evaluates and summarizes advances

4. Making botanical literature available via CD-ROM or the Internet.

The botanical teaching literature contains hundreds of factual errors and misconceptions (Firn 1990, Storey 1989, Wood-Robinson 1991), insuring that teachers who use the literature teach inaccurate information. Again, the problem is not new (Ganong 1906, McMenamin 1948). Gager (1907) complained of the "impossible botany" in popular magazines. A major reason for the problem is that many recent authors of botanical teaching literature have little or no background in botany, e.g. a computer consultant coauthored two junior high books on botany science fair projects, and a commercial pilot authored an elementary-level book on botany projects. Many botany errors and misconceptions have been repeated so often that the misconception or error has become widely accepted as the truth. Also, the referee system for science education journals is often inadequate because of widespread botanical illiteracy. To avoid future errors, only well-trained botanists should author teaching publications on botany, authors should more carefully check the botany literature, and botany articles should be refereed with extra care. Also, *ABT* could establish a monthly column to alert biology teachers to the widespread misconceptions in botany teaching.

A major reason why the botany teaching literature is weak is that grants are not available to support scholarly publications in botany teaching. In contrast to botany teaching, grants for individual research have long been the backbone of botanical research. Typically, a single botanical research article represents thousands of dollars just for the time spent in manuscript preparation, postage, reprints, and travel to present the results at scientific meetings. These same manuscript preparation and presentation costs are incurred for a botany article in a refereed teaching journal, because an article typically represents several hundred hours of work. However, no small grants are available to support this type of teaching scholarship. As a result, botany teachers are not encouraged to publish their teaching innovations and insights, the quality of many botany teaching articles is diminished due to lack of grant support, and botany teachers often cannot travel to science teaching meetings due to lack of funds. The National Science Foundation (NSF) defines research as including projects to "improve the teaching and learning of science." However, the lack of grant support for publication of research in botany teaching reduces the perceived value of such work to administrators and colleagues from highly valued research to poorly regarded volunteer or service activities.

A solution to this problem is for the National Science Foundation, and other botanical and educa tion granting agencies to award many small grants of about $5,000 to $10,000 to support scholarly publications in botany teaching and presentations at science teaching society meetings. Also, botanical science or science teaching societies should establish awards for outstanding articles on botany teaching similar to the four annual awards for outstanding research articles given by the American Society for Horticultural Science. Such awards would provide an incentive for publication of excellent articles on botany teaching.

More Solutions

In addition to the solutions mentioned above, numerous suggestions to improve botany teaching were provided by Uno (1994) and Bozniak (1994), who were primarily urging action by individual college botanists. Given widespread zoochauvinism and research chauvinism, individual botanists should be aware that too much effort spent on improving botany teaching could cause harm to their professional careers. To be successful, actions to improve botany teaching should come from botanical and biological societies and state and federal science education agencies, such as the NSF. These organizations have to offer incentives, such as awards and grants, to encourage and justify efforts by botanists to overcome the many problems in botany teaching. Because of the crisis in botany teaching, a National Center for Plant Biology Teaching should be federally funded to provide leadership, e.g. nationwide establishment of a college botany course specially designed to fulfill the needs of education majors.

One of the things most needed for botany teaching is more marketing (Mathes 1983) such as that practiced successfully by NASA and by other teaching disciplines such as math, chemistry and physics. Science teaching societies and botanical societies could send press releases to national newspapers, magazines, radio and television stations. Given the public ignorance of botany and the popularity of gardening, there are an almost unlimited number of topics that could grab public attention, e.g. carnivorous plants, endangered plants, state trees and flowers, world record plants, holiday plants, hydroponics, poisonous plants, fall leaf coloration, chestnut blight, Arbor Day, plants in space, famous botanists (e.g. Charles Darwin, Luther Burbank, William Gericke), grafting, etc.

One marketing program for precollege botany could focus on a nationwide school campaign to choose a national tree. Each state has a state tree and a state flower, but there is no national tree to go with the national flower, the rose. Neighboring nations have national trees. Canada's national symbol is the maple (*Acer*), with a maple leaf prominently featured on the Canadian flag. Mexico's national tree is the Montezuma baldcypress (*Taxodium mucronatum*). Another possibility would be to link the country's schools together to form a nationwide teaching arboretum where students could identify, inventory, propagate, plant, prune, graft, irrigate, fertilize, observe and experiment with campus trees and shrubs; exchange seeds and information with other schools via the Internet; and give arboretum tours to other students and citizens.

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