UTILIZING HERBARIA IN MEDICAL BOTANY CURRICULA

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Abstract. The importance of plant-based medicines (phytomedicines) is becoming increasingly recognized by scientists, industry, and consumers. Post-secondary institutions, particularly those with strong programs in medicine or pharmacology, are adding or strengthening components of their curricula related to medical botany. Herbaria are uniquely suited to address the instructional needs of medical botany courses (or courses with a medical botany component), but are typically underutilized. Three lesson modules are presented here to demonstrate how herbaria may be used in medical botany curricula, emphasizing the importance of herbarium information in both research and societal contexts. Suggestions are given for how these modules may be incorporated into both botany- and medicine-based courses.

Keywords: economic botany; ethnobotany, materia medica, phytomedicine, planta medica.

Eighty percent of the global population relies on traditional medicine (Weragoda 1980), comprised mainly of plant-based medicines or phytomedicines. In Western society, many pharmacological preparations are prepared from or modeled on plant sources (Cowan 1999). Despite their significant contributions to modern health, these drugs represent only a very minor fraction of the total pool of phytochemicals with potential therapeutic properties. Stuart (2004) estimated that approximately 10,000 plant species have been used in some medicinal capacity; however, few have been systematically investigated. The importance of potential drugs from uninvestigated plant species is becoming increasingly palpable, especially with the continuing loss of biological diversity.

Medical botany, from both consumer/industrial and scientific standpoints, has experienced resurgence in the last several decades with growing appreciation of the diversity and efficacy of phytomedicines (Jagtenberg & Evans 2003; Pal & Shukla 2003). To better educate its constituents about the nature and efficacy of plants and their products, post-secondary educational institutions are adding or strengthening components of their curricula related to medical botany. The task can sometimes be daunting, however, due to the multi-disciplinary nature of medical botany, incorporating elements from anthropology, botany, chemistry, horticulture, medicine, pharmacology, soil sciences, and zoology.

The importance of herbaria in medical botany research is becoming increasingly recognized (Funk 2003; Funk et al. 2005). Herbaria are indispensable repositories of biological information, both in terms of the actual specimens, as well as information contained on herbarium labels (as outlined in Table 1). Specimens can serve as vouchers for material used in research and to document field locations, or may themselves be used for extraction of phytochemicals when necessary. Herbarium labels can contain important data on habitat needs, flowering time, or morphological characteristics that may assist both field botanists/collectors as well as horticulturalists propagating plants for commercial or research purposes. If part of an ethnobotanical investigation, labels may also contain critical notes on medicinal uses, proper preparation, or dosages.

Beyond research, herbaria are also ideally suited to meet the instructional needs of medical botany courses. The purpose of the present investigation was to develop a set of instructional modules to demonstrate how herbarium collections can be utilized in the medical botany curricula, as a unit or independently. As few institutions offer a stand-alone medical botany course, these modules have been designed for integration into other courses that may contain a medical botany component, such as economic botany/ethnobotany, herbarium science, or medicine/pharmacology courses.

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TABLE 1. Properties of herbaria that make them valuable for medicinal plant research, organized by research purpose.

Purpose (Example)
A. Plant Collection
1. Sheet labels may indicate sites where plant is growing
2. Sheet labels may indicate times when plant is flowering or dormant
3. Specimens may be examined by collectors prior to field trip for plant familiarization
B. Plant Conservation
Specimens may serve as vouchers for at-risk plants/ecosystems and aid in natural area preservation
C. Plant Propagation
Sheet labels may indicate habitat preferences (soil, moisture, temperature, etc.)
D. Plant Research
1. Specimens may be used to verify or dispute identification
2. Specimens may be used in phytochemical research (i.e., compound extraction from material)

METHODS

A three-phase learning cycle model (Rakow 1986; Colbourn & Clough 1997) was used as the template for each lesson module. Briefly, a student-focused concept exploration phase introduces the main concepts of the lesson, followed by a group-focused concept development phase, and finally a concept application phase where students apply newfound knowledge to a similar but novel situation (Senchina 2004). Each lesson incorporates an inquiry-oriented element to give students an experience more closely resembling the scientific endeavor. Required instructional materials are detailed within each respective lesson. Lists of additional resources that may enhance the lesson were compiled.

RESULTS

Three lesson modules that may be utilized at either the undergraduate or graduate level were developed (Appendices A–C). Organized according to the learning cycle format (see Methods), each module also contains a summary, objectives, time and materials required, preparation, procedure, assessment, and discussion and extension activities. Appendix A—Plants in Medicine—is a survey activity which introduces students to the diversity and prevalence of medicinal plants. Appendix B—Importance of Herbaria in Medical Botany—helps students develop a concept of the many ways in which herbaria are invaluable resources for medical botany. In Appendix C—Doctrine of Signatures—students are introduced to one traditional method whereby the medicinal uses of plants were remembered.

DISCUSSION

Three lesson modules have been presented to help students learn the importance of herbaria in modern medical botany. The lessons presented here may be used independently or in conjunction, and in any order. Discussion and extension activities are assigned to particular modules but are frequently interchangeable. As herbaria (especially teaching herbaria) vary greatly in size, lessons have been organized in such a way that they should be tenable to most institutions.

I have implemented several (but not all) of these activities in my undergraduate health studies courses with success. Students are engaged by the novelty and hands-on nature of the activities, and assessments (both formative and summative, including individual journaling, demonstration of skills proficiency, and group discussion) indicate that they attain the conceptual objectives. Keeping each lesson student-focused is critical: the pace of instruction should match the pace of learning

TABLE 2. Opportunities for connecting modules to supporting disciplines of medical botany including anthropology, botany, chemistry, horticulture, medicine, and pharmacology. Abbreviations: L = lesson, S# = supplementary activity and number.

	Appendix A	*Appendix B*	*Appendix C*
Anthropology	L	L, S1	L, S1, S2
Botany	L, S1	L, S1, S2	L, S1
Chemistry		L, S1, S3	S2
Horticulture	S2	L, S1	
Medicine	L, S1, S2	L, S1, S3	L, S1, S2
Pharmacology		L, S1, S3	S2

and, if students are from varying academic backgrounds, it is important to take time out to make sure everyone is familiar with the relevant concepts and vocabulary of the different sciences involved. A diverse student pool is actually an asset, as it facilitates dialogue between the students. Class conversation, versus instructor lecturing, is an excellent way to conduct the "concept development" portions of the modules and is achievable when the instructor asks guiding questions but allows the student body to construct most of the thought. It is also paramount, especially in Appendix C, to foster creativity and originality.

A cardinal feature of these lessons is their ability to be integrated into many different courses, not just those focusing on botany or herbarium studies. Medical botany is a multidisciplinary topic, comprising diverse subdisciplines. Table 2 suggests some ways in which these modules may be incorporated into courses whose primary emphasis is one of these subdisciplines. However, Table 2 should not be considered all-inclusive: for example, connections could be made to disciplines such as soil science and, although not explicitly pointed out, many of these lessons could be incorporated into history of science courses.

Due to its diverse nature, medical botany is a subject area ideal for highlighting the contributions of different ethnic groups. Increasing student awareness and appreciation of multi-cultural diversity is an ever-growing goal of many educational institutions. As each module contains an element highlighting contributions from different cultures to the field of medical botany, these lessons may be used to strengthen multicultural components of curricula. For example, in Appendix A, the concept of the Native American "medicine wheel" is introduced in extension activity #2. In Appendix C, students are introduced to the Doctrine of Signatures, a guiding philosophy observed in Chinese cultures (Sumner 2000).

Additional print resources which may be of benefit to instructors and/or students are organized by module and presented in Table 3. An essential skill for students of science is the ability to read and digest scientific literature. Becoming comfortable with the technical nature and vocabulary of scientific reports is difficult for many undergraduate students; consequently, they often avoid reading peer-reviewed sources. Many of the print materials from Table 3 are written in such a manner that they are more approachable to novices in the field, and as such represent excellent opportunities for veteran scientists to immerse younger scientists in the peer-reviewed literature while concomitantly helping them become more comfortable reading such items. Excellent class discussions can be launched from these articles.

In conclusion, three lesson modules have been presented to help educate students about the importance of herbaria in modern medical botany. A simple yet plastic structure was chosen such that each may be incorporated into diverse post-secondary curricula. Each module suggests a primary activity but also proffers supplementary activities to expand on main concepts. Connections are shown between these lessons and the subdiscipines of medical botany, the scientific literature, and the historical contributions of different ethnic groups. It is hoped that these lessons will be of practical use to post-secondary educators and will better help students realize the importance of herbaria.

TABLE 3. Additional print resources which may be of benefit to instructors and/or students, organized by module.

Medical Botany	*Appendix A Plants in Medicine*	*Appendix B Importance of Herbaria*	*Appendix C Doctrine of Signatures*
Lewis & Elvin-Lewis (2003)	Balunas & Kinghorn (2005)	Funk (2003); Funk et al. (2005)	Court (1967)
Moerman (1998)	Raskin et al. (2002)	Gurib-Fakim (2006)	Friend (1953)
Schultes & von Reis (1995)	Rios & Recio (2005)	Jiang et al. (2005)	Halberstein (2005)
Stuart (2004)	Vuorelaa et al. (2004)	Phillipson (1995)	
Sumner (2000)		Soejarto (1996)	

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APPENDIX A

Plants in Medicine

Summary: Using herbarium specimens and ethnobotanical literature, students will explore the diversity of medicinal uses for plants.

Objectives:

1. Individually, students will compile a list of at least 10 medical applications for which plants and their products may be useful.
2. Working in small groups, students will select 5 plant species and determine whether these plants have a traditional and/or modern use in medicine by using ethnobotanical databases.

Time required: ~ 2 hours

Materials needed:

- Herbarium (a small, local collection, such as a classroom or teaching collection, works best; alternatively, you can pre-select a sampling of specimens for students as is appropriate to the activity)
- Computers with Internet access to the University of Michigan—Dearborn Native American Ethnobotany database (available from: http://herb.umd.umich.edu/) or copies of *Native American Ethnobotany* (Moerman 1998)
- Paper and pencil for each student
- Chalkboard, greaseboard, opaque projector, or similar device

Preparation: Have all materials ready for student use

Procedure:

Concept Exploration

1. Ask students to individually brainstorm a list of the different ways plants are used in medicine based on the students' current knowledge. Encourage students to cite specific examples when known.
2. From individual student knowledge, generate a class list of such uses on a chalkboard or similar device. Leave the list on the board for use later.

Concept Development

3. Ask students to organize themselves into pairs. Each pair is to select 5 plants from the herbarium and, using either the Internet or book copies of the database, determine if the plant was used medicinally by Native Americans. Students should write down each known medicinal use for each species. Ask students to also note if a given plant had other uses (as textile, food, etc.), or whether certain organs were more useful than others. Students should compile this information in the form of a table to be turned in at the end of the activity.
4. Allow student work time.
5. When pairs are finished, lead a group discussion where student groups share some of their findings. For example, students can name all the uses for their species. Encourage students to share anything they felt was surprising during their investigation (such as if a plant had more than one medicinal use, or if it had other non-medicinal uses).
6. Emphasize that these uses are purported medicinal uses and that not all have been substantiated through scientific investigation.
7. Ask students to consider the total number of plants investigated in this activity. Make a tally of those that had catalogued use medicinally versus those that did not. Are medicinal properties found only in a few plants, most of the plants, or something in between? What factors might bias?

8. Afterwards, revisit the student list of medicinal uses for plants generated earlier. Have students add any new uses discovered during the activity to the list. Before moving on to the next phase of the lesson, ask students to study the list.

Concept Application

9. Have students individually write a list of at least 10 ways plants have been used for medicinal purposes. Cite examples when possible.
10. Ask students to include in their discussion a reaction statement indicating their perception of medicinal plants before and after the activity. This is to be an honest reaction: if students' perceptions have not changed, they should indicate why their thoughts are the same,

Assessment: Objective #1 may be assessed formally through step #9 above. Objective #2 may be assessed informally during step #4. For graduate or upper-level undergraduate classes, instead of having students complete step #9 in class, give step #9 as a homework assignment and additionally ask students to locate (through literature or database sources) at least two medicinal plants that have been used for each of the 10 purposes on their list. Encourage students to find members of two different genera for each purpose.

Discussion and extension activities:

1. Medicinal Properties by Family—Depending on the students' knowledge of plant diversity and the different families, you may be able to take the knowledge shared in step #5 above and, as a class, compare medicinal properties by families. If we consider medicinal plants as a general group, are members of the group mainly representative of ancient (evolutionarily primitive) lineages, mainly representative of modern (more recently evolved) lineages, or evolutionarily diverse? Are some purported medicinal properties more common in certain groups compared to others?
2. Medicinal Plant Gardens—Herbalists and doctors have many ways to obtain their plants. Beyond wildcrafting, the deliberate planting/transplantation and maintenance of a garden of medicinal plants was a common practice. For Native Americans, this garden often took the form of a "medicine wheel" where plants were organized in a deliberate wheel-and-spoke pattern. For Europeans and their descendants, physic gardens next to cottages and health care facilities were the most frequent representation. Ask students to suppose that their university wished to recreate a medicine wheel or physic garden on campus for educational purposes. Working in groups, ask students to determine how an herbarium could be used to help achieve this aim. How would the garden be planned to underscore the diversity of plants from which medicines may be derived?

APPENDIX B

Importance of Herbaria in Medical Botany

Summary: Students explore the many and varied ways herbaria are critical to modern medical botany research through a scenario-based exploratory activity. This exercise is also good for familiarizing students with the organization of the herbarium.

Objectives:

1. Individually, students will be able to generate a list of at least 5 distinct ways herbaria are of use to modern medical botany research.
2. Working in small groups, students will be able to use herbarium specimens to answer at least 5 questions that mimic questions faced by medical botanists and individuals of allied disciplines.

Time required: ~ 1 hour

Materials needed:

- Herbarium (a larger research herbarium works best)
- One photocopy of the scenario sheet per group (see "Preparation" below)
- Chalkboard, greaseboard, opaque projector, or similar device

Preparation: In this activity, student groups will be given four or five "dilemmas" that can be resolved using an herbarium (see step #5 in "Procedure" below). The dilemmas are engineered to illustrate the attributes of herbaria that are important to medical botany research (Table 1). Some specific examples you might use for this activity are given in Table B1 using specimens that are common in American herbaria; however, some tailoring may need to be made for a given herbarium's particular holdings. Prior to class, decide if you would like to use the scenarios in Table B1, edit them, or add new ones as suits your herbarium. Type these scenarios onto a worksheet to be distributed to student groups during the activity, and make enough copies beforehand.

Procedure:

Concept Exploration

1. Divide the class into groups of 3–4 students.
2. Pose the following open-ended question to groups: "How are herbaria important for scientists investigating the medicinal properties of plants?" Ask students to write a list within their groups.
3. When groups are finished working, initiate a class discussion where groups share their thoughts. Compile a list on the blackboard. Ask students to give examples whenever possible to better explain their ideas. Leave the list on the board for use later.
4. Explain that the purpose of the following exercise is to better help students understand the myriad important uses of herbaria in modern medical botany research.

Concept Development

5. Distribute scenario sheets prepared ahead of time to student groups (see "Preparation" above). Instruct students that to solve the dilemmas posed in each scenario, they will need to locate and examine herbarium specimens and sheet labels (depending on student familiarity with the herbarium, you may need to instruct them on handling of specimens). It is almost like a scavenger hunt. During the investigation, students should use scratch paper to record their outcomes.
6. Allow for group work time, circulating and assisting as necessary.
7. When finished, have students work together to consolidate their answers onto the scenario sheet.

Concept Application

8. Revisit the list produced by students in step #3 above. Students should add or subtract from the list based on the experiences they just had in the activity.
9. Offer probing questions to the students to help them expand their list such that it encompasses the attributes as proposed in Table 1.
10. Ask each student to individually write a list of at least 5 distinct ways herbaria are of use to modern medicinal plant research on their own paper.
11. Collect individual student papers.

Assessment: Objectives #1 and #2 may both be assessed formally by surveying the sheets turned in at step #11 above. Although not indicated, you may opt to collect scenario sheets from students for additional evaluation. For graduate or upper-level undergraduate courses, direct students to the American Society of Plant Taxonomists' position statement on the importance of herbaria (viewable online at http://www.newberrynet.com/sabs/SHC/HerbASPT.htm and through several other links). Using this position statement as a model, ask students (working individually or in groups) to compose their own position statement on the importance of herbaria specifically in the context of medical botany, giving examples when possible. Depending on the levels and experiences of the students, some discussion on academic integrity and/or plagiarism may be appropriate.

Discussion and extension activities:

1. Devise Your Own Dilemma—Ask students to write their own scenario illustrating one of the attributes from the list generated by the class (steps #8 and #9 in "Procedure" above). Prior to class, select 6–8 medicinal plant specimens not used in the scenarios activity for students to use. Scenarios may be developed by individual students, in pairs, or in groups. Emphasize that the point of the exercise is for your scenario to reflect one of the attributes as generated by the class' list; students should not worry about having extensive knowledge of the plant itself.
2. Maintaining Herbaria—The importance of the herbarium is not always recognized at the university level, and herbaria sometimes do not receive adequate funding or are dissolved for budgetary reasons. Have students consider a situation in which the university is thinking of cutting funds or closing the herbarium. Based on the activity, what kind of arguments can be drafted in favor of keeping the herbarium? What arguments can be generated in favor of expanding the herbarium?
3. Validated Medicinal Properties—Select some of the plants from Table B1 or from the list of the most popular botanical supplements (Blumenthal et al. 2006) and have students perform literature searches to ascertain what research has concluded about these plants using databases such as PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?DB=pubmed). Students could work individually, in pairs, or in groups. For species with validated bioactivity, ask students to discover which chemical compounds are believed to be active and what their properties are. Do concentrations of these compounds vary by organ or season of harvest/growing conditions? As a group, make a table of the bioactive compounds that students discovered on the board. To what classes do these compounds belong? Are there any similarities or differences across the supplements? As a class, discuss the geographic distribution of plants with validated medicinal properties versus those that have yet to be scientifically investigated. Are plants from certain continents or regions more robustly represented in the scientific literature than plants from other continents (representation or cultural bias)? Contrast what is known of European or North American plants versus African or South America plants.

TABLE B1. Specific examples of scenarios that can be used in Appendix B to illustrate the importance of herbaria in medical botany research. Examples were chosen based on plants common to American herbaria.

Herbarium Attribute	*Scenario Illustrating Value of Attribute*	*References*
A1	St. John's Wort (*Hypericum perforatum* L., Clusiaceae) may provide anti-depressant therapy. Dr. Mawenh, a resident of Nebraska, wishes to collect some specimens from the field to see if levels of phytochemicals vary based on geography. She needs to determine where a good site would be to collect.	Caccia (2005); Linde et al. (2005)
A2	Dr. Ochoa works in New York and has read several papers documenting the potential anti-cancer properties of phytochemicals from bloodroot (*Sanguinaria canadensis* L., Papaveraceae). However, she is uncertain what time of year the plant flowers in this region.	Adhmai et al. (2004); Ahmad et al. (2000)
A3	Multiple members of the genus *Echinacea* Moench (Asteraceae) have documented *in vitro* immunomodulatory activities that vary slightly by species. Dr. Andresen, working at a university in Arkansas, wishes to collect some specimens from the field but is aware that over 5 species grow in the state. He is wanting to familiarize himself with some features of the different species prior to collecting.	Barnes et al. (2005); Senchina (2006)
B	The medicinal properties of goldenseal (*Hydrastis canadensis* L., Ranunculaceae) have led to its overcollection. Dr. Varenkov is trying to determine locations in Michigan where the plant is growing to begin conservation efforts to maintain current population, but is unsure where the plant may be found.	Rehman et al. (1999); Scazzocchio et al. (2001)
C	The anti-cancer drug taxol was derived from the Pacific yew (*Taxus brevifolia* Nutt., Taxaceae). Dr. Blackfeather wishes to cultivate this species in the lab for further study, but is unsure what soil or other habitat conditions this species may prefer.	Arbuck et al. (1994); Kummalue (2005)
D1	Prairie spiderwort (*Tradescantia occidentalis* (Britton) Smyth, Commelinaceae) was used by some Native Americans as a disinfectant. However, these properties have not been scientifically investigated. Researchers in Arizona want to test the hypothesis that the plant harbors disinfectant properties. They have made vouchers from field-collected material, but want to verify the identification of the plants by comparing to other collections and are uncertain where they can find similar specimens for comparison.	Moerman (1998)
D2	Recently, investigators found an 85-year old sample of black cohosh (*Actaea racemosa* L., Ranunculaceae). Methanol extracts from the cured material harbored antioxidant capabilities similar to fresh extracts. Dr. Sim wondered if other plants known for their antioxidant properties would exhibit similar stability after long storage times. He is looking for aged samples from introduced mints such as sage (*Salvia pratensis* L., Lamiaceae) and yellow sweet clover (*Melilotus officinalis* (L.) Lam., Fabaceae), but doesn't know where he could find some.	Jiang et al. (2005); Miliauskas et al. (2004)

APPENDIX C

Doctrine of Signatures

Summary: Students will follow a centuries-old philosophy for remembering the potential medicinal functions of plants by noting their shape, texture, and color.

Objectives:

1. Individually, students will be able to explain verbally the philosophy behind the Doctrine of Signatures and give at least 1 fact of its importance in history.
2. Working in small groups, students will apply the Doctrine of Signatures to at least 8 herbarium specimens through writing.

Time required: 45 minutes

Materials needed:

- Herbarium specimens suitable to Doctrine of Signatures (see "Preparation" below)
- Paper and pencil per student

Preparation: Prior to class, select about 12–18 herbarium specimens that are amenable to interpretation via the Doctrine of Signatures. Traditional examples are given in Table C1. There should be enough specimens for each group to work with one at a time plus several extra. The activity works best if several student groups examine the same herbarium specimens. For each specimen, make sure a notecard is attached giving common name, scientific name, and best-supported/most common/traditional use for that plant. Also set aside one specimen that groups will not examine until the concept application phase of the activity.

Procedure:

Concept Exploration

1. Pose the following situation to students: "Suppose you are a member of a culture with no written language or a form of writing that is only accessible to an elite few. How would you pass on your herbal knowledge from one generation to the next?"
2. Solicit student answers and discuss them as a class. Students will most likely propose an oral tradition.

Concept Development

3. Introduce the concept of the Doctrine of Signatures. Give a brief overview of how different cultures throughout history employed the Doctrine to remember most frequently employed medicinal functions of plants.
4. Ask students what features of plants may be useful for applying the Doctrine. Through student answers and group discussion, come up with a list that includes color, texture, shape, and taste, and perhaps other physical properties.
5. Explain to students that in the activity they will have the opportunity to practice applying the Doctrine of Signatures to herbarium specimens. Instruct students to select 6–10 herbarium specimens from the collection you have made. As groups of 2–3 students, they are to apply the Doctrine by finding some feature of the plant they can use to help them remember that particular plant's best-supported medicinal purpose.
6. Allow for group work time. Encourage creativity. Let students know that it is okay for a group to develop more than one interpretation.
7. When students are finished, select one of the specimens and ask students how they applied the Doc-

trine to that particular specimen. Garner answers from multiple groups for the same specimen. For which specimens did student answers converge, and for which specimens were they discrepant?

8. Emphasize that just because a given plant may be interpreted by the Doctrine for a specific medicinal use, this does not imply that the plant was initially chosen for that specific medicinal use based solely on its morphological features. Rather, improvement of symptoms would have been the standard for gauging a plant's medicinal efficacy; the Doctrine served as a memory device.
9. Based on their experiences in this activity, ask students to individually formulate an opinion about the Doctrine. Then share these opinions as a group. Be supportive of student responses, but challenge them to think about their answers critically. For example, if students say it is a good method, point out examples of how multiple plants may share the same feature being employed in the Doctrine but not have the same medicinal purposes. If students say it is a bad method, point out how different cultures have used this strategy for millennia. Though no longer employed today, how did the Doctrine persist for thousands of years? What has it been replaced with? What is its status in contemporary society, or does the answer to that question vary depending on which culture you are considering?

Concept Application

10. Bring out the single herbarium specimen you set aside in preparing for the lesson. Allow students to examine it, but ask that they not share their observations.
11. On their own sheet of paper, ask students to individually (a) write a definition of the Doctrine of Signatures, including at least one statement of its historical importance, and (b) write how the Doctrine of Signatures may be applied to that particular specimen.
12. Collect student papers at the end of class.

Assessment: Objective #1 may be assessed formally after step #11. Objective #2 should be assessed informally during step #6. For graduate or upper-level undergraduate classes, you may choose to omit step #9 above and use those discussion questions as written assessments—working independently on those questions will require critical thought by each student personally.

Discussion and extension activities:

1. History of Medical Botany—Ask students to research the history of medical botany and/or the Doctrine of Signatures. An excellent starting point is Sumner (2000), but Table 3 also lists other outstanding sources. Students should pay particular attention to people who influenced prevailing thought and how the scientific basis of the field changed over time.
2. Withstanding the Test of Time—Using Table C1, select some plants and research their history of use. Have these plants always been popular, only in the past, or only recently? Has their use changed over time? Is there any scientific basis to their use and, if so, which phytochemicals likely harbor medicinal activity?

TABLE C1. Plants amenable to interpretation by the Doctrine of Signatures. For use in Appendix C.

Name	*Species*	*Family*	*Feature*	*Traditional Use*
Adder's tongue	*Ophioglossum* spp.	Ophioglossaceae	Tongue-shaped organs	Snakebites
Bloodroot	*Sanguinaria* spp.	Papaveraceae	Red sap in roots	Blood disorders
Boneset	*Eupatorium* spp.	Asteraceae	Leaf/stem structure	Healing broken bones
Bryony	*Bryonia* spp.	Cucurbitaceae	Root shape	Dropsy
Cardinalflower	*Lobelia* spp.	Campanulaceae	Red flowers	Blood ailments
Eyebright	*Euphrasia* spp.	Orobanchaceae	Bright floral centers	Eye ailments
Goldenrod	*Solidago* spp.	Asteraceae	Yellow flowers	Jaundice/kidney ailments
Iris	*Iris* spp.	Iridaceae	Flower colors	Bruising (petal color resembles bruise)
Liverwort	*Hepatica* spp.	Ranunculaceae	Liver-shaped leaves	Liver ailments
Lungwort	*Pulmonaria* spp.	Boraginaceae	Spotted leaves	Lung ailments
Maidenhair fern	*Adiantum* spp.	Pteridaceae	Silky stalks	Hair ailments
Mandrake	*Mandragora* spp.	Solanaceae	Human-shaped root	Many, including pregnancy aid
Quaking aspen	*Populus tremuloides*	Salicaceae	Shaking	Palsy
St. John's wort	*Hypericum* spp.	Clusiaceae	"Holes" on leaves	Skin ailments
Toothwort	*Cardamine* spp.	Brassicaceae	Flower color, shape	Tooth ailments
Walnut	*Juglans* spp.	Juglandaceae	Seed resembles head	Head ailments
Wormwood	*Artemisia* spp.	Asteraceae	Leaf shape	Intestinal worms