

Chapter 5
**An Evolutionary Approach to Teaching about
Ferns in a Plant Kingdom Course**

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Introduction

Students in introductory biology courses are usually presented with well-structured factual information. This is especially true when dealing with classifications of living things. The taxonomy of the textbook author is adopted, and most students are satisfied. Occasionally, however, industrious students come upon different taxonomic schemes in outside reading and demand an explanation of “who is right?” A number of such questions, from students in an upper division Morphology of Vascular Plants course some years ago provoked me into designing a laboratory exercise in which the students formed their own classification of the ferns, using criteria provided by authorities and based on careful observations. The exercise was based on the groundplan/divergence method devised by Wagner (1969). Subsequently I have modified the exercise for use in a freshman-level course.

The objectives are to have students: 1) carefully examine and describe one fern, 2) observe a wide variety of structural modifications in other ferns, 3) construct a phylogenetic fern classification, and 4) gain an appreciation for some of the problems and biases inherent in phylogenetic classifications.

Set-up time is minimal, requiring only that a variety of ferns be made available and handouts prepared for the students. Data collection requires approximately 2 hours, assuming that the students are already familiar with the structure and life cycle of a typical fern. Data analysis and construction of the classification is an out-of-class assignment. Discussion of the analysis and classification requires approximately ½ hour during the subsequent class period.

Student Materials

Four handouts should be provided to the students prior to beginning the exercise. The first is a list of important characteristics showing evolutionary trends within each character (Table 5.1). This list is based on the work of Bower (1923–1928). It has been pointed out recently (Wagner 1969) that some of the trends proposed by Bower (e.g. stem habit, stele type, and sorus position) are inconclusive. Nevertheless, Bower’s “Dicta” provide a useful and usable tool.

The second handout (Fig. 5.1) illustrates some of the terminology used by Bower. Much of this information is covered in the previous lecture, but it is useful to have the illustrations before the students as they try to interpret each of the characters in their fern.

The third handout (Table 5.2) is a data summary sheet which is used to accumulate information from the tally cards for each specimen examined. A plain piece of paper will suffice, but a prepared sheet facilitates orderly accumulation of data for later analysis.

Table 5.1. Some evolutionary trends in the ferns

Character: Primitive	Specialized Condition
1. Shoot: upright, radial symmetry	→ prostrate, dorsoventral symmetry
2. Hairs: simple, linear	→ branched → expanded scales
3. Stele: protosteles	→ solenosteles → dictyosteles
4. Leaf trace: simple, single	→ complex, many bundles
5. Leaf venation: open venation	→ reticulate venation with large meshes → reticulate with small meshes
6. Leaf blade: equal dichotomies	→ unequal dichotomies (sympodial) → pinnate (monopodial)
7. Type of sorus: individual sorus	→ fused sorus
8. Position of sporangia: terminating vascular bundle (marginal)	→ underside of leaf (superficial) → protected by indusium
9. Sequence of sporangium development: simultaneous	→ basipetal → random
10. Sporangium size: few, large	→ many, smaller
11. Sporangium stalk: thick (3+ files), short	→ thin (1 file), long
12. Sporangium dehiscence: jacket > 1 cell thick, ruptures longitudinally	→ ruptures obliquely → jacket 1 layer thick, ruptures transversely
13. Spore output: large, indefinite number	→ fewer, constant number (64 or less)
14. Spore differentiation: homosporous	→ heterosporous

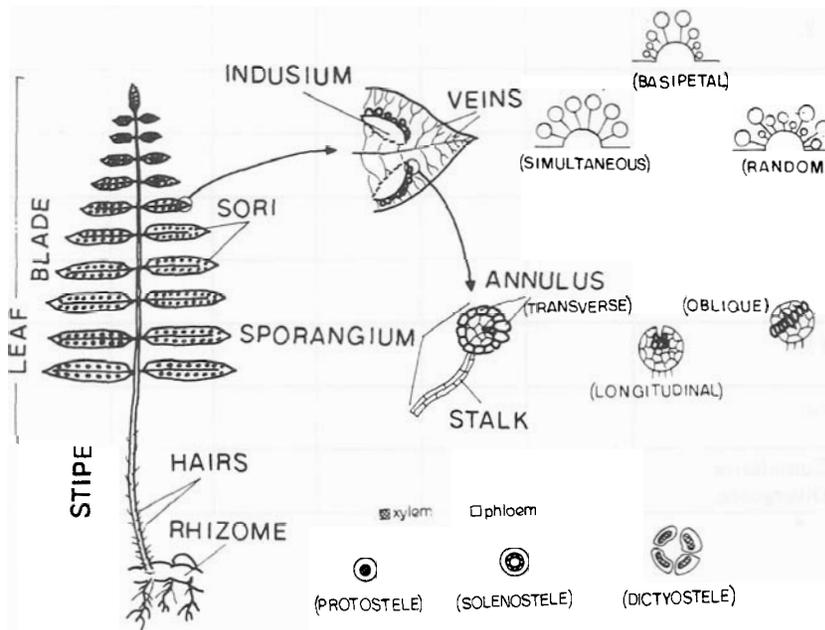


Figure 5.1 Diagrammatic illustration of some of the terminology used in studying ferns.

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Table 5.2. Class summary data sheet

<i>Character</i>	<i>Name</i>	Scoring: 0 = primitive, 0.5 = intermediate, 1.0 = advanced					
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
Cumulative Divergence							

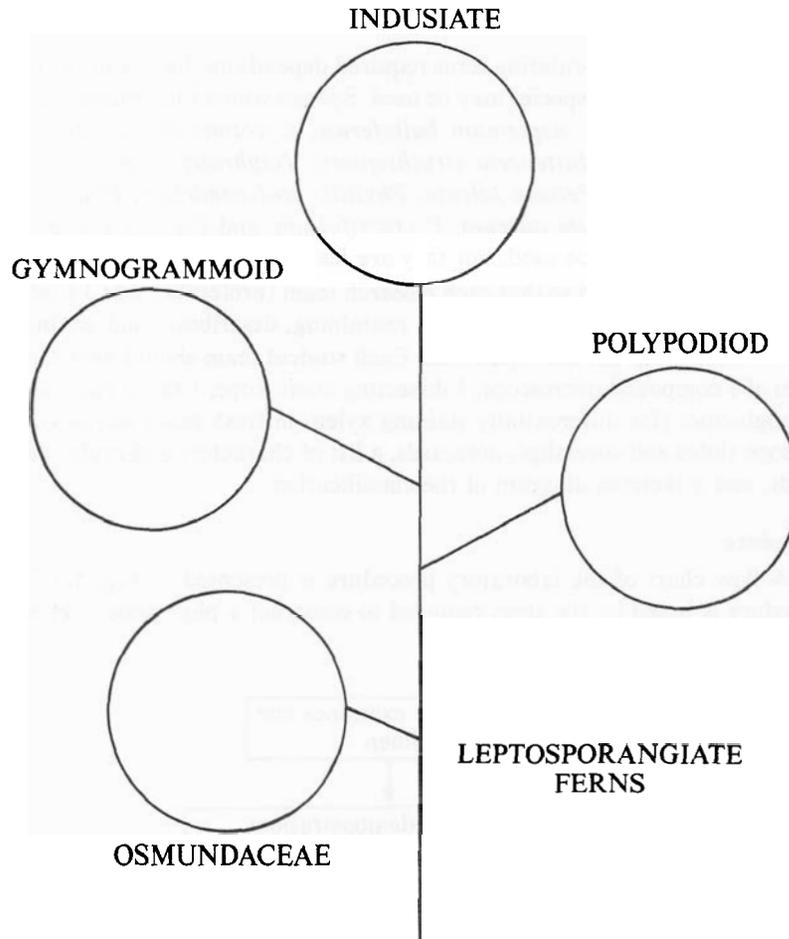


Figure 5.2. Skeleton outline classification of the Leptosporangiate ferns. See text for distinguishing characteristics of each group.

The fourth handout (Fig. 5.2) is a skeleton classification of the leptosporangiate ferns, with a brief definition of the four major groups, based on sorus position and the presence or absence of an indusium (Lloyd 1971). With the time constraints of a two-hour laboratory period it is important to give the students some initial direction in forming their classification. By having the primary characters indicated it is an easy matter for the students to assign each fern to the appropriate group and later rank ferns within groups.

Instructors' Materials

The number of sporulating ferns required depends on the size of the class. Both native and exotic species may be used. Species which I have used include: *Adiantum reddianum*, *Asplenium bulbiferum*, *Cyrotomium falcatum*, *Lygodium japonicum*, *Matteuccia struthiopteris*, *Nephrolepis exaltata*, *Osunda Claytoniana*, *Pellaea falcata*, *Phyllitis scolopendrium*, *Platycerium bifurcatum*, *Polypodium aureum*, *P. crassifolium*, and *Pteris erectica*. Preserved materials may be used, but they are less desirable than living plants.

The class is divided so that each research team (preferably 2 or 3 students per team) is responsible for carefully examining, describing, and setting up demonstrations for one fern specimen. Each student team should have a minimum of 1 compound microscope, 1 dissecting microscope, 1 sharp razor blade, phloroglucinol (for differentially staining xylem in fresh hand sections), microscope slides and coverslips, notecards, a list of characters and evolutionary trends, and a skeleton diagram of the classification.

Procedure

A flow chart of the laboratory procedure is presented in Fig. 5.3. This procedure is based on the steps required to construct a phylogenetic classi-

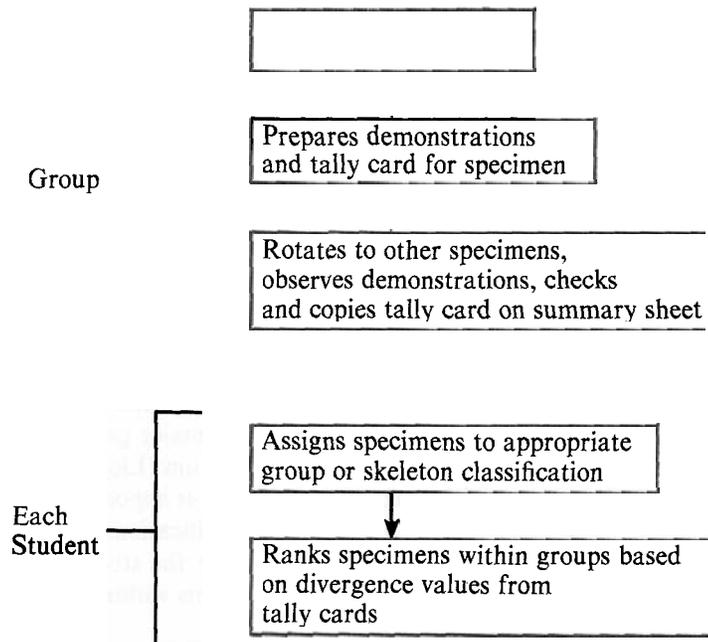


Figure 5.3. Flow chart of laboratory procedure.

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cation (Wagner 1961). The first step is to examine carefully as many characters as possible in a wide variety of plants so as to gain an understanding of the contrasting characters. This, of course, is not possible for a beginning student in a 2 hr laboratory. Student teams, however, can do a reasonable job of examining specific characters on a single plant, which can later be compared with the work of fellow students on different plants. Each team prepares a tally card describing the characters exhibited by its specimen (Table 5.3). They must also set up demonstrations of their fern which will later be examined by their classmates.

Typical problems at this step deal mostly with basic fern morphology. Students should be reminded that the stem (rhizome) of a fern is usually underground, and that the stipe is actually part of a leaf. Most of the characters can be examined directly, but in a few cases hand sections are required (stele and leaf trace) and in some cases dissection and/or preparation of whole mounts may be desirable (spore and sporangium characters).

The second step is to determine the primitive vs advanced condition for each character examined. This step assumes that plants with common ancestry share common characteristics, and that generally the most widespread condition is primitive (Wagner 1961). There are exceptions to the latter principle: e.g. sealed carpels are the widespread condition in flowering plants, while unsealed carpels are generally considered to be primitive. Only an authority who specializes in a group is competent to determine the direction of evolution within a set of characters; therefore, this information, provided by F. O. Bower (1923) is supplied to the students (Table 5.1).

Table 5.3. Tally sheet for *Polypodium aureum*

<i>Character</i>	<i>Condition</i>	<i>Score</i>
Shoot	Prostrate	1
Hairs	Scales	1
Stele	Dictyostele	1
Trace	Complex	1
Venation	Reticulate, small	1
Blade	Pinnate	1
Sorus	Individual	0
Sporangia	Underside, no indusium	.5
Sporangia development	Random	1
Sporangia stalk	Thin, long	1
Dehiscence	Transverse	1
Spore output	Fewer	1
Spore differentiation	Homosporous	0
Cumulative Divergence = Sum of the above		10.5

The biggest problem with step two is interpreting subjective terms, e.g. large, small, many, few (Table 5.1). I usually suggest that the students estimate numbers and average sizes, withholding subjective judgment until they have the opportunity to examine the demonstrations of other teams. There is also occasional difficulty in determining the sequence of sporangium maturation, usually because an overmature frond was chosen for study. Examining a younger frond is usually remedial. In addition, a useful correlation is that sporangia of a sorus with basipetal development usually has a protruding peg of tissue on which the sporangia are inserted.

The third step is to assign a value for each character. Some philosophical arguments concerning the value assigned to characters (weighting) have been discussed recently by Mayr (1981). He points out that a careful analysis of characters within a group almost always shows some characters to be more valuable than others. Nevertheless, for the sake of simplicity all characters are weighted equally in this exercise. The primitive condition is given the value 0, intermediate conditions are 0.5, and specialized conditions are 1.0. Thus, from the information presented on the tally card for each species, a cumulative divergence value from a hypothetical ancestor, primitive for each character, can be determined by adding the total points for each set of characters.

The fourth step is to list each of the specimens examined, along with their divergence values. The students are now ready to examine the ferns described and documented by the other research teams. The teams rotate from specimen to specimen checking the demonstrations against the tally cards and recording tally card information for each specimen. This enables each student to see a number of variations from the pattern he/she examined and also provides a check on the validity of the information presented on the tally cards.

The fifth step is to group specimens with mutual characters and divergences. This can certainly be done in an upper division course as part of a larger exercise (Wagner 1969). However, with freshmen and the time constraints of a 2 hr period, I find it useful to give students a skeleton classification, allowing them to position their specimens in the appropriate location (Fig. 5.2). Depending on time limitations this may be done at the end of the laboratory or as a homework assignment.

The skeleton classification asks the student to place each fern examined into the appropriate group. Sorus position and presence or absence of an indusium are the key characters. The osmundaceae are characterized by entire leaves or leaf segments being modified into strictly reproductive organs. The gymnogammoid ferns have marginal sori and a modified leaf margin which functions as an indusium. The polypodioid ferns have sori on the abaxial (lower) side of the frond but lack an indusium. The indusiate ferns have a true indusium covering the sorus. (Fig. 5.3)

1971; Foster and Gifford 1974). Likewise, to analyze rates of evolution of different characters requires an understanding of the correlations between attributes and ecological and distributional patterns that are beyond the scope of an introductory course. Nevertheless, students do gain a feel for how phylogenetic classification is done, they recognize some of the problems involved, and they gain an appreciation for the types of information which can be used in solving the problems. Even more important is that they are forced to make careful observations and apply terminology to individual specimens. Finally, they realize that there is not always "a right answer."

References

- Bierhorst, D. W. *Morphology of vascular plants*. New York: Macmillan; 1971.
- Bower, F. O. *The ferns*, 3 vol. Cambridge: Cambridge Univ. Press; 1923–1928.
- Foster, A. S.; Gifford, E. M., Jr. *Comparative morphology of vascular plants*. San Francisco: W. H. Freeman & Co.; 1974.
- Lloyd, R. M. Systematics of the onocleoid ferns. *Univ. Calf. Pub. Bot.* 61:1–93; 1971.
- Mayr, E. Biological classification: Toward a synthesis of opposing methodologies. *Science* 214:510–516; 1981.
- Wagner, W. H., Jr. *Problems in the classification of ferns*. Recent advances in botany. Toronto: Univ. of Toronto Press; 1961:841–844.
- Wagner, W. H., Jr. The construction of a classification. *Systematic biology* (Pub. 1692) Washington, D.C.; Nat. Acad. Sci.; 1969:67–103.