Cornell Institute for Biology Teachers

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Title: **Evolving Trees**

Authors: Jacqueline Lopez, Cornell University, Ithaca, NY
Cookie Barker, Schroon Lake Central School, Schroon Lake, NY

Appropriate Level: Grades 9-12 Living Environment, Advanced Biology

Abstract:
This exercise introduces the basic methods of phylogenetic analysis. Students are asked to hypothesize the evolutionary relationships of groups of organisms and to become familiar with the methods for building evolutionary trees using the basic principles of taxonomy and classification.

Time requirement: one 45-50 minute period

Materials needed:
1. Pictures of Species Examples (in lecture notes)
2. Lab handout

Objectives:
1. To understand taxonomy and classification
2. The students will deduce the evolutionary links of hypothetical flies using the Phylogenetic methods.

Background info for teacher:

Teacher Preparation time: ~1 hour

Reviews of Cladistics can be found online *"Google it"*

Article from Natural History: (1995) Eugene S. Gaffney, Lowell Dingus, and Miranda K. Smith. Why Cladistics? Natural History pp. 176-178.

Resources:

Erik W.A. Gergus and Gordon W. Schuett*, Labs for Vertebrate Zoology: An Evolutionary Approach.* (1997) Biological Sciences Press.

Eugene S. Gaffney, Lowell Dingus, and Miranda K. Smith. (1995) *Why Cladistics?* Natural History pp. 176-178.

Evolution Mark Ridley (1993) Blackwell Scientific Publications, p 390.

Interactive Concepts in Biology 2.0 CD-ROM (2000) Brooks Publishing Company.

What did T. rex Taste Like? Sept 2005. http://www.ucmp.berkeley.edu/education/explorations/tours/Trex/phych3A.html

Fly illustrations provided by Frances Fawcett.

Other Notes:

This exercise should occur after the students have also discussed other basic evolutionary concepts, particularly descent with modification.

Before the students begin to assemble their cladograms for the hypothetical flies, build the tree from the natural history article (or other example found online) with the class to demonstrate basic tree building methods. Also, begin the first few steps of the fly exercise together with the class on the board.

Lecture notes for teacher:

The process of evolution through natural selection leads to the good fit of organisms to the environment - what we often refer to as adaptation. But we also observe an enormous diversity of kinds of organisms and we must ask how that diversity arises? Diversification must involve the splitting of single lineages into two (or more) daughter lineages. The process of lineage splitting is speciation, the origin of species. Before we can discuss the process, we must take time to carefully consider what we mean by a species.

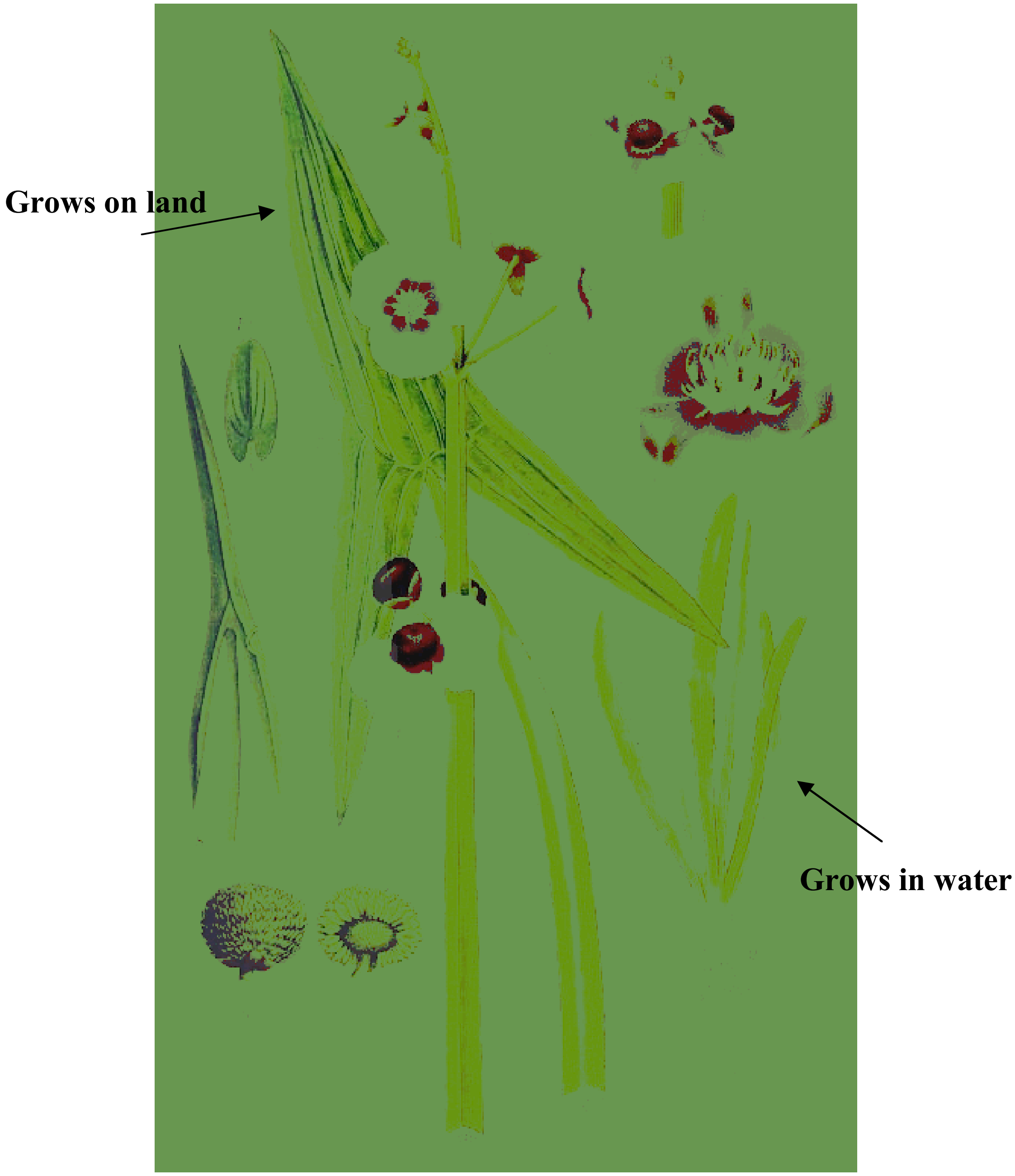
WHAT IS A SPECIES?

Species are fundamental units of natural diversity - of interest to evolutionary biologists, systematists, ecologists, and conservation biologists. There is still considerable disagreement about how species should be defined.

The “default” species concept among process-oriented evolutionary biologists has been the **Biological Species Concept (BSC).** Essentially, the Biological Species Concept is that there is interbreeding (genetic exchange) *within* a species and reproductive isolation (barriers to gene exchange) *between* species. In other words, if two organisms can mate and successfully reproduce, producing fertile descendants, then they would be considered species by this definition.

PHOTO 1: Arrowhead plants. *Sagittaria sagittifolia*

Arrowhead plants look morphologically dramatically different. One grows on land the other grows in water. These plants CAN interbreed, however, and therefore are designated one species by BSC standards (Brooks, 2000).



Sagittaria sagittolia

PHOTO 2: Gray tree frogs

Conversely, animals exist that look the same, but are considered a different species. The tree frogs *Hyla versicolor* and *Hyla chrysoscelis* look the same, live in the same habitat and hunt the same food, yet they do not interbreed. Why? The mating songs of these frogs are unique and their number of chromosomes are different. Therefore these frogs do not mate and if they did, they would be unable to produce viable offspring (Hv. is tetraploid and Hc. is diploid). (Brooks, 2000) http://bioweb.wku.edu/froglogger/ for sound of *Hyla chrysoscelis*

Hyla chrysoscelis
Cope's Grey Treefrog

Eastern Grey Treefrog
Hyla versicolor

PHOTO 3: Mules

Mules provide the classic example of different species that do produce viable offspring upon mating. A male donkey mated to a female horse produces a mule, which is sterile. Since the mules are sterile, they are unable to have descendents and therefore fit the BSC definition.

The BSC has many conceptual and practical problems:
For example:

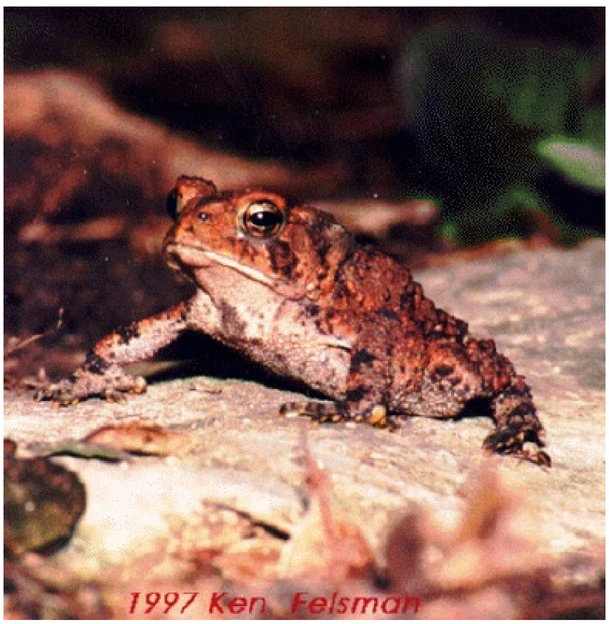
— Judgments about interbreeding cannot be made for taxa that are geographically isolated. In fact, assessments often are made on the basis of morphology.
— Cannot be applied to asexual lineages.

An alternative to the Biological Species Concept is: the **Phylogenetic Species Concept.** This concept holds that retention of interbreeding is not a criterion for grouping. Species defined as separate according to the BSC may be of different group according to cladistic methods. For example:

PHOTO 4: Toads (Ridley, 1993)

Bufo fowleri and *Bufo americanus* are morphologically separate species, though closely related. The American toad has dark blotches with one or two warts, while the Fowler usually has four to six warts. When they do mate, a hybrid toad is found that IS fertile and exists as a separate species! These species defined as separate by cladistics would be considered the same species according to the BSC.

Bufo fowleri



Bufo americanus

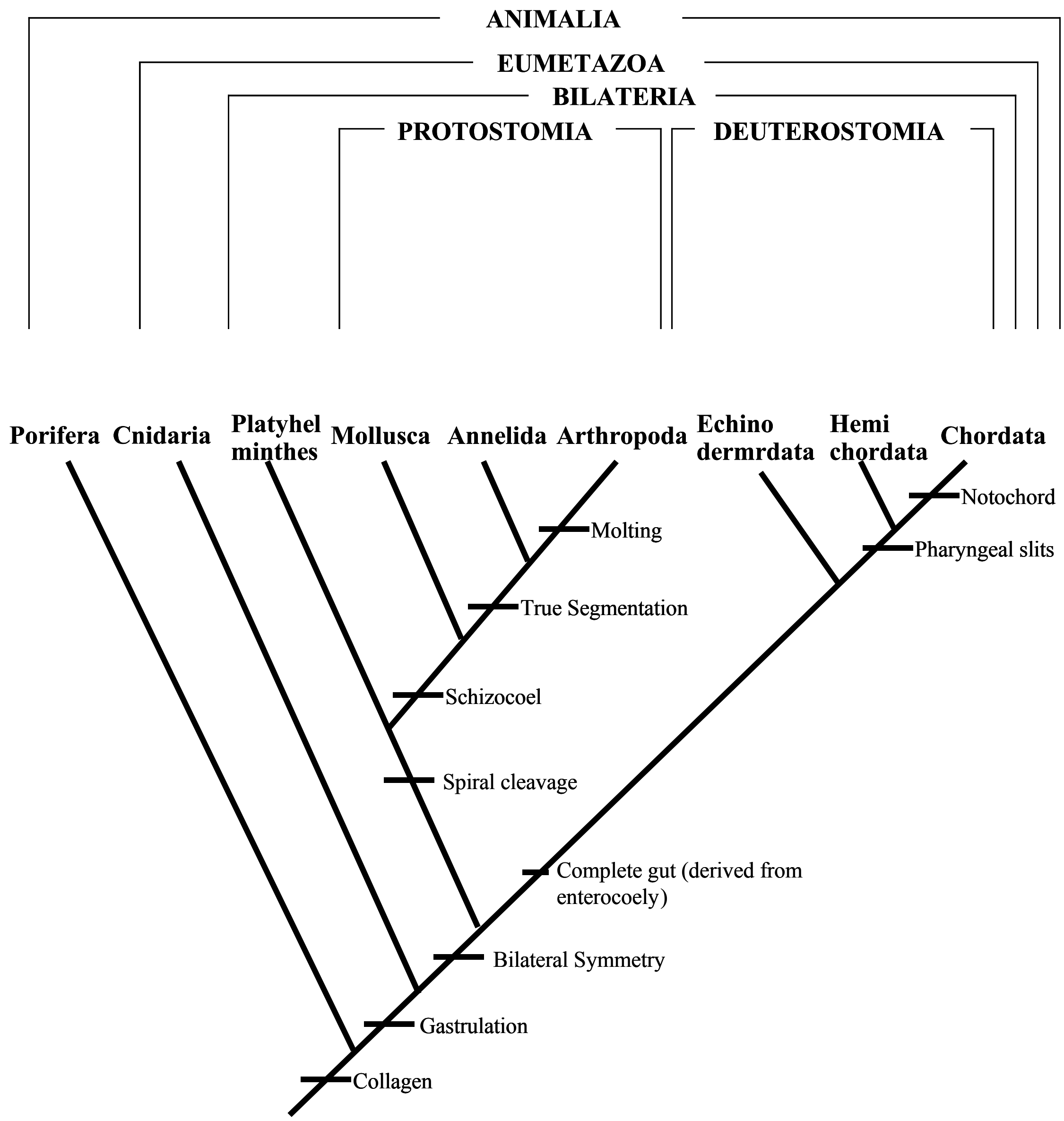
For purposes of consistency with phylogenetic analysis, cladistics argue that a species should be defined in terms of unique combinations of “characters.”

During today’s exercise, we will hypothesize evolutionary relationships from a group of imaginary animals to build a phylogenetic tree. This method, called “cladistics” or “phylogenic systematics” attempts to reconstruct evolutionary relationships of both living and extinct organism.

Cladograms are tree-like diagrams that attempt to hypothesize common descendent relationships for organisms.

PHOTO 5: Cladogram Example

How is the common ancestry deduced?
The evidence for common ancestry is based on shared characters by a group (taxa) under investigation.
A very important principle in cladistics is “parsimony”---the simplest explanation possible. A tree that can be constructed in the simplest manner is considered the closest to representing evolutionary truth.



Answers to questions in student section

Answers to Part 1:

	Porifera	Cnidaria	Platyhel minthes	Mollusca	Annelida	Arhropoda	Echinodermata	Hemichordata	Chordata
Notochord								++	+
Pharyngeal slits								++	+
Complete gut							+		+
Molting						+			
True Segmentation					+	+			
Schizocoel				+	+	+			
Spiral cleavage			+	+	+	+		++	
Bilateral Symmetry			+	+	+	+	+	++	+
Gastrulation		+	+	+	+	+	+	++	+
Collagen	+	+	+	+	+	+	+		+

Answers to Part II:

1. Answers will vary –

2. Fill in the chart with the data regarding the presence or absence of a particular character.

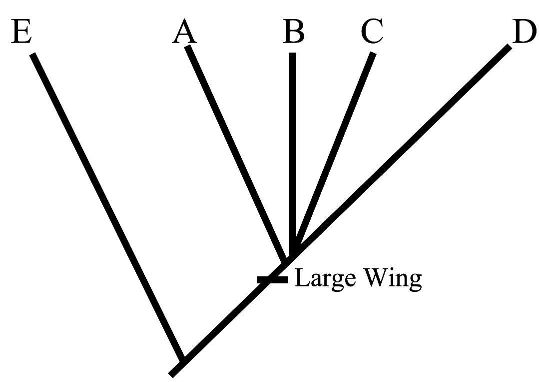
	Species A	Species B	Species C	Species D	Species E
Large Wings	+	+	+	+	
Stinger	+		+		
Wing Veins			+		
Bug Eyes (Bg)		+		+	
Leg Bulbs	+	+	+		+

3. Build a series of cladograms beginning with Large Wings and adding each characteristic as you go. Build the most parsimonious cladogram. (Sketch the new cladograms below.) (Hint: the absence of a trait can also be a characteristic.)

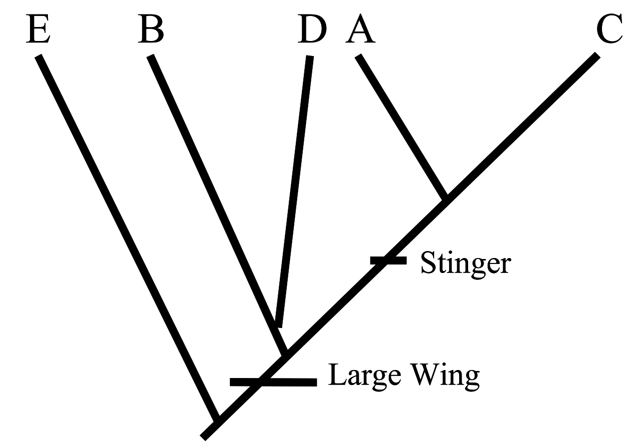
Note that this cladogram is but one variation of possible answers.

Group E can be characterized as sharing the fewest characters of all the flies, and is designated as an out-group. A-D share more derived characters.

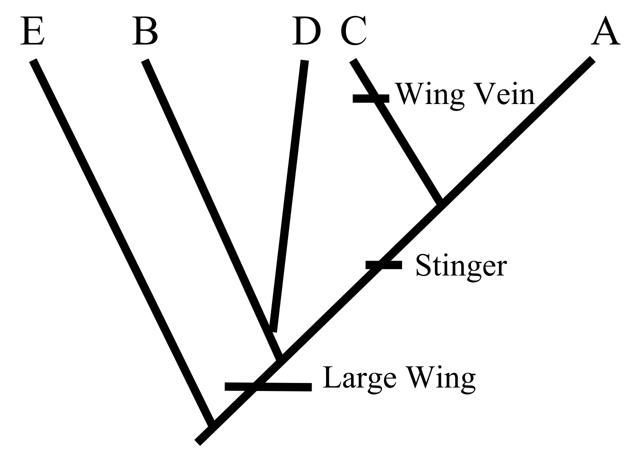
1. Large Wing



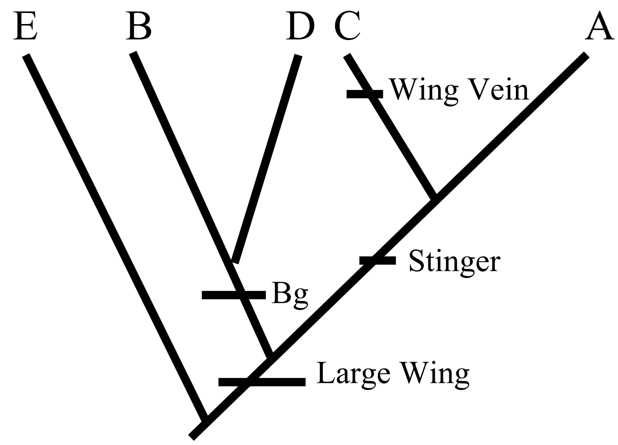
2. Stinger



3. Wing Vein

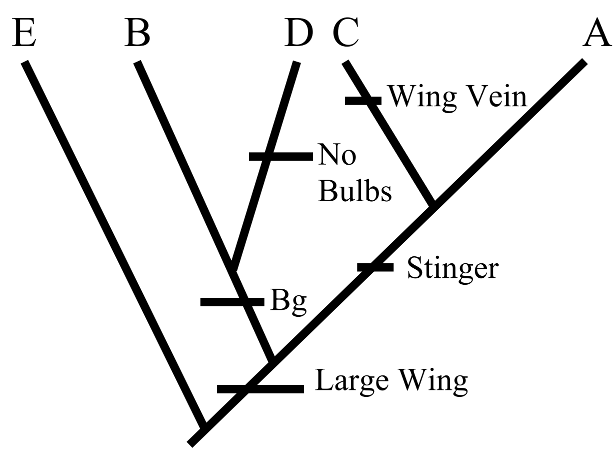


4. Bug Eyes (Bg)



5. Missing leg Bulbs

This is an example in which the character is lost, rather than acquired.



4) Answers will vary – but should indicate that as new evidence becomes available the trees could change.

5) With the most parsimonious cladogram that the students can build, a hierarchical taxonomy can be made. Below is an example of some fun names the students can invent.