Fish Family Tree

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Undergraduate Lesson Plan
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This lesson plan is designed to convey the central concepts behind constructing phylogenetic trees using primitive and derived fishes as examples. This lesson was conceived as an activity to engage students during a laboratory session that might accompany a lecture course that has described basic fish anatomy and some background biology of fishes, and thus much of the specific physiological vocabulary has already been introduced. The lesson is geared to either a highschool or introductory undergraduate class level.

Central Concept: Phylogenies graphically represent how groups of organisms are related to each other. Phylogenies can be constructed by comparing anatomical structures to determine whether groups are closely related. ONLY shared derived characters (synapomorphies) can be used to create a phylogeny.

Vocabulary:

Phylogeny	(true evolutionary relationship among groups of organisms)
Synapomorphy	(shared derived character)
Homoplasy	(non-homologous similarity, due to convergence or reversal)

Invitation

"Today we're going to play a game to figure out how a bunch of fish are related to one another. Everyone in this room is now (*shazam*) a different fish species, and you're all each other's relatives. Your job is to figure out how you're related and to create a family tree."

Each student will be given a card with a picture and some information about "themselves" as a fish. Before the cards are distributed, students are instructed to look at their cards, study the picture and the information for a couple minutes and come up with a name for their fish. The names should be as creative and memorable as possible. The cards will not have the real names on them, and students are told that even if they know the actual name of the species they should try and come up with their own creative name.

After the students quietly study their cards for a couple of minutes on their own, the teacher brings their attention back as a group. Now they are told that they are going to one by one come up front and tell the entire class about themselves. They should share the information that is on the card and something else that they notice about their fish based on the picture. They should also tell us their name. Before this starts, the teacher tells all the students that everyone in this room should pay close attention to everyone's

characteristics, because later they'll have to go and pick the other fish that they think is most closely related to them. And everyone here has a partner, so be on the lookout.

Then students come up and describe themselves. The teacher will ask them what their name is and write the name on a "Hello, my name is…" name tag. When the student is done, they put the nametag on their shirt and sit down.

Once all the introductions are made, the teacher invites everyone to stand up and go find the partner that they think is most related to them. They are told to do their best even if they're not sure. Depending on teacher discretion, groups of more than two can be formed (although ideally groups of just two are discovered). Once everyone has found their partner, the teacher writes down all of the parings/groups (using their fish names) on the board. Everyone is then asked to sit back down.

This will be followed by a very short debrief. Each group will be asked what characters they used to decide that they were related to one another. That character will be written on the board as well. Students will also be asked what characters were not useful in deciding relationships. Time permitting, a couple groups will be asked what other pairs of fish they think are most related to their group, and what characters make them think that.

Exploration/Concept Introduction

Students are now told that they are going to build a formal family tree using the characters they learned about each other. To do this they will use a character chart. This chart will be put up on the board, and consists of a table with pre-selected characters and all of the species. The teacher will write the creative names on the board (they will be numbered and keyed to the real names that the teacher has on a sheet hidden away somewhere). Each student will then come up and put an X in their column for each character that their fish HAS, and leave blank those characters that their fish does not have.

Note: Some fish will have traits that are secondarily lost (for instance, both perciformes have secondarily lost an adipose fin). Each student's card will note whether the absence of a character is due to a secondary loss or not. If it is secondarily lost, that species will go ahead and mark an X in the box for that trait. Later, this will be used to discuss homoplasies.

After the chart has been filled in, the teacher will tally up the X's for each column. The teacher will then lead a group discussion about how to draw the relationships on the board. At this point vocabulary will be introduced. Synapomorphies will be discussed, as will homoplasies. The secondarily lost characters will be identified as homoplasies. The teacher may ask what would have happened if they had not X'd the boxes for the secondarily lost characters (i.e. it would have confused the relationships between the species).

Application

The class will then draw the tree together. The teacher will guide the discussion to show that the columns with fewer X's are more basal while the more X's indicate derived species. Species with the same number of X's are pairs.

Once the tree is drawn, the students are guided to mark the emergence of characters on the tree. This can be used to further decide what's a synapomorphy and what is not.

Finally, the teacher will put up a real tree showing the relationships among the fish (with their real names) and see if the tree the class discovered is similar or not. If not, discuss what might have been the problem and what they would have liked to have known to help resolve the differences. This certainly would be a good time to discuss how difficult it is to build trees in the real world, and how many different characters (and genetics) is often needed. Also, the trees we create are guesses, estimates at the "true" trees.

DIAGRAMS & HANDOUTS

FISH INFO CARDS

1.) Hagfish
- Jawless
- Notochord but no true vertebral column
- Cartilaginous skeleton
- Extremely slimy
- Can tie selves in knots
- Lack a true stomach
- No scales, no true fins (including adipose), no eyes

2.) Lamprey
- Jawless
- Notochord but no true vertebral column
- No scales, no true fins, no eyes
- Cartilaginous skeleton
- Teeth on tongue
- Parasitic or scavengers

3.) Great White Shark
- Jaws
- Backbone w/notochord & cartilaginous skeleton
- Placoid scales
- Cartilage rods in fins, not true fin rays
- No adipose fin
- Teeth derived from scales
- Have excellent nighttime vision

4.) Sting Ray
- Jaws
- Backbone w/notochord & cartilaginous skeleton
- Placoid scales
- Cartilage rods in fins, not true fin rays
- No adipose fin
- Swim by flapping pectoral “wings”
- Have serrated venomous spines

5.) Coelacanth
- Bony skeleton & backbone w/notochord
- Special lobed fins, no true fin rays
- Jaws
- Cosmoid scales
- No adipose fin
- Elecroreception organ for prey detection
- Bodies excrete oil and mucus

6.) Lungfish
- Bony skeleton & backbone w/notochord
- Special lobed fins, no true fin rays
- Jaws
- Cosmoid scales
- No adipose fin
- Can breathe air with modified swim bladder
- Survives in mud/mucus cocoon when water dries up

7.) Shad
- Bony skeleton & backbone w/notochord
- Jaws
- Rayed fins but no adipose fin
- Otophysic connection between ear and gas bladder for good hearing
- Can hear best at frequency of dolphin whistles
- Special modified jaw joint
- Cycloid scales

8.) Herring
- Bony skeleton & backbone w/notochord
- Jaws
- Rayed fins but no adipose fin
- Cycloid scales
- Otophysic connection between ear and gas bladder for good hearing
- Special modified jaw joint
- May communicate by releasing bubble “flatulence”

9.) Catfish
- Bony skeleton & backbone w/notochord
- Jaws
- Rayed fins and adipose fin
- No scales (cycloid scales secondarily lost)
- Gas bladder connected to ears by Weberian apparatus
- Release a fright substance in water when injured to alert others (Schreckstoff)
- Use highly sensitive barbells to feel around

10.) Minnow
- Bony skeleton & backbone w/notochord
- Jaws
- Rayed fins and adipose fin
- Cycloid scales
- Gas bladder connected to ears by Weberian apparatus
- Release a fright substance in water when injured to alert others (Schreckstoff)
- Have protrusible jaws to suck in prey

11.) Sea Bass
- Bony skeleton & backbone w/notochord
- Jaws
- Rayed fins, adipose fin secondarily lost
- Ctenoid scales
- Change sex from female to male
- Make weak grunting sounds
- True fin spines (unsegmented)

12.) Butterfly fish
- Bony skeleton & backbone w/notochord
- Jaws
- Rayed fins, adipose fin secondarily lost
- Ctenoid scales
- Pointy mouths allow prey to be picked from crevices
- False eye spots
- True fin spines (unsegmented)

CHARACTER CHART

	Hagfish	Lamprey	Shark	Ray	Coelacanth	Lungfish	Shad	Herring	Catfish	Minnow	Sea Bass	Butterfly Fish
Notochord	X	X	X	X	X	X	X	X	X	X	X	X
Jaws			X	X	X	X	X	X	X	X	X	X
Bony skeleton					X	X	X	X	X	X	X	X
Rayed fins							X	X	X	X	X	X
Adipose fin									X	X	X	X
Ctenoid scales											X	X
TOTAL	1	1	2	2	3	3	4	4	5	5	6	6

TRUE PHYLOGENY