

Evolution across the biology curriculum at UWV:

Design and Assessment of Evolution content modules in Organismal Biology Courses

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Objectives

The Evolution Across Curriculum initiative at UWV was implemented using student-centered learning modules in each of our core courses (General, Organismal, Plant, and Animal Biology, Cell, Ecology, Genetics, Anatomy and Physiology). Modules included student exploration and activities to reinforce presented content. Modules were originally tested among control and experimental sections (when possible). Here we present examples of modules used in our 200 level organismal courses.

Course specific approach:

Evolutionary topics were assigned to each course based on a cross departmental evaluation of evolution content in our core courses. (* see Kathryn Perez et al.'s poster for more!)

Steps:

1. Course specific learning objectives for assigned evolutionary topics were developed.
2. Following a workshop on student-centered teaching, individual faculty worked on developing content modules that included student engagement and activities that link real-world examples to concepts they are learning. Once modules were drafted, faculty presented their modules to the team for peer review.
3. Modules were deployed in control and treatment sections (when possible) and learning gains were assessed in Fall 2012 and Spring 2013 semesters.

Objectives:

e.g. *Geologic Time for Organismal Biology*
Students should be able to:

- place major events in animal evolution on a timeline paired with those in plant and fungal evolution.
- recognize evolution of complexity repeatedly in multiple lineages.
- grasp how long life has existed/evolved and that rates of divergence vary.

e.g. *Evolution & Development for Animal Biology*

- *Evolution can occur by changes in regulation:* Given that developmental processes are often shared, novel phenotypes often evolve via changes in regulation (e.g., co-option or deployment of gene regulatory networks to different tissues or stages of development).
- *A small number of mutations can make a large evolutionary difference:* It is possible for novel phenotypes to evolve as the result of the fixation of a small number of mutations that cause significant changes in the regulation of developmental processes.
- *Development can bias evolutionary outcomes*

Examples of Student-Centered Modules

Geologic Time Scale:

1. Engagement Question:

- Students transition from building phylogenies using phenotypic traits
- Q1 requires applying prior knowledge
- Molecular clocks and time scale have not been introduced.
- Q2 engages their curiosity.

Using molecular data to build your tree

- A. AAA OCTACT (outgroup)
- B. AAC OCTACT
- C. AAA OCTACT
- D. AAC OCTACT



1. Create a phylogeny for organisms A, B, C, and D based on the genetic changes seen in their sequences.
2. How long ago did their lineages diverge?

2. Student Exploration:

- Students get to explore their ability to apply a molecular clock story problem to their tree.

3. Instructor Explanation:

- Q2 engages their curiosity.

Time scale is based on multiple lines of evidence

Molecular Clocks
Molecular data must be calibrated to be used as a molecular clock.

Fossil Record
- Where are they distributed?
- Radiometric dating of carbon

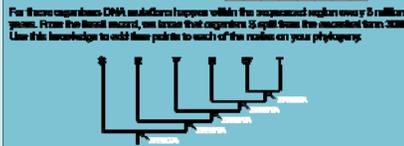
Current divergence time hypotheses: emphasize order of events

4/5. Extension Activity/Assessment:

Graded Homework Assignment

- Students use a set of molecular data to build a character matrix and phylogeny

Character	A	B	C	D
1	0	1	1	1
2	0	1	1	1
3	0	1	1	1
4	0	1	1	1
5	0	1	1	1
6	0	1	1	1
7	0	1	1	1
8	0	1	1	1
9	0	1	1	1
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26	0	1	1	1
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93	0	1	1	1
94	0	1	1	1
95	0	1	1	1
96	0	1	1	1
97	0	1	1	1
98	0	1	1	1
99	0	1	1	1
100	0	1	1	1



- The fossil record clearly shows the split of organisms B from the ancestor 200 MYA, however fossil evidence for this line becomes patchy for the other groups. Organisms Y and U did not show up in the fossil record 200 MYA. First organism V appears 200 MYA while organism K appears 250 MYA in the fossil record.
- Do these observations support your molecular divergence time estimates? Explain. (The answer is not really... the molecular data and fossil record do not provide the same divergence time picture)
 - Do these observations reject your molecular divergence time estimates? Explain. (Not... although they do not support the estimates, they do not reject the molecular clock but they do challenge it enough to say that the fossil record is patchy)

Evolution of Development:

1. Engagement Question:

- Students transition from discussing basic developmental pathways.
- Discussion question engages students to answer "Why is the number of neck vertebrae fixed in mammals but variable in birds?"

2. Student Exploration:

Students answer the question out loud or discuss with a neighbor to explore possible answers. Hopefully, they will come up with evolutionary constraints on their own.

Development can bias evolutionary outcomes.
All mammals have only 7 neck vertebrae (even giraffes). What is the most plausible explanation for this lack of variation in mammals?

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Fixed at 7 for 200 my!

3. Instructor Explanation:

Development can bias evolutionary outcomes

Phenotypic constraints bias the specific developmental lines
The genes for limb patterning, essential for limb development, are shared with genes that control major developmental constraints. Evidence: Strong evidence indicates, in very high percentages have identical vertebrate limb development.

Apply this same logic to test wing-pair development in insects
Early insects had six limbs all photos on each thoracic and abdominal segment. In modern flies, the abdomen is reduced to a few segments. If you were this gene off in neoptera you can make other "wing" changes. But, in 400 my of evolution, no insects have evolved quadrupedalism from pairs of wings for flight.

A small number of mutations can make a large evolutionary difference

Normal fruit fly: **Fruit fly with mutation in the ultrabithorax gene**

Shark, paddlefish, zebrafish, mouse

In that case, mutations in Hox genes can pattern the top where an embryo should be flat.

Vertebrate limb development depends on similar Hox genes that vary in timing of expression.

4/5. Extension Activity/Assessment

The Case of the Threespine Stickleback: A Model of Microevolution by James E. Platt, University of Denver

While students through have exposure of one gene-codon surface in their morphology. Note that pattern in the ultrabithorax ("Ubx") region and the homeo gene (expressed in a part of the embryo) in the pattern in the ultrabithorax region in fly. The Pbx2 orthologous in the pattern of the ultrabithorax fly fly.

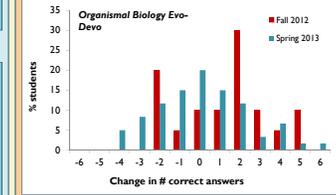
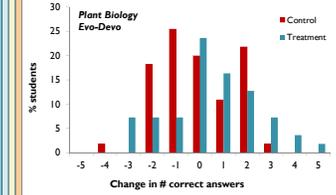
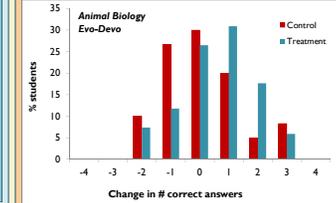
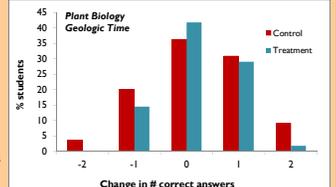
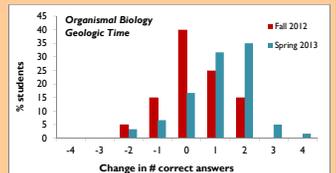
Clicker Questions

- Hoxes, ultrabithorax, and ultrabithorax fall into the class of developmental genes that are expressed in the same tissue in all species — even though, the digits of the adult form look quite different. Which of the below is the best explanation for this pattern?
- Applying the five-step approach to the ultrabithorax developmental pattern
 - A single mutation in the ultrabithorax gene, which then spread to all other species, led to the different patterns.
 - A single mutation in the ultrabithorax gene, which then spread to all other species, led to the different patterns.
 - Multiple mutations in the ultrabithorax gene, which then spread to all other species, led to the different patterns.
 - Multiple mutations in the ultrabithorax gene, which then spread to all other species, led to the different patterns.

Assessment

Geologic Time:

- For Organismal Biology the largest gains were in student understanding of the sequence of divergence among organisms.
- Plant Biology also showed gains but they were not significantly higher in the treatment vs. control.



Evolution of Development:

- In both Animal Biology and Plant Biology, students had higher gains in the treatment vs. control.
- Organismal Biology students also performed better on post tests both semesters.
- Gains were highest in Animal Biology and Organismal Biology, Fall 2012. This is likely due to implementation of the Stickleback Case study for all students in those sections.

Conclusions: Modules that were paired with large scale in-class or out of class activities (e.g. stickleback case study, clock assignment) showed the largest student gains. Certain topics like evo-devo and geologic time scale/molecular clocks have large potential gains when compared with better known topics like co-evolution and sexual selection.

